

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

Overview of Work Packages

Report
to the Water Research Commission

by

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- 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 3: Bacteriological assessment of water sources and retrospective analysis of diarrhoeal prevalence in Nelson Mandela Bay (WRC report no. 3229/4/25)
- 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)

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EXECUTIVE SUMMARY

BACKGROUND

Adequate water supply and sanitation are critical for sustainable development in South Africa, yet significant challenges persist. Approximately 3 million and 14.1 million people lack access to basic water and sanitation services, respectively, hindering progress toward Sustainable Development Goals (SDGs) 6.1 and 6.2. Water quality degradation—driven by nutrient enrichment, microbial contamination, and dysfunctional wastewater treatment infrastructure—threatens human health, ecosystems, and agricultural productivity. Compounding these issues are climate extremes, population growth (31% over 20 years), and a R33 billion water infrastructure backlog, with 41% of the population in metropolitan areas nearing water deficits.

Climate change exacerbates water scarcity and disease transmission. Rising temperatures, reduced snow cover, and intensified rainfall alter pathogen dynamics, increasing risks of waterborne illnesses. Droughts concentrate contaminants, while floods overwhelm sanitation systems. Schistosomiasis, linked to freshwater snails (e.g., *Biomphalaria* spp.), resurges due to climate-driven habitat shifts. Nelson Mandela Bay exemplifies these challenges: reservoirs at 2.3% capacity (July 2022) led to water rationing, poor-quality water linked to child fatalities, and heightened health risks from inadequate hygiene.

Water-related diseases, including diarrhoeal illnesses and schistosomiasis, disproportionately affect low-income communities. Diarrhoea, a leading cause of under-five mortality (525,000 deaths annually), is tied to unsafe water and poor sanitation. Schistosomiasis prevalence in regions like Kwa Nobuhle (26% infection rate in 2021) underscores persistent transmission hotspots. Despite 90.5% household access to flush toilets in Nelson Mandela Bay, gaps remain: 22% of early childhood centres use unsafe sanitation practices, and 79% lack hygienic handwashing. Addressing these challenges requires integrated strategies: upgrading water infrastructure, enhancing wastewater treatment, and scaling Water, Sanitation, and Hygiene (WASH) initiatives. Community engagement, snail vector monitoring, and climate-resilient policies are critical. Multidisciplinary approaches, leveraging existing expertise and infrastructure, offer pathways to mitigate risks and achieve water security. Prioritizing WASH standards, predictive water quality assessments, and sustainable sanitation investments remains urgent to safeguard public health and environmental sustainability.

AIMS

The following were the aims of the project:

1. Assessment of natural water bodies to determine vegetation type, and water physico-chemical properties in each sampling site, and the impact on schistosomiasis intermediate host (snail) distribution. (Work Package 1)
2. Assessment of natural water bodies in the study area to determine the presence of snail intermediate host (potential transmission sites) and infected snails (transmission sites). (Work Package 1)
3. Assessment of knowledge, attitude, and practices (KAPs) and risk factors associated with schistosomiasis prevalence and transmission among primary school-going children. (Work Package 2)
4. Determining the prevalence and intensity of *S. haematobium* and *S. mansoni* infection through urine and faecal samples, respectively, in school-going children. (Work Package 2)
5. To assess the bacteriological quality of water sources as well as the retrospective prevalence of diarrhoea in the study area. (Work Package 3)
6. Assessment of an educational intervention on hygiene knowledge and practices among municipal waste and sanitation workers pre- and post-intervention in the study area. (Work Package 4)

METHODOLOGY

Below is a consolidated summary of the methodologies from Work Packages 1 to 4:

Environmental Water Quality & Ecological Assessment (Work Package 1)

Design: Quantitative cross-sectional study over 9 months, covering wet and dry seasons.

Sampling:

- Sites: 8 locations near residential areas.
 - Water Analysis:
 - Physico-chemical properties (pH, conductivity, TDS) measured using a Bante 900P multiparameter meter, Macherey Nagel PF-12 plus, and hardness meter.
 - Surface water samples collected via the simple dip method.
 - Ecological Sampling:
 - Snails captured using a 300 µm mesh scoop net.
 - Vegetation composition (% cover) visually estimated; dominant plant species identified by botanists at Nelson Mandela University.
- Data Analysis: R software (v4.3.1) and Excel 365 for statistical and descriptive analysis.

Schistosomiasis Epidemiology & Biomarker Profiling (Work Package 2)

Design: Three-phase cross-sectional study in school-aged children (5–14 years).

Phases:

- Phase 1 (Risk Factors & KAPs):
 - Structured interviews to assess socio-demographics, environmental risks, and knowledge/attitudes/practices (KAP).
 - Data analysed for associations between variables.
- Phase 2 (Prevalence & Diagnostics):
 - Urine: Dipsticks (haematuria screening), filtration (*S. haematobium* eggs), and cPCR (Dra1 repeat for cfDNA confirmation).
 - Stool: Kato-Katz and POC-CCA tests for *S. mansoni*/STHs; cPCR (*cox-1* gene) for confirmation.
- Phase 3 (Biomarkers):
 - Urinary biomarkers (proteins, leukocytes, etc.) analysed via Siemens Multistix 10SG dipsticks.
 - Correlations between biomarkers and schistosomiasis explored.

Municipal Water Quality & Public Health Linkages (Work Package 3)

Design: Seasonal analysis (June 2023–April 2024) of water sources in Kariega, Eastern Cape.

Sampling:

- 52 samples (40 municipal, 12 environmental: Swartkops River, Willow Dam, Strelitzia Dam).

Laboratory Analysis:

- Microbial: Colilert™-18 MPN for coliforms/*E. coli*; PCR for *Salmonella* (*invA*), *Shigella* (*ipaH*), *Vibrio cholerae* (*ompW*, *ctxAB*).
 - Physicochemical: pH, conductivity, TDS.
- Data Integration:
- Correlation of microbial results with municipal records and pending diarrheal prevalence data (NICD/DHIS).

Statistics: Non-parametric tests (Spearman's correlation, Welch tests, ANOVA) due to non-normal data distribution.

Hygiene Intervention Impact Assessment (Work Package 4)

Design: Quasi-experimental pre-/post-test study (1 group).

Participants: 201 waste/sanitation workers from NMBM depots and wastewater plants.

Intervention:

- Pre-intervention: Structured questionnaire on demographics, hygiene knowledge/practices.
- Educational intervention based on national guidelines.
- Post-intervention: Follow-up survey after ≥ 2 months.

Analysis:

- Data captured via QuestionPro, analysed in Excel 365 and R (v4.4.1).
- Reliability assessed via Cronbach's alpha.
- Inferential statistics: Pearson's correlations, t-tests, ANOVA, multivariable regression.

Integration & Synergies

- Environmental-Health Links: WP1 (water quality/snails) and WP3 (pathogen detection) inform schistosomiasis risk factors (WP2) and diarrheal disease trends.
- Diagnostic Overlap: Molecular methods (cPCR) used in WP2 and WP3 enhance pathogen specificity.
- Intervention Context: WP4's hygiene training addresses behavioural risks identified in WP2 (KAPs).
- Statistical Consistency: R and Excel used across WPs for harmonized analysis.

This integrated approach provided a holistic understanding of waterborne disease dynamics, environmental drivers, and intervention impacts in the Nelson Mandela Bay region.

RESULTS AND DISCUSSION

This cross-sectional study evaluated the risk factors and employed comprehensive diagnostics, which revealed significant discrepancies in disease prevalence rates in the study area: 0.1% (urine filtration) versus 31.4% (cPCR) for *S. haematobium*, and 0% (Kato-Katz) versus 32.1% (cPCR) for *S. mansoni*. These findings emphasize the need for more sensitive diagnostic techniques, such as DNA amplification (cPCR) and POC-CCA tests, to accurately detect schistosomiasis and STH infections in low-transmission areas. Furthermore, the study designed a predictive tool to examine the relationships between water quality, hygiene practices, and NTDs, revealing a critical nexus that informs disease prevention and control strategies. Water physicochemical properties, vegetation type, and other prevailing factors, such as adaptability and competition among the snails, may have contributed to the documented numbers of the snail species: *Bulinus* (0.9%), *Biomphalaria* (0.6%), and *Physa* (95.9%). The project also focused on assessing bacteriological water quality and retrospective prevalence of diarrhoea; evaluating the impact of an educational intervention on hygiene knowledge and practices among municipal waste and sanitation workers; investigating the role of water physicochemical properties and vegetation type on the distribution of schistosomiasis intermediate host snails and determining the status of schistosomiasis prevalence in the study area. Key findings include: The implemented educational intervention improved WASH knowledge among municipal waste and sanitation workers, school children and the community at large. Poor knowledge, attitudes, and practices (KAP) and significant environmental risk factors for schistosomiasis transmission were identified. Environmental water samples contained total coliforms and *E. coli*. Most water bodies in the study area provided an environment conducive to snail survival.

GENERAL

The aims of all work packages have been completed and recommendations made to all relevant stakeholders.

CONCLUSIONS

We developed a comprehensive diagnostic framework for the evaluation of schistosomiasis infection: Prediction of hidden infections; Evaluation of water quality, environmental factors and hygiene practices: Findings inform disease prevention and control strategies, emphasizing the need for improved WASH standards and targeted interventions.

A comprehensive diagnostic framework was developed for assessing schistosomiasis prevalence in low-transmission settings, highlighting the importance of molecular diagnostics in detecting the disease. The study highlights the importance of molecular diagnostics in detecting schistosomiasis and the potential for urinalysis to identify biomarkers linked to the disease.

Predictive tool enabled the following:

- Comprehensive diagnostic framework: We have developed a comprehensive diagnostic framework for the evaluation of schistosomiasis infection.
- Prediction of hidden infections: Identify areas with high likelihood of hidden infections attributed to low prevalence.
- Evaluation of water quality, environmental factors and hygiene practices: Assess the relationship between water quality, hygiene practices, environmental factors and schistosomiasis.
- Our strategy ensured community involvement in decision-making and the design of intervention strategies to enhance uptake and,
- Sustainability. Findings inform disease prevention and control strategies, emphasizing the need for improved WASH standards and targeted interventions.

RECOMMENDATIONS

Our recommendations highlight the importance of a multifaceted approach to combat schistosomiasis and related communicable diseases. We encourage Environmental Health Practitioners (EHPs) to monitor waterbodies and intermediate host snails such as *Physa*, study their ecological adaptability, and investigate their role in biological control. Plant-based prevention strategies should be implemented in conjunction with the identification of research voids regarding environmental factors (pH, turbidity, water depth, pollutants) and plant types that influence snail abundance. The integration of culturally sensitive, customised schistosomiasis and helminth education into schools should be a priority in education initiatives, as it can leverage children as community educators. Advanced, sequential and comprehensive diagnostics, expanded mass drug administration (MDA) with affordable praziquantel, and enhanced surveillance are all necessary for health systems. Installation of sanitation facilities, enhancement of waste management, and monitoring of freshwater sources are all examples of environmental measures. Community engagement strategies encourage the use of tech-driven, multilingual health literacy tools and hygiene campaigns. The following are the future research priorities: adaptive water-sanitation interventions, molecular analysis of *Schistosoma* strains, and longitudinal studies. The integration of education, healthcare, and environmental management is essential to enhance hygiene practices and reduce the transmission of disease through collaboration among governments, policymakers, EHPs, and researchers. See the conclusions and recommendations chapter from each work package for more details.

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ACRONYMS & ABBREVIATIONS

DWS	Department of Water and Sanitation
EPEC	Enteropathogenic <i>E. coli</i>
EAEC	Enteraggregative <i>E coli</i>
ETEC	Enterotoxigenic <i>E coli</i>
IFRC	International Federation of Red Cross and Red Crescent Societies
KAPs	knowledge, attitude, and practices
NMBM	Nelson Mandela Bay Municipality
WASH	Water, sanitation and hygiene
WHO	World Health Organisation
WinS	WASH in schools

GLOSSARY

Cercariae: Larval stage of parasitic worms (schistosomes) released by snails into water; can infect humans through skin contact.

Cercariometry: Measurement or detection of cercariae in water to assess infection risk, often for schistosomiasis control.

Diarrhoeal disease: Illness marked by frequent loose/watery stools, typically caused by infections from contaminated food/water.

Industrialisation: Shift from agrarian to machine-based manufacturing economies, driving technological and economic growth.

Schistosomiasis: Tropical disease caused by parasitic worms (schistosomes) transmitted via freshwater contaminated by infected snails.

Urbanisation: Growth of cities due to population migration from rural areas, often linked to industrialization and job opportunities.

Vector-borne diseases: Infections spread by organisms like mosquitoes or ticks (e.g., malaria, dengue, Lyme disease).

WASH standards: Guidelines for safe Water access, Sanitation infrastructure, and Hygiene practices to prevent disease.

Water quality: Condition of water based on physical, chemical, and biological traits, determining its safety for use (e.g., drinking, farming)

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

Adequate water supply is a cornerstone for South Africa's sustainable socio-economic development (DWS 2019). An estimated 3 and 14.1 million people, respectively, do not have access to basic water supply and sanitation services in South Africa (DWS 2019), which is indicative of the poor progress made with regard to achieving targets related to Sustainable Development Goals 6.1 and 6.2. Water quality is a vital indicator that informs and guides fitness-for-use for various uses, including human consumption, recreational use, and agricultural use (Machiwal and Jha, 2010). The chemical, biological, microbiological, and aesthetic characteristics of water greatly influence aquatic ecosystem health, human welfare and environmental sustainability. Raw water quality is a priority challenge in South Africa, primarily due to a high number of dysfunctional municipal and industrial wastewater treatment works (DWS 2019). To this end, nutrient and salt enrichment, microbial contamination, suspended solids, and toxicants are among the widespread water quality issues.

South Africa battles to meet its water security objectives primarily due to the interplay of environmental, built environment, socio-economic, and political drivers (Ruiters and Matji, 2015). For instance, the country is naturally semi-arid with a low mean annual run-off (465 mm) (DWS, 2019) and the 20-year population growth is estimated at 31% (STATSSA 2020), whilst there is an estimated R 33 billion water infrastructure investment backlog (DWS 2019). An estimated 41% of the country's population resides in metropolitan areas, which, by 2020, were approaching or had reached a water deficit, with an overall 10% water deficit forecast for 2030 (DWS 2019). Globally, the looming water scarcity was reported before the 21st century and the situation has further deteriorated due to escalating climatic changes. South Africa currently faces climate-driven extremes as some parts face drought-driven water shortages, whereas elsewhere, flood disasters occur. The number of people facing 'economic water scarcity' is rising and approximately 2.5 billion people lack adequate sanitation, while 884 million people do not have access to safe water (UNICEF and WHO, 2017). Furthermore, about half of the population in developing countries is exposed to poor water quality, which could be associated with disease incidence and prevalence recorded in such places. The current situation may be similar to 1991–2000, when 90% of natural disaster deaths were due to water quality and 97% were from developing countries (IFRC, 2001).

On 18 July 2022, it was reported that three of the main reservoirs that supply about a third of Nelson Mandela Bay's 1.3 million people were close to empty. Much of the remaining water is of poor quality and the overuse of chemicals to treat the water is suspected to have led to the deaths of at least two children and livestock. Hence, there is an urgent call for water users to reduce water consumption by 20 percent. Around the same period, a further drop in the capacity was reported, with usable water levels reported to be as low as 2.3% of the dam capacity. The current shortage will influence the usage of water in the municipality, leading to inadequate hygienic practices and associated health challenges. Water quality is largely associated with the quality of life and environment, further determining fitness for use.

The increase in urbanisation and industrialisation is synonymous with the growing increase in water pollution, hence the need to design an effective strategy that predictively evaluates the quality of water bodies/sources and provides informed knowledge on contamination sources and levels, as well as possible control measures.

1.1.1 Climatic change

Water scarcity has been further compounded by an increase in the average surface temperature that has led to a significant increase in accumulated heat, which, in turn, has driven the regional and seasonal temperature extremes, reducing snow cover, sea ice and intensifying heavy rainfall. Temperature has been reported to affect the various trophic levels (Schael & Gama, 2019) directly or indirectly. These changes have, in turn, altered the pathogen's survival, replication, and virulence. Heavy rainfall can mobilise pathogens and compromise water and sanitation infrastructure, while drought can concentrate pathogens in limited water supplies (Levy et al., 2016).

In South Africa, the story is no different, as in the last half of the 20th century, the country has experienced upward trends in temperature (MacKellar et al., 2014; van Wilgen et al., 2016). Changes in climate have been observed in most terrestrial, freshwater, and marine ecosystems (Rius et al., 2014; Peron et al., 2016; Midgley & Bond, 2015), and as a result, species are changing genetically, physiologically, and morphologically and their distribution is shifting. This affects food webs and causes transmission of infectious diseases (Scheffers et al., 2016). In addition, it was noted that after an increase in temperatures, there was an upsurge in vector-borne diseases and overall, this has impacted breeding and survival of snail species implicated in schistosomiasis (Kalinda et al., 2017). Urogenital schistosomiasis was first described in Uitenhage, Eastern Cape, in 1863 (Appleton & Naidoo, 2012), followed by a decline in the 1900s. This was led by various environmental and biological factors that included a lengthy drought, to which *Biomphalaria africanus* populations in both rivers and disjunct water pools are vulnerable. It was proposed that severe winters followed by poor rainy seasons could lead to the local extinction of *B. africanus* (DeKock, 1973). However, adult snails can survive for long periods in sediment with a surface moisture content as low as 1.8%-1.9% and temperatures of 45°C (Brown, 1994). There is a need to identify the transmission sites and the relative abundance of cercariae-infected snails. A survey of the species of snails present in the selected water body in the study area will be carried out to determine the presence, absence, or abundance of the snail intermediate hosts of *Schistosoma* species. Furthermore, collected snails will be screened for the presence of cercaria qualitatively and semi-quantitatively.

The presence of cercariae-infected snails is confirmation that the water body is a transmission site, while the presence of an uninfected snail intermediate host indicates that the water body is a potential transmission site. Although cercariometry could provide vital information on active transmission sites, diurnal and seasonal fluctuations, as well as the spatial distribution of cercariae in infested natural water bodies, its limitations on practical application have been emphasized. Simple snail sampling to identify the suitable intermediate hosts and infested water bodies has the advantage of a quick, cheap, wider-angle data collection coverage (Ouma et al., 1989) and cost-effective data collection relative to other methods, such as cercariometry, microscopic examination of collected snails, as well as the use of sentinel rodents and sentinel snails. Unfortunately, snail collection and examination are carried out by very few laboratories and the dearth of skills to identify snails and cercaria (Appleton & Miranda, 2015) has been noted not only in the study area but in most areas where the disease is endemic.

A previous study in Morocco recorded active participation of the community members in identifying several intervention strategies for schistosomiasis control targeted against the snail intermediate host as well as health education of community members to enhance understanding of the transmission pattern and measures to reduce water contact (Barkia et al., 2015). Similarly, efforts to reduce the burden of schistosomiasis have centred on improving access to water and sanitation. Despite the advancement made concerning water and sanitation, a vast number of areas in South Africa still lack adequate sanitation facilities and safe hygienic practices.

South Africa has explored several strategies to improve the sanitation situation; however, the challenges remain in the area of sustainability of improved sanitation. Nelson Mandela Bay (NMB) reportedly had about 1.26 million residents in 2016, with 92.5% having access to formal dwellings and 77.3% having access to piped water in their dwellings. Flush toilets connected to sewage were available in 90.5% of households.

Similarly, in 2016, a total of 26 500 households in NMB had no formal refuse removal, while in 28 600 households, refuse removal exceeded one week (ECSECC, 2017). A cross-sectional survey carried out in 2017 elicited responses from 46 early childhood development (ECD) centres, which had a total of 3,254 children and 172 caregivers (Melariri et al., 2019). The aforementioned study evaluated the WASH in schools' indicators (WinS) and findings showed that despite improved water sources being available in 91% of the facilities, WinS for hygiene was poor. The use of the bucket system was noted in 22% of the ECD centres. In 79% of the ECD centres, children washed their hands in a communal plastic bowl. Only 11% of the study population washed hands hygienically under a running tap or tippy tap. Adequate WASH reduces the vulnerability of the populace to infectious and contagious diseases.

1.1.2 Wash and waterborne diseases

Poor water supply, sanitation and hygiene have been associated with a wide variety of childhood diseases, including gastroenteritis, stunted growth, schistosomiasis infections and other neglected tropical diseases. The World Health Organization estimates that South Africa has a 12.1 (per 100 000 population) mortality rate attributable to exposure to unsafe water, sanitation and hygiene conditions. Water, sanitation and hygiene (WASH) emphasizes the provision of safe water for basic human needs such as drinking, washing and domestic activities. Interestingly, implementation of WASH standards is closely associated with water quality, which are vital elements in human development, growth and well-being (Shrestha et al., 2017).

In low socio-economic areas, increased morbidity and mortality have been attributed to unsafe water supply, poor hygiene practices and inadequate WASH standards (Reddy et al., 2017). Contaminated water and poor sanitation are linked to transmission of diseases such as diarrhoea, cholera, dysentery, typhoid, polio, giardiasis, helminth infections, among others (Herrador et al., 2019). These diseases can cause a wide array of symptoms, including diarrhoea, fever, flu-like symptoms, neurological disorders, liver damage and others. Diarrhoea is transmitted by waterborne diseases and comprises a substantial proportion of the global burden of diseases (GBD, 2017; Troeger et al., 2018). Globally, diarrhoea, which is associated with poor water quality, remains one of the leading causes of death in children below five years old (Fischer Walker et al., 2012). Annually, it is responsible for 525 000 deaths of children under the age of five years (World Health Organization, 2018). Diarrhoeal disease is also the leading cause of severe dehydration and malnutrition in children under the age of five and can lead to impaired growth and cognitive development (Bartram et al., 2010, Schaible & Kaufmann, 2007). On average, 1.7 million diarrhoeal cases are reported globally every year.

Previous reports were associated with unsafe drinking water, inadequate sanitation, and hygiene (Karon et al., 2017; World Health Organization, 2018). Diarrhoeal disease outbreaks are associated with both heavy and dry periods, where dry periods can concentrate on enteric pathogens and precipitation can mobilise enteric pathogens and this in turn contaminates drinking water sources and increases chances of human-pathogen contact (Curriero et al., 2001; Effler et al., 2001). Diarrhoeal diseases constitute enteric pathogens that cause the most severe acute diarrhoea and include *rotavirus*, *Vibrio cholera*, *Shigella spp*, *Salmonella spp*, *enteropathogenic E. coli (EPEC)* and *Enteroaggregative E coli (EAEC)*, *Enterotoxigenic E coli (ETEC)*, *Ascaris lumbricoides*, *Cryptosporidium spp*, *Entamoeba histolytica*, *Giardia lamblia* and *Trichuris trichiura*. However, other waterborne diseases like schistosomiasis, caused by trematodes shed by freshwater snails (*Biomphalaria spp.*) penetrate human skin and, once established in humans, can result in both acute and chronic disease. In the acute phase, it results in abdominal pain, gastrointestinal disturbance that leads to diarrhoea, nausea and fever. While in chronic diseases, severe intestinal manifestations lead to bloody diarrhoea (Bizimana et al, 2018; Chatterjee et al, 2001). A recent study on retrospective prevalence of the disease from 2014 to 2018 in the study area observed that out of 405 samples from Kwa Nobuhle (a township on the outskirts of Kariega) 107 (26%) individuals tested positive for *S. haematobium* (Hambury et al., 2021). The technological risk associated with this project is to a large extent mitigated by the multidisciplinary nature of the project, access to equipment and infrastructure, as well as the track record, expertise and proven ability of the team members to handle projects of this size.

1.2 PROJECT AIMS

The following were the aims of the project:

7. Assessment of natural water bodies to determine vegetation type, and water physico-chemical properties in each sampling site, and the impact on schistosomiasis intermediate host (snail) distribution. **(Work package 1)**
8. Assessment of natural water bodies in the study area to determine the presence of snail intermediate host (potential transmission sites) and infected snails (transmission sites). **(Work package 1)**
9. Assessment of knowledge, attitude, and practices (KAPs) and risk factors associated with schistosomiasis prevalence and transmission among primary school-going children. **(Work package 2)**
10. Determining the prevalence and intensity of *S. haematobium* and *S. mansoni* infection through urine and fecal samples, respectively, in school-going children. **(Work package 2)**
11. To assess the bacteriological quality of water sources as well as the retrospective prevalence of diarrhoea in the study area. **(Work package 3)**
12. Assessment of an educational intervention on hygiene knowledge and practices among municipal waste and sanitation workers pre- and post-intervention in the study area. **(Work package 4)**

Aims 1 and 2 as well as 3 and 6 were carried out on site or via field data collection from the community, while aims 4 and 5 were completed in the laboratory. The overall approach was designed to cover the wet and dry seasons in order to establish baselines that can be applied for disaster prediction and management for drought and flood events.

1.3 SCOPE AND LIMITATIONS

This was a comparative cross-sectional study that used quantitative methods to determine the prevalence and intensity of *S. haematobium* among school-aged children in the study areas within the Nelson Mandela Bay Municipality (NMBM). Data was collected using various means: water sampling; intermediate host distribution; laboratory investigation (urinalysis and bacteriological evaluation) as well as structured questionnaires from the participants. Furthermore, the relationship between water quality (ecological, bacteriological and physico-chemical parameters) and the transmission of disease pathogens in the study area was determined.

The proposed study identified six aims. To achieve the identified aims, we used a combination of desktop and laboratory methods as well as on-site and data field assessment.

CHAPTER 2: GENERAL METHODOLOGY

2.1 INTRODUCTION

This section outlines the overarching methodological framework for the project. The implementation of specific objectives is organised across four distinct work packages. Work Package 1 (WP1) details the methodologies for Aim 1 and Aim 2. Work Package 2 (WP2) addresses Aim 3 and Aim 4. Work Package 3 (WP3) elaborates on Aim 5. Finally, Work Package 4 (WP4) encompasses Aim 6. Each work package is described in subsequent sections, with technical specifications, workflows, and analytical pipelines provided to ensure reproducibility.

2.2 WORK PACKAGE 1 (WP1)

2.2.1 Study design

A quantitative cross-sectional research design approach was used in the current study. Data was collected over a nine-month period, with water sampling taking place once a month from March to November 2023. The study was investigated in two phases: Phase one: physicochemical properties of the water bodies were measured, and environmental conditions of the surrounding water bodies were noted; Phase two: determined the type of vegetation preferred by schistosomiasis intermediate host snails, as well as their distribution and habitat preferences.

2.2.2 Study area

The study was conducted in NMB in two towns, namely, Kariega and Kwa Nobuhle, which both have several water bodies in proximity to communities. Kariega, formally known as Uitenhage, is a town situated in the Eastern Cape Province of South Africa, located at (33.7479 S, 25.4124 E). On the other hand, Kwa Nobuhle, which means 'a place of beauty' in Xhosa, is a township located on the outskirts of Kariega at (33.8153 S, 25.3817 E). For the Kariega area, the population was projected to be 103 639 with a density of 1376 persons/km² according to the 2011 census (StatsSA, 2023a). Whereas the population of the Kwa Nobuhle area was projected to be 107 474, with a density of 4577 persons/km² (StatsSA, 2023b). The following water bodies were selected both in Kariega and Kwa Nobuhle; dam at Willow Park (33°45'01.8"S 25°24'47.7"E), river at Mel Brooks (33°47'31.1"S 25°24'57.9"E), watershed at Doornhoek (33°45'27.9"S 25°22'02.0"E), pond at Winterhoek (33°44'54.0"S 25°25'50.3"E), river at Cuyler (33°46'18.5"S 25°23'09.8"E), dam at Godolozzi (33°48'50.6"S 25°24'09.1"E), wetland at Matanzima (33°47'38.9"S 25°23'07.5"E) and river at Sangcaphe (33°49'06.9"S 25°22'20.4"E).

2.2.3 Study population

Phase one of the study focused on physico-chemical properties and the environmental conditions of water bodies, while phase two focused on snail abundance and vegetation type. Since both of these phases focused on other elements rather than the members living in the area, there was no study population. Phase three of the study was carried out at the Kariega and Kwa Nobuhle and they were both the primary study areas. Community members between the ages of 18-65 living in close proximity to water bodies that were sampled were selected for the pretest-post-test survey in the form of interviews. In between the pre- and post-interviews, an educational intervention was implemented to enhance the participants' KAPs on schistosomiasis.

2.2.4 Sampling techniques Data collection, and instruments

2.2.4.1 Phase one: Water physicochemical properties and environmental conditions

Plastic containers (1 L) were used to collect water samples via a simple dip method (Marie *et al.*, 2015). Physicochemical characteristics were measured using a handheld Bante 900P multiparameter meter, a Macherey Nagel PF-12 Plus and a hardness meter. Field observations were carried out to determine environmental conditions.

2.2.4.2 Phase two: Vegetation types and Snail abundance

Dominant species of vegetation at each sampling site were collected and taken to experts in the Botany Department at Nelson Mandela University for the identification process. Vegetation composition and percentage cover were visually estimated and recorded at each sampling point.

The researcher employed previously used sampling methods to collect snails. Snails were caught with a standard 300 µm mesh scoop net on a metal frame (Opisa *et al.*, 2011; Olkeba *et al.*, 2020). Snails collected from each waterbody were stored in bottles containing water from that specific waterbody and were later identified to species level according to shell morphology using the Danish Bilharziasis Laboratories manual and

2.3 WORK PACKAGE 2 (WP2)

2.3.1 Study area

The study was conducted in five towns within NMB: Motherwell, Despatch, KwaNobuhle, Kariega, and Ibhayi. Located on the shores of Algoa Bay in the Eastern Cape, NMB is one of South Africa's eight metropolitan municipalities, established on December 5, 2000. Covering an area of 1,959 km², it has geographical coordinates of 33.57°S, 25°36'E. According to the 2022 census, NMB's population is 1.2 million, with the majority being Black (60%), followed by Coloured (23.6%) and White (14.4%) (Stats, 2022). The predominant languages spoken are isiXhosa, Afrikaans, and English. NMB experiences long, cool winters and short, warm summers, with a dry, clear, and windy climate year-round. In 2023, the average temperature was 22.7°C, with a high of 35.5°C in April and a low of 12°C in July. NMB is a major seaport with a large automotive manufacturing industry, contributing significantly to the local economy, along with community services. Fishing, agriculture, and recreational activities are key human activities in the area.

2.3.2 Study design

An observational cross-sectional study design using quantitative methods was utilised in this study. Sample and data collection were done from September 2023 to February 2024. The study was divided into three phases. Phase 1 was to determine the risk factors and KAP associated with schistosomiasis transmission in the study area. A semi-structured questionnaire survey was used in an interview-based method. Phase 2 was to determine the prevalence of schistosomiasis (*S. haematobium* and *S. mansoni*) and STHs among school-going children in Motherwell, Despatch, Kariega, KwaNobuhle and Ibhayi towns of NMB. Phase 3: urinalysis to profile parameters was performed in all the participants in the study and the association between the detected biomarkers and schistosomiasis infections was determined.

2.3.3 Study population

The study population comprised school-going children aged 5-14 years from the towns of Motherwell, Despatch, KwaNobuhle, Kariega, and Ibhayi in NMB. Participants who met the inclusion criteria were randomly selected from 15 public primary schools within these towns.

2.3.4 Research methods: Sampling techniques, data collection, and instruments

In order to achieve the research objectives and provide comprehensive insights into the transmission, prevalence, and diagnosis of schistosomiasis among school-going children in NMB, a detailed and structured study approach was designed. This section outlines the general methodologies and strategies employed in each phase of the study, highlighting the data collection processes, diagnostic tools, and statistical techniques utilised to ensure robust and reliable findings.

2.3.4.1 Phase 1: Risk Factors Associated with Schistosomiasis Transmission

In Phase 1 of the study, which is provided in detail in Chapter 3, the risk factors associated with the risk of schistosomiasis infection among school-going children in NMB are identified, as well as examining how the KAP of school-going children contributes to the risk of schistosomiasis infection in this population. This was a cross-sectional study design, with data collected through an interview-based questionnaire administered to school-going children aged 5-14 years. The responses were uploaded to QuestionPro for analysis. The questionnaire gathered demographic, clinical and environmental information, including details on water sources, sanitation, and hygiene practices. The KAP assessment aimed to understand the children's knowledge about schistosomiasis, their attitudes towards prevention, and their practices regarding water contact and hygiene. To analyse the data, multivariate logistic regression was used to identify relationships between the identified risk factors, including KAP and environmental factors, with the risk of schistosomiasis infection. The expected outcomes from this phase included the identification of behavioural, environmental, and demographic factors that influence schistosomiasis risk and insights into how children's knowledge, attitudes and practices affect their exposure to schistosomiasis.

2.3.4.2 Phase 2: Schistosomiasis Prevalence and Epidemiology

In Phase 2, the study concentrated on determining the prevalence of *S. haematobium* infections among school-going children aged 5-14 years in NMB through a comprehensive diagnostic approach. This objective is detailed in Chapter 4. A cross-sectional study design was employed, involving the collection of biological samples (urine) from the children. The diagnostic methods for *S. haematobium* included urine filtration for detecting *S. haematobium* eggs, haematuria assessment as an indirect indicator, and cPCR (conventional PCR) for molecular confirmation of infection. The data obtained allowed for the calculation of prevalence rates, which were then stratified to compare differences in prevalence based on age, gender, and school grade. This phase aimed to produce detailed prevalence data and evaluate the effectiveness of diagnostic tools for detecting *S. haematobium* in a low-endemic region like NMB.

Phase 2 also focused on assessing the prevalence of *S. mansoni* and STHs infections among the same group of school-going children aged 5-14 years in NMB. Stool samples were collected and analysed using multiple diagnostic techniques, which are given in full in Chapter 5. These included the Kato-Katz method for quantifying *S. mansoni* and STHs eggs, the POC-CCA test for detecting *S. mansoni* antigens, and cPCR for molecular confirmation. Prevalence rates were calculated for *S. mansoni* and STHs, with stratified analysis conducted to examine variations in prevalence across different ages, genders, and school grades. The expected outcomes of this phase included comprehensive data on the prevalence of *S. mansoni* and STHs among school children and an evaluation of diagnostic approaches to identify the most reliable tools for detecting these infections in low-endemic settings.

2.3.4.3 Phase 3: Schistosomiasis Diagnostic Biomarkers

Phase 3 of the study focused on profiling key urinary parameters measured by dipsticks urinalysis in school-going children aged 5-14 years in NMB and identifying detectable urinary biomarkers associated with *Schistosoma* infections in this population. A cross-sectional study design was used, where urine samples were collected and analysed for urinary biomarkers. The samples were subjected to urinalysis using Siemens Multistix 10SG dipsticks to profile parameters such as haematuria and proteinuria. Statistical analysis involved descriptive statistics to summarize the distribution of urinary biomarkers. Correlation analysis was conducted to examine the relationship between specific urinary biomarkers and schistosomiasis infection. The expected outcomes included the identification of reliable urinary biomarkers associated with schistosomiasis infection in school-going children, with recommendations on the use of dipstick urinalysis as a cost-effective tool for screening schistosomiasis in resource-limited settings.

2.3.5 1.9.5 Recruitment

The Department of Basic Education was contacted to request access to the schools, and written approval was obtained before sample collection began. The researcher met with school authorities to explain the study's procedures and benefits. Written consent was then obtained from the headmasters or principals before contacting parents/guardians for consent to access participants and share study details. Children who met the inclusion and exclusion criteria were recruited into the study and assigned unique identifier numbers, ranging from 1 to 759, which were labelled on questionnaires and urine and stool samples to ensure anonymity. The numbering system ensured that neither the researcher nor anyone else could link the participant's identity to their samples or questionnaires, except in the case of a positive schistosomiasis result, when the number would be traced to provide medical assistance. Each school was assigned a letter (A, B, C, etc.) to maintain anonymity.

2.4 WORK PACKAGE 3 (WP3)

2.4.1 Study Area

Kariega (formerly Uitenhage) is situated in the Eastern Cape Province of South Africa, centred at coordinates 33.7479°S, 25.4124°E, approximately 30 km northwest of Gqeberha. The town falls within the Nelson Mandela Bay Municipality, which also encompasses Despatch, KwaNobuhle, Gqeberha, and adjacent regions. Three environmental water bodies within the Kariega study area were selected for analysis.

2.4.2 Sampling Protocol

Water samples were collected seasonally (summer, autumn, winter, spring) between June 2023 and April 2024 to capture both dry and wet season conditions. A total of 52 samples were analysed: 40 from municipal water supply points and 12 from environmental sources (13 samples per season). Samples were aseptically collected, stored on ice, and couriered (DHL) to the CSIR laboratory for analysis. Target analytes included total coliform bacteria, *Escherichia coli*, *Salmonella* spp., *Shigella* spp., and *Vibrio cholerae*.

2.4.3 Sample Size

The study comprised 52 water samples: 40 from treated municipal outlets and 12 from environmental raw water sources.

2.4.4 Analytical Methods

2.4.4.1 Total Coliform Bacteria and *E. coli*

Total coliforms and *E. coli* were quantified using the Colilert™-18 Most Probable Number (MPN) method (IDEXX, USA). Samples were incubated at 35°C for 18–24 hours. Coliforms were identified by yellow fluorescence under visible light, while *E. coli* was detected via blue fluorescence under UV light. MPN values were calculated using the IDEXX MPN Generator.

2.4.4.2 *Salmonella* spp. and *Shigella* spp. Detection

A 100 mL aliquot was filtered through 0.22 µm polycarbonate membranes. Filters were incubated overnight in buffered peptone water at 35°C. DNA extracted from pelleted cells (13,000 rpm, 2 min) using InstaGene™ Matrix (Bio-Rad) was analyzed via real-time PCR. *Salmonella* spp. was identified using the *invA* gene (Malorny et al., 2003), while *Shigella* spp./enteroinvasive *E. coli* (EIEC) were detected via the *ipaH* gene (Theron et al., 2001).

2.4.4.3 *Vibrio cholerae* Detection

Following filtration (100 mL through 0.22 µm membranes), filters were incubated in alkaline peptone water (pH 8.4) at 35°C. DNA extraction (InstaGene™ Matrix) preceded real-time PCR targeting the *ompW* gene for *V. cholerae* identification (le Roux & van Blerk, 2011; Nandi et al., 2000) and the *ctxAB* operon for toxigenic strains (Goel et al., 2005).

2.4.4.4 Physicochemical Parameters

Electrical conductivity, total dissolved solids (TDS), and pH were measured in situ using calibrated portable probes. Analyses were conducted within 24 hours of collection.

2.4.5 Data Acquisition and Statistical Analysis

Diarrhoeal disease prevalence data (June 2023–April 2024) will be sourced from the National Institute for Communicable Diseases (NICD) and District Health Information System (DHIS), restricted to the Kariega region. Municipal water quality records will also be reviewed for correlative analysis. Non-parametric statistical methods were applied due to non-normal data distribution. Analyses included Spearman's rank correlation, Welch's t-test, and one-way ANOVA.

2.5 WORK PACKAGE 4 (WP4)

2.5.1 Study Area

The study was conducted across all five municipal waste depots and six wastewater treatment plants (WTPs) in the Nelson Mandela Bay Metropolitan Municipality (NMBM), South Africa. NMBM spans 1,959 km², with a population of 1.26 million (2018 census), and is characterized by high organic (39%) and recyclable (37%) waste generation.

2.5.2 Study Design

A quasi-experimental design with pre- and post-intervention assessments was employed to evaluate the impact of an educational program on hygiene knowledge and practices among municipal waste and sanitation workers (MWSW).

2.5.3 Population and Sampling

2.5.3.1 Target Population

618 MWSW (street sweepers, latrine cleaners, waste transporters).

2.5.3.2 Sampling

Convenience sampling was used due to limited worker availability. Slovin's formula determined a minimum sample size of 243 (5% margin of error). Initially, 244 participants were enrolled, but 43 were lost to follow-up, resulting in 201 participants analysed per-protocol.

2.5.4 Intervention

A 30-minute educational program (Microsoft PowerPoint presentation in English/isiXhosa, supplemented with flyers and posters) was delivered to enhance hygiene practices. Key topics included disease prevention and hygiene protocols.

2.5.5 Data Collection

A structured, self-administered questionnaire (three sections: demographics, knowledge, practices) with closed-ended questions. Pre- and post-tests were conducted two months apart. Questionnaires were distributed during work hours, with pre- and post-intervention data collected in secure, anonymized formats.

2.5.6 Data Analysis:

Cronbach's alpha scores of 0.81 (knowledge) and 0.75 (practices) confirmed internal consistency. Descriptive statistics, Pearson's correlation, paired t-tests (pre/post comparison), ANOVA (demographic differences), and linear regression. Scores were categorized as poor/fair/good for interpretation.

2.6 RESULTS, DISCUSSION, CONCLUSION & RECOMMENDATIONS

These sections are addressed in four separate work packages (WP1–WP4) to guarantee methodological rigour, facilitate the coherent dissemination of findings, and comprehensively address the research aims. The individual phases of each work bundle are intended to sequentially unpack critical components of the research lifecycle, including methodology development, results synthesis, contextualised discussions, and actionable conclusions/recommendations. See the packages for more information.

REFERENCES

- Adekiya, T. A., Aruleba, R. T., Oyinloye, B. E., Okosun, K. O., & Kappo, A. P. (2020). The effect of climate change and the snail-schistosome cycle in transmission and bio-control of schistosomiasis in sub-saharan africa. *In International Journal of Environmental Research and Public Health* (Vol. 17, Issue 1). MDPI AG. <https://doi.org/10.3390/ijerph17010181>
- Angora EK, Boissier J, Menan H, Rey O, Tuo K, Touré AO, Coulibaly JT, Méité A, Raso G, N'Goran EK, Utzinger J, Balmer O. Prevalence and Risk Factors for Schistosomiasis among Schoolchildren in two Settings of Côte d'Ivoire. *Trop Med Infect Dis*. 2019 Jul 23;4(3):110. <https://doi.org/10.3390/tropicalmed4030110>
- Appleton CC, Miranda NA. Two Asian freshwater snails newly introduced into South Africa and an analysis of alien species reported to date. *African Invertebrates*. 2015 Jan 1;56(1):1-7. <https://doi.org/10.5733/afin.056.0102>
- Appleton, Chris C., & Naidoo, Inbarani. (2012). Why did schistosomiasis disappear from the southern part of the Eastern Cape?. *South African Journal of Science*, 108(1-2), 01-11. Retrieved November 30, 2023, from http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532012000100011&lng=en&tling=en
- Atmore, E., van Niekerk, L. J., & Ashley-Cooper, M. (2012). *Challenges facing the early childhood development sector in South Africa*. *South African Journal of Childhood Education*, 2(1), 120- 139. <https://doi.org/10.4102/sajce.v2i1.25>
- Barkia, H., Barkia, A., Yacoubi, R., Guamri, Y.E., Madhi, Y.E., & Belghyti, D. (2015). Trematode infection among freshwater gastropods in the Gharb area, Morocco. *Journal of environment and earth science*, 5, 174-181. Retrieved November 30, 2023, from <https://www.iiste.org/Journals/index.php/JEES/article/view/19442>
- Bartram J, Cairncross S (2010) Hygiene, Sanitation, and Water: Forgotten Foundations of Health. *PLoS Med* 7(11): e1000367. <https://doi.org/10.1371/journal.pmed.1000367>
- Bernardo, R., Herrador, G., Freiesleben, B., MacDonald, E., Nichols, G., Sudre, B., Vold, L., Semenza, C. and Nygård, K. 2015. Analytical studies assessing the association between extreme precipitation or temperature and drinking water-related waterborne infections: a review. *Environ Health*. Mar 27;14:29. <https://doi.org/10.1186/s12940-015-0014-y>.
- Birhanu, B., Traoré, K., Sanogo, K., Tabo, R., Fischer, G., & Whitbread, A. (2023). Contour bunding technology-evidence and experience in the semiarid region of southern Mali – CORRIGENDUM. *Renewable Agriculture and Food Systems*, 38, E37. <https://doi.org/10.1017/S1742170523000315>
- Bizimana N. Traditional veterinary practice in Africa. TZ-Verlag-Ges.; 1997.
- Boland, A., Cherry, M.G. and Dickson, R. (2017). Doing a systematic review : a student's guide. *SAGE Publishing*. https://uk.sagepub.com/sites/default/files/upm-assets/87631_book_item_87631.pdf
- Brouwer, K. C., Ndhlovu, P. D., Wagatsuma, Y., Munatsi, A., & Shiff, C. J. (2003). Epidemiological assessment of *Schistosoma haematobium*-induced kidney and bladder pathology in rural Zimbabwe. *Acta Tropica*, 85(3), 339–347. [https://doi.org/10.1016/S0001-706X\(02\)00262-0](https://doi.org/10.1016/S0001-706X(02)00262-0)
- Brown DS. *Freshwater snails of Africa and their medical importance*. CRC press; 1994 May 26.
- Centola, Damon and Zhang, Jingwen, Social Networks and Health: New Developments in Diffusion, Online and Offline (July 2019). *Annual Review of Sociology*, Vol. 45, pp. 91-109, 2019, Available at SSRN: <http://dx.doi.org/10.1146/annurev-soc-073117-041421> Chatterjee S, De Man J, Van Marck E. Somatostatin and intestinal schistosomiasis: therapeutic and neuropathological implications in host-parasite interactions. *Trop Med Int Health*. 2001 Dec;6(12):1008-15. <https://doi.org/10.1046/j.1365-3156.2001.00744.x>.
- Choto, E. T., Mduluzza, T., Mutapi, F., & Chimbari, M. J. (2020). Association of schistosomiasis and risk of prostate cancer development in residents of Murehwa rural community, Zimbabwe. *Infectious Agents and Cancer*, 15(1), 59. <https://doi.org/10.1186/s13027-020-00327-2>

- Civitello, D. J., Angelo, T., Nguyen, K. H., Hartman, R. B., Starkloff, N. C., Mahalila, M. P., Charles, J., Manrique, A., Delius, B. K., Bradley, L. M., Nisbet, R. M., Kinung'hi, S., & Rohr, J. R. (2022). Transmission potential of human schistosomes can be driven by resource competition among snail intermediate hosts. *Proceedings of the National Academy of Sciences*, 119(6), e2116512119. <https://doi.org/10.1073/pnas.2116512119>
- Colley DG, Bustinduy AL, Secor WE, King CH. Human schistosomiasis. *The Lancet*. 2014 Jun 28;383(9936):2253-64. [https://doi.org/10.1016/S0140-6736\(13\)61949-2](https://doi.org/10.1016/S0140-6736(13)61949-2).
- Curriero FC, Patz JA, Rose JB, Lele S. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994. *Am J Public Health*. 2001 Aug;91(8):1194-9. <https://doi.org/10.2105/ajph.91.8.1194>.
- De Boni L, Msimang V, De Voux A, Freaun J. Trends in the prevalence of microscopically confirmed schistosomiasis in the South African public health sector, 2011-2018. *PLoS Negl Trop Dis*. 2021 Sep 16;15(9):e0009669. <https://doi.org/10.1371/journal.pntd.0009669>.
- DeKock, C.C., 1973. Nelspruit 1200.
- Department of Health: Communicable Diseases Control Directorate: 2019: <https://www.health.gov.za/communicable-diseases/>
- Desye, B. (2021). COVID-19 Pandemic and Water, Sanitation, and Hygiene: Impacts, Challenges, and Mitigation Strategies. *Environmental Health Insights*, 15, 11786302211029447. <https://doi.org/10.1177/11786302211029447>
- Effler E, Isaäcson M, Arntzen L, Heenan R, Canter P, Barrett T, Lee L, Mambo C, Levine W, Zaidi A, Griffin PM. Factors contributing to the emergence of Escherichia coli O157 in Africa. *Emerg Infect Dis*. 2001 Sep-Oct;7(5):812-9. <https://doi.org/10.3201/eid0705.017507>.
- Ferraz AA, de Albuquerque PC, Lopes EP, de Araújo JG Jr, Carvalho AH, Ferraz EM. The influence of periportal (pipestem) fibrosis on long term results of surgical treatment for schistosomotic portal hypertension. *Arg Gastroenterol*. 2003 Jan-Mar;40(1):4-10. <https://doi.org/10.1590/s0004-28032003000100002> . Epub 2003 Oct 6.
- Fischer Walker, C. L., Perin, J., Aryee, M. J., Boschi-Pinto, C., and Black, R. E. 2012. Diarrhea incidence in low- and middle-income countries in 1990 and 2010: A systematic review. *BMC Public Health*, 12(1), 220. <https://doi.org/10.1186/1471-2458-12-220>.
- Ganguly P. (2020). Impact of COVID-19 on waste and sanitation workers. The Daily Star. Available online: <https://www.thedailystar.net/opinion/news/impact-covid-19-waste-and-sanitation-workers-1901353>. (Accessed 16 August 2021).
- GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018 Nov 10;392(10159):1789-1858. [https://doi.org/10.1016/S0140-6736\(18\)32279-7](https://doi.org/10.1016/S0140-6736(18)32279-7) . Epub 2018 Nov 8. Erratum in: *Lancet*. 2019 Jun 22;393(10190):e44.
- Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2015 (GBD 2015) Life Expectancy, All-Cause and Cause-Specific Mortality 1980-2015. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2016. Retrieved from <https://ghdx.healthdata.org/record/ihme-data/gbd-2015-life-expectancy-all-cause-and-cause-specific-mortality-1980-2015> (Accessed 30 November 2023)
- Goel, A.K., Tamrakar, A.K., Nema, V. et al. Detection of Viable Toxigenic *Vibrio cholerae* from Environmental Water Sources by Direct Cell Duplex PCR Assay. *World J Microbiol Biotechnol* 21, 973–976 (2005). <https://doi.org/10.1007/s11274-004-7317-4>

- Gryseels B, Polman K, Clerinx J, Kestens L. Human schistosomiasis. *Lancet*. 2006 Sep 23;368(9541):1106-18. [https://doi.org/10.1016/S0140-6736\(06\)69440-3](https://doi.org/10.1016/S0140-6736(06)69440-3). PMID: 16997665.
- Hambury, S. D., Grobler, A. D., & Melariri, P. E. (2021). Knowledge, Attitudes, and Practices on Urinary Schistosomiasis among Primary Schoolchildren in Nelson Mandela Bay, South Africa. *Journal of parasitology research*, 2021, 6774434. <https://doi.org/10.1155/2021/6774434>
- Herrador Z, Fernández-Martínez B, Quesada-Cubo V, Díaz-García O, Cano R, Benito A, Gómez-Barroso D. Imported cases of malaria in Spain: observational study using nationally reported statistics and surveillance data, 2002-2015. *Malar J*. 2019 Jul 10;18(1):230. <https://doi.org/10.1186/s12936-019-2863-2>.
- Hotez PJ, Kamath A. Neglected tropical diseases in sub-Saharan Africa: review of their prevalence, distribution, and disease burden. *PLoS Negl Trop Dis*. 2009 Aug 25;3(8):e412. <https://doi.org/10.1371/journal.pntd.0000412>.
- IFRC, 2001. Unseen need in IFRC world disaster report. Australian Journal of Emergency Management, The, 34(1), p.15.
- Ishida K, Hsieh MH. Understanding Urogenital Schistosomiasis-Related Bladder Cancer: An Update. *Front Med (Lausanne)*. 2018 Aug 10;5:223. <https://doi.org/10.3389/fmed.2018.00223>.
- Kalinda, C.; Chimbari, M.; Mukaratirwa, S. Implications of Changing Temperatures on the Growth, Fecundity and Survival of Intermediate Host Snails of Schistosomiasis: A Systematic Review. *Int. J. Environ. Res. Public Health* 2017, 14, 80. <https://doi.org/10.3390/ijerph14010080>
- Karon, A. J., Cronin, A. A., Cronk, R., and Hendrawan, R. 2017. Improving water, sanitation, and hygiene in schools in Indonesia: A cross-sectional assessment on sustaining infrastructural and behavioral interventions. *International Journal of Hygiene and Environmental Health*. <https://doi.org/10.1016/j.ijheh.2017.02.001>
- King, A, Shackleton, C.M, Maintenance of public and private urban green infrastructure provides significant employment in Eastern Cape towns, South Africa, *Urban Forestry & Urban Greening*, Volume 54, 2020, 126740, ISSN 1618-8667, <https://doi.org/10.1016/j.ufug.2020.126740>.
- King, C. H. (2011). Schistosomiasis: Challenges and Opportunities. In the Causes and Impacts of Neglected Tropical and Zoonotic Diseases: Opportunities for Integrated Intervention Strategies. *National Academies Press (US)*. <https://www.ncbi.nlm.nih.gov/books/NBK62510/>
- Knopp S, Corstjens PL, Koukounari A, Cercamondi CI, Ame SM, Ali SM, de Dood CJ, Mohammed KA, Utzinger J, Rollinson D, van Dam GJ. Sensitivity and Specificity of a Urine Circulating Anodic Antigen Test for the Diagnosis of *Schistosoma haematobium* in Low Endemic Settings. *PLoS Negl Trop Dis*. 2015 May 14;9(5):e0003752. <https://doi.org/10.1371/journal.pntd.0003752>.
- le Roux, W.J., van Blerk, G.H. (2011) The use of a high-resolution melt real-time polymerase chain reaction (PCR) assay for the environmental monitoring of *Vibrio cholerae*. *African Journal of Microbiology Research* 5 : 3520-3526. <https://doi.org/10.5897/AJMR11.695>
- Levy K, Woster AP, Goldstein RS, Carlton EJ. Untangling the impacts of climate change on waterborne diseases: a systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. *Environ Sci Technol*.2016;50:4905–22. <https://doi.org/10.1021/acs.est.5b06186>.
- M'Bra RK, Kone B, Yapi YG, Silué KD, Sy I, Vienneau D, Soro N, Cissé G, Utzinger J. Risk factors for schistosomiasis in an urban area in northern Côte d'Ivoire. *Infectious diseases of poverty*. 2018 Dec;7(1):1-2. <https://doi.org/10.1186/s40249-018-0431-6>
- Machiwal, D., & Jha, M.K. (2010). Tools and Techniques for Water Quality Interpretation.1;354(6313):aaf7671. <https://doi.org/10.1126/science.aaf7671>.
- MacKellar, Neil, New, Mark, & Jack, Chris. (2014). Observed and modelled trends in rainfall and temperature for South Africa: 1960-2010. *South African Journal of Science*, 110(7-8), 1-13. Retrieved November 30, 2023,

- from http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532014000400014&lng=en&tlng=en
- Magaisa, K., Taylor, M., Kjetland, E. F., & Naidoo, P. J. (2015). A review of the control of schistosomiasis in South Africa. In *South African Journal of Science* (Vol. 111, Issues 11–12). Academy of Science of South Africa. Retrieved May 10, 2022, from <https://doi.org/10.17159/sajs.2015/20140427>
- Malorny B., Hoorfar, J., Bunge, C., Helmuth, R. (2003) Multi-center validation of the analytical accuracy of Salmonella PCR: towards an international standard. *Applied and Environmental Microbiology* 69: 290–296. <https://doi.org/10.1128/AEM.69.1.290-296.2003>
- Mbabazi PS, Andan O, Fitzgerald DW, Chitsulo L, Engels D, Downs JA. Examining the relationship between urogenital schistosomiasis and HIV infection. *PLoS neglected tropical diseases*. 2011 Dec 6;5(12):e1396. <https://doi.org/10.1371/journal.pntd.0001396>.
- McManus RJ, Mant J, Franssen M, Nickless A, Schwartz C, Hodgkinson J, Bradburn P, Farmer A, Grant S, Greenfield SM, Heneghan C. Efficacy of self-monitored blood pressure, with or without telemonitoring, for titration of antihypertensive medication (TASMINH4): an unmasked randomised controlled trial. *The Lancet*. 2018 Mar 10;391(10124):949-59. [https://doi.org/10.1016/S0140-6736\(18\)30309-X](https://doi.org/10.1016/S0140-6736(18)30309-X)
- Melariri, P., Steenkamp, L., Williams, M., Mtembu, C., Ronaasen, J., and Truter, I. 2019. Water, sanitation and hygiene practices in early childhood development (ECD) centres in low socioeconomic areas in Nelson Mandela Bay, South Africa. *Journal of Water, Sanitation and Hygiene for Development*. 9 (1): 164–171. <https://doi.org/10.2166/washdev.2019.130>.
- Midgley, G., Bond, W. Future of African terrestrial biodiversity and ecosystems under anthropogenic climate change. *Nature Clim Change* 5, 823–829 (2015). <https://doi.org/10.1038/nclimate2753>
- Müller I, Yap P, Steinmann P, Damons BP, Schindler C, Seelig H, Htun NS, Probst-Hensch N, Gerber M, du Randt R, Pühse U, Walter C, Utzinger J. Intestinal parasites, growth and physical fitness of schoolchildren in poor neighbourhoods of Port Elizabeth, South Africa: a cross-sectional survey. *Parasit Vectors*. 2016 Sep 5;9(1):488. <http://doi.org/10.1186/s13071-016-1761-5>.
- Nandi, B., Nandy, R.K., Mukhopadhyay, S., Nair, G.B., Shimada, T., Ghose, A.C. 2000. Rapid method for species-specific identification of *Vibrio cholerae* using primers targeted to the gene of the outer membrane protein OmpW. *Journal of Clinical Microbiology* 38: 4145–4151. <https://doi.org/10.1128/jcm.38.11.4145-4151.2000>
- Nelwan, M. L. (2019). Schistosomiasis: Life Cycle, Diagnosis, and Control. *Current Therapeutic Research*, 91, 5–9. <https://doi.org/10.1016/j.curtheres.2019.06.001>
- Nenzhelele DC. Workplace Bullying: Experiences and Perspectives of Black Women Retail Workers from Johannesburg. University of Johannesburg (South Africa); 2020. <https://hdl.handle.net/10210/478002>
- Nepal A, Kadariya J, Thapaliya D, Bhatta S, Mahatara RL, Bempah S, Dhakal N, Smith TC. Multidrug-resistant *Staphylococcus aureus* colonization in healthy adults is more common in Bhutanese refugees in Nepal than those resettled in Ohio. *BioMed research international*. 2019 Jul 1;2019. <https://doi.org/10.1155/2019/5739247>
- Nour, N. M. (2010). Schistosomiasis: Health effects on women. *Reviews in Obstetrics & Gynecology*, 3(1), 28–32. PMID: PMC2876318 PMID: 20508780
- Nyati-Jokomo Z, Chimbari MJ. Risk factors for schistosomiasis transmission among school children in Gwanda district, Zimbabwe. *Acta Tropica*. 2017 Nov 1;175:84-90. <https://doi.org/10.1016/j.actatropica.2017.03.033>
- Olkeba BK, Boets P, Mereta ST, Yeshigeta M, Akessa GM, Ambelu A, Goethals PL. Environmental and biotic factors affecting freshwater snail intermediate hosts in the Ethiopian Rift Valley region. *Parasites & vectors*. 2020 Dec;13(1):1-3. <https://doi.org/10.1186/s13071-020-04163-6>

- Olveda DU, Li Y, Olveda RM, Lam AK, Chau TN, Harn DA, Williams GM, Gray DJ, Ross AG. Bilharzia: pathology, diagnosis, management and control. *Tropical medicine & surgery*. 2013 Aug 20;1(4). <https://doi.org/10.4172/2329-9088.1000135>
- Ondigo Qa. Effects Of Inmate Characteristics And Institutional Capacity On Prison Rehabilitation Outcomes In Selected Prisons In Nairobi City County, Kenya (Doctoral Dissertation, Kenyatta University. <http://ir-library.ku.ac.ke/handle/123456789/21355>
- Ouma JH, Sturrock RF, Klumpp RK, Kariuki HC. A comparative evaluation of snail sampling and cercariometry to detect *Schistosoma mansoni* transmission in a large-scale, longitudinal fieldstudy in Machakos, Kenya. *Parasitology*. 1989 Dec;99(3):349-55. <https://doi.org/10.1017/s0031182000059060>
- Peron, G.; Altwegg, R.; Jamie, G.A.; Spottiswoode, C.N. Coupled range dynamics of brood parasites and their hosts responding to climate and vegetation changes. *J. Anim. Ecol.* 2016, 85, 1191–1199. <https://doi.org/10.1111/1365-2656.12546>
- Reddy, V. B., Kusuma, Y. S., Pandav, C. S., Goswami, A. K., & Krishnan, A. 2017. Water and Sanitation Hygiene Practices for Under-Five Children among Households of Sugali Tribe of Chittoor District, Andhra Pradesh, India. *Journal of Environmental and Public Health*, 2017. <https://doi.org/10.1155/2017/7517414>.
- Rius, M.; Clusella-Trullas, S.; McQuaid, C.D.; Navarro, R.A.; Griffiths, C.L.; Matthee, C.A.; von der Heyden, S.; Turon, X. Range expansions across ecoregions: Interactions of climate change, physiology and genetic diversity. *Glob. Ecol. Biogeogr.* 2014, 23, 76–88. <https://doi.org/10.1111/GEB.12105>
- Ruiters C, Matji MP. Water institutions and governance models for the funding, financing and management of water infrastructure in South Africa. *Water Sa.* 2015 Oct 1;41(5):660-76. <http://dx.doi.org/10.4314/WSA.V41I5.09>
- Saathoff E, Olsen A, Magnussen P, Kvalsvig JD, Becker W, Appleton CC. Patterns of *Schistosoma haematobium* infection, impact of praziquantel treatment and re-infection after treatment in a cohort of schoolchildren from rural KwaZulu-Natal/South Africa. *BMC Infectious Diseases*. 2004 Dec;4(1):1-0. <https://doi.org/10.1186/1471-2334-4-40>
- Sacolo-Gwebu, H., Kabuyaya, M., & Chimbari, M. (2019). Knowledge, attitudes and practices on schistosomiasis and soil-transmitted helminths among caregivers in Ingwavuma area in uMkhanyakude district, South Africa. *BMC Infectious Diseases*, 19(1), 734. <https://doi.org/10.1186/s12879-019-4253-3>
- Schael DM, T Gama PH. Ecosystem process and function of temporary wetlands: baseline data for climate change predictions. Water Research Commission, Pretoria. *WRC Report*. 2019 May(2348/1):19.
- Schaible UE, Kaufmann SH. Malnutrition and infection: complex mechanisms and global impacts. *PLoS Med.* 2007 May;4(5):e115. <https://doi.org/10.1371/journal.pmed.0040115>.
- Scheffers BR, De Meester L, Bridge TC, Hoffmann AA, Pandolfi JM, Corlett RT, Butchart SH, Pearce-Kelly P, Kovacs KM, Dudgeon D, Pacifici M, Rondinini C, Foden WB, Martin TG, Mora C, Bickford D, Watson JE. The broad footprint of climate change from genes to biomes to people. *Science*. 2016 Nov 11;354(6313):aaf7671. <https://doi.org/10.1126/science.aaf7671>.
- Schistosomiasis and Soil-transmitted helminthiasis Mapping in Eastern Cape Province, 2017.
- Schmidt, K., & Azzi-Lessing, L. (2019). The experiences of early childhood development home visitors in the Eastern Cape province of South Africa. *South African Journal of Childhood Education*, 9(1), 1-12. <http://dx.doi.org/10.4102/sajce.v9i1.748>.
- Shrestha A, Sharma S, Gerold J, Erismann S, Sagar S, Koju R, Schindler C, Odermatt P, Utzinger J, Cissé G. Water quality, sanitation, and hygiene conditions in schools and households in Dolakha and Ramechhap districts, Nepal: results from a cross-sectional survey. *International journal of environmental research and public health*. 2017 Jan;14(1):89. <https://doi.org/10.3390/ijerph14010089>

Simoonga C, Utzinger J, Brooker S, Vounatsou P, Appleton CC, Stensgaard AS, Olsen A, Kristensen TK. Remote sensing, geographical information system and spatial analysis for schistosomiasis epidemiology and ecology in Africa. *Parasitology*. 2009 Nov;136(13):1683-93. <https://doi.org/10.1017/S0031182009006222>. Epub 2009 Jul 23.

STATSSA 2020. South African population. Retrieved from <https://www.statssa.gov.za/?p=13453#:~:text=South%20Africa%E2%80%99s%20mid%20year%20population%20is%20estimated%20to,15%2C5%20million%20people%20%2826%2C0%25%29%20living%20in%20th is%20province>. (20 August 2023)

Steenkamp, L. et al. (2020) 'Handwashing knowledge and practices among caregivers of preschool children in underprivileged areas of Nelson Mandela Bay', *South African Journal of Clinical Nutrition*. Taylor & Francis, 0(0), pp. 1–5. <https://doi.org/10.1080/16070658.2020.1769336>.

Tamarozzi F, Ursini T, Hoekstra PT, Silva R, Costa C, Gobbi F, Monteiro GB, Motta L, van Dam GJ, Corstjens PL, van Lieshout L, Buonfrate D. Evaluation of microscopy, serology, circulating anodic antigen (CAA), and eosinophil counts for the follow-up of migrants with chronic schistosomiasis: a prospective cohort study. *Parasit Vectors*. 2021 Mar 9;14(1):149. <https://doi.org/10.1186/s13071-021-04655-z>.

The Centers for Disease Control and Prevention (CDC) (2021). Schools and Childcare: COVID-19 Guidance for Operating Early Care and Education/Child Care Programs. Available online: <https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/child-careguidance.html>.

(Accessed 16 August 2021).

Theron J, Morar D, Du Preez M, Brözel VS, Venter SN. A sensitive seminested PCR method for the detection of *Shigella* in spiked environmental water samples. *Water Research*. 2001 Mar;35(4):869-874. [https://doi.org/10.1016/s0043-1354\(00\)00348-1](https://doi.org/10.1016/s0043-1354(00)00348-1).

Troeger C, Colombara DV, Rao PC, Khalil IA, Brown A, Brewer TG, Guerrant RL, Houpt ER, Kotloff KL, Misra K, Petri WA Jr, Platts-Mills J, Riddle MS, Swartz SJ, Forouzanfar MH, Reiner RC Jr, Hay SI, Mokdad AH. Global disability-adjusted life-year estimates of long-term health burden and undernutrition attributable to diarrhoeal diseases in children younger than 5 years. *Lancet Glob Health*. 2018 Mar;6(3):e255-e269. [https://doi.org/10.1016/S2214-109X\(18\)30045-7](https://doi.org/10.1016/S2214-109X(18)30045-7).

UNICEF (2016). The State of the World's Children 2016: A fair chance for every child. <https://www.unicef.org/reports/state-worlds-children-2016>

UNICEF and WHO (2017). Progress on Drinking Water, Sanitation and Hygiene Update and SDG Baselines 2017. Launch version July 12 Main report', WHO Library Cataloguing in Publication Data. Available at: <http://apps.who.int/bookorders>.

van Wilgen, N. J., Goodall, V., Holness, S., Chown, S. L., & McGeoch, M. (2016). Rising temperatures and changing rainfall patterns in South Africa's national parks. *International Journal of Climatology*, 36(2), 706-721. <https://doi.org/10.1002/joc.4377> .

Victor Ngobeni, Marthinus C. Breitenbach; Production and scale efficiency of South African water utilities: the case of water boards. *Water Policy* 1 August 2021; 23 (4): 862–879. <https://doi.org/10.2166/wp.2021.055>

WHO Water, Sanitation and Hygiene strategy 2018-2025. Geneva: World Health Organization; 2018 (WHO/CED/PHE/WSH/18.03). Licence: CC BY-NC-SA 3.0 IGO. <https://www.who.int/publications/i/item/WHO-CED-PHE-WSH-18.03>

WHO. (2022). Schistosomiasis. Retrieved February 14, 2022, from <https://www.who.int/newsroom/factsheets/detail/schistosomiasis>.

World Bank, ILO, WaterAid, and WHO. 2019. "Health, Safety and Dignity of Sanitation Workers: An Initial Assessment." World Bank, Washington, DC. Available online: https://www.who.int/water_sanitation_health/publications/health-safety-dignity-ofsanitation-workers.pdf?ua=1. (Accessed 16 August 2021).

Wu, G. Y. (2000). Schistosomiasis: Progress and problems. *World Journal of Gastroenterology*, 6(1), 12. <https://doi.org/10.3748/wjg.v6.i1.12>

Zahra K. Gastrointestinal helminthic challenges in sheep and goats in afro-asian region: a review. *Journal of Animal Research*. 2020 Feb 1;10(1):1-8. <http://doi.org/10.30954/2277-940X.01.2020.1>

APPENDIX A: KNOWLEDGE DISSEMINATION ACTIVITIES

Technical workshop 2



Faculty of Health Sciences



JOIN US FOR
A WORKSHOP

**A WATER QUALITY
BASED PREDICTIVE
TOOL FOR DISASTER
MANAGEMENT OF
WATER BORNE
INFECTIONS DURING
DROUGHT EVENTS**

Hosted by the Department
of Environmental Health

WRC Sponsored Project

**YOU ARE
INVITED**

The Nelson Mandela University (Department of
Environmental Health) invites you to a Water
Research Commission (WRC) Workshop.





North Campus Conference Centre
Nelson Mandela University
Gqeberha, Summerstrand

Kindly RSVP by scanning the QR code or
contacting Ms Thembela Festile
by **31 August 2023**

22 NOVEMBER 2023
09:00 - 16:00

Contact Us  (041) 504 3523  Thembela.Festile@mandela.ac.za  health.mandela.ac.za





Technical workshop 3



NELSON MANDELA
UNIVERSITY
Faculty of Health Sciences

JOIN US FOR
A WORKSHOP

A WATER QUALITY
BASED PREDICTIVE
TOOL FOR DISASTER
MANAGEMENT OF
**WATER BORNE
INFECTIONS** DURING
DROUGHT EVENTS

Hosted by the Department
of Environmental Health



WRC Sponsored Project



21 NOVEMBER 2024
09:00 - 16:00



**YOU ARE
INVITED**

The Nelson Mandela University (Department of
Environmental Health) invites you to a Water
Research Commission (WRC) Workshop.

Research progress on the various projects will
be given



North Campus Conference Centre
Nelson Mandela University
Gqeberha, Summerstrand
Kindly RSVP to Birthlin Mouton via email
Birthlin.Mouton@mandela.ac.za
by **31 October 2024**

Contact Us

Birthlin.Mouton@mandela.ac.za

health.mandela.ac.za



Presentation at Scientific Seminar “Our Health – Our Future”: Enhancing Public Health in the Eastern Cape (EC) hosted by the EC Department of Health.



Presentation to the Nelson Mandela Bay Public Health Standing Committee



Community engagement





Interviews to Nelson Mandela University news outlet

www.mandela.ac.za


Ensuring access to adequate water supply is vital for South Africa's sustainable development. Unfortunately, many communities still lack basic water supply and sanitation services, with three million people without to water and 14.1 million without sanitation.

News

These were some of the key sentiments and statistics from the Water Research Commission (WRC) sponsored a research project, led by Professor Paula Melariri, to explore the impact of water quality on public health. The team's research findings were recently presented in a workshop, providing valuable insights into this important issue.

Stakeholders from the departments of Education, Water Research commission, Public Health; and experts from Nelson Mandela Municipality attended the workshop in a hybrid format, combining on-site participation at Mandela University's North Campus Conference Centre and online engagement via the ZOOM platform.

A total of 86 delegates attended, with 82 participating on-site and four joining online.



<https://news.mandela.ac.za/News/Curbing-the-spread-of-water-borne-diseases>

APPENDIX B: DECISION SUPPORT TOOL

Decision Support Tool for Schistosomiasis and STH

WHAT LEVEL OF DECISION DOES THE PROJECT SEEK TO CONTRIBUTE INFORMATION TO?

Local Level

- Municipality- Environmental Health
- Schools- Governing Body
- Early Development Centres
- Non-Government Organisations

Provincial Level

- Provincial Disaster Authorities, District Authorities
- Dept of Health, Basic Education, Environmental Affairs, Public Works

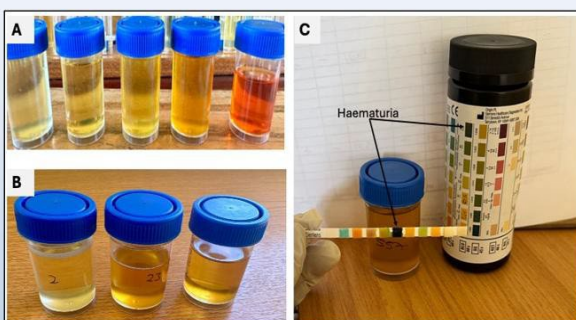
SECTION 1: DISEASE INFORMATION

1.1. Prevalence of Schistosomiasis in the study area

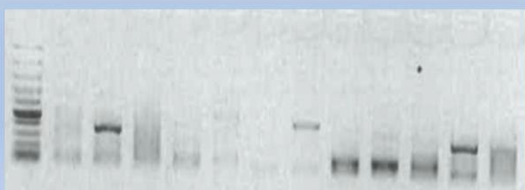
S. haematobium prevalence

- **Low Prevalence with Traditional Diagnostics:**
- **Urine filtration** detected **0.1% prevalence**, and only one sample was egg-positive via microscopy.
- **Haematuria** had a 33.6% prevalence.
- **High Detection with cPCR:**
- Molecular analysis revealed **31.4% cPCR-positive samples**, highlighting the prevalence of undetected low-intensity infections.

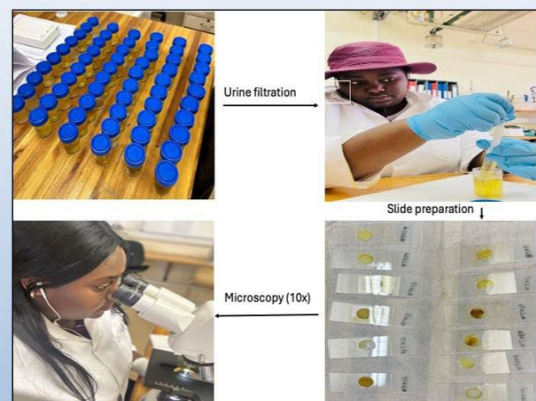
S. haematobium and haematuria detection



Haematuria detection by dipstick test



Agarose gel electrophoresis: cPCR results

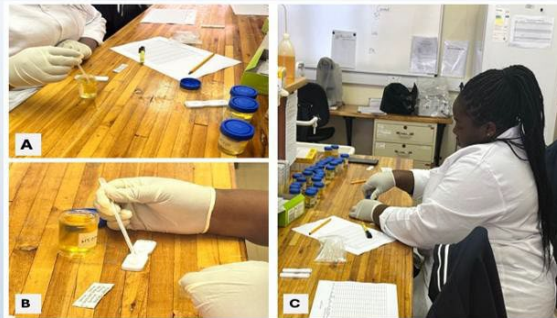


Urine filtration- detection of *S. haematobium* eggs

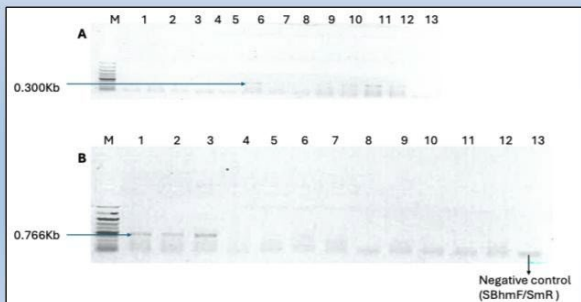
S. mansoni prevalence

- **Kato-Katz:** Detected **0% prevalence** for *S. mansoni*.
- **POC-CCA:** Identified **3.2% prevalence**.
- **cPCR:** Revealed a significantly higher **32.1% prevalence**, indicating the sensitivity of molecular diagnostics.

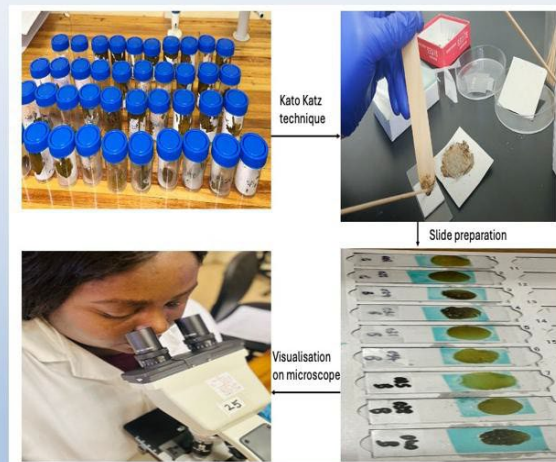
Advanced Diagnostics for Intestinal Helminths



POC-CCA test for *S. mansoni*



Agarose gel electrophoresis results for *S. mansoni*



Kato-Katz technique for *S. mansoni* and STHs

1.2. Number of cases reported from previous retrospective data (Hambury et al., 2021 and the NDOH study: 20% and 0.2% respectively.

1.3. Prevalence of soil transmitted helminths in the study area.

- **Kato-Katz:** *A. lumbricoides* was found in **2 cases**, yielding a **0.3% prevalence**

1.4. Species of Schistosoma present:

- *Schistosoma mansoni*
- *Schistosoma haematobium*

1.5. Soil Transmitted Helminths (STH) present:

- *A. lumbricoides*

1.6. Primary transmission route:

- Water infested with Schistosoma parasites

Soil contaminated with STH parasites

SECTION 2: SNAIL INTERMEDIATE HOST

2.1. Presence of intermediate host snails:

- Yes

2.2. Species of Intermediate host snails present:

- *Bulinus*
- *Biomphalaria*

SECTION 3: BACTERIOLOGICAL ASSESSMENT OF WATER SOURCES

3.1. Water sources tainted with pathogens such as *Shigella* and *V. cholerae*

- Yes

3.2. Tap water and environmental samples above Total Coliform standards

- Yes

3.3. Tap water and all environmental samples surpassed *E. coli* thresholds, signifying faecal contamination

- Yes

SECTION 4: INTERVENTION OPTIONS

- Health education and awareness campaigns
- Water, Sanitation, and Hygiene (WASH) improvements
- Snail control measures
- Physico-chemical properties of environmental water bodies
- Early diagnosis
- 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.

- 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.
- Advocate for the allocation of funding to enhance the laboratory's capacity for pathogen detection.

SECTION 5: HUMAN CAPACITY DEVELOPMENT

- Postgraduate training
- Community members participating as field workers
- Health Education in schools and communities

SECTION 6: IMPLEMENTATION AND CONTINUOUS MONITORING

Develop an implementation plan, including:

- Timeline
- Budget allocation
- Human resource allocation
- Monitoring and evaluation plan

Additional Considerations

- Presence of co-infections (e.g., malaria and other NTDs)
- Availability of diagnostic tools and laboratory capacity
- Community engagement and participation