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Nuanced perspectives on the challenges, prospects and opportunities confronting sustainable access to potable water and sanitary services in South Africa's Nompumelelo community

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Access to safe water and adequate sanitary services in South Africa's peri-urban areas remains a major challenge, despite being recognized as a basic human right that is essential for people's dignity, health and well-being. Efforts to address this deficiency are often undermined by the rapid growth of informal settlements and inadequate waste management and the adverse effects of climate change. This study provides informative insights into the link between excessive alcohol abuse and sanitation nature and explores potential solutions based on case study data. The study used semi-structured interviews with 15 purposively selected key informants, including local leaders, WASH experts, policymakers, youth and women representatives, health staff, and NGO members. A matrix questionnaire method was also applied to evaluate the alignment between key informants' views and broader community perspectives. Thereafter, the information compiled was analyzed using ATLAS.ti24 and matrix scoring. ATLAS.ti 24 facilitated theme generation through systematic coding and categorization, while network visualizations were employed to map relationships and uncover patterns within the data, enhancing analytical depth. The results show that infrastructural deficiencies, poor maintenance, lack of community engagement and wide-ranging climate change-related externalities are the main barriers that continue to undermine securitized access to safe water and adequate sanitary services. Our findings suggest that community-led initiatives, local partnerships, and informed adaptation strategies can improve sustainable access to potable water and sanitation services. The take-home message from these findings is that sustainable access to WASH services can be enhanced by assimilating objectively informed climate change interventions, improving the infrastructure facilities at our disposal, building capacity through community education and collectively promoting the increased uptake of user-friendly, climate-smart and indigenous adaptation strategies. The study concludes by urging and inviting those interested to complement our efforts by offering innovative strategies on how to advance our capacities to sustainably provide adequate WASH services.

KEYWORDS

challenges, water, sanitation, hygiene, peri-urban areas

Introduction

Access to water, sanitation, and hygiene (WASH) services is a fundamental human right that is crucial for public health and development (Gurung et al., 2023). Globally, communities in peri-urban areas (PUAs) face significant challenges in getting adequate access to these essential services (Nel et al., 2023; Yan et al., 2024). Despite ongoing efforts to improve WASH services, current initiatives remain insufficient (Yan et al., 2024). In South Africa (SA) for example, the substantial strides that have been made since the end of apartheid, have not yielded enough to meet the increasing demands of growing populations in most of this country's PUAs which still struggle to provide enough of the globally recommended standard sanitary services (Carbonell et al., 2023). These areas are some of the most underserved localities because of their positioning in transitional zones where the coexistence of rural and urban characteristics present formidable challenges to the sustainable provisioning of adequate WASH services. This is partly because most communities in these areas are often characterized by rapid population growth, unplanned expansion of informal settlements and overwhelming dependence on livelihood strategies that consist of a mix of agricultural and industrial activities, which complicate the development of WASH infrastructure (Qadir et al., 2010; Munyai, 2023).

In 2016, approximately 30% of households had piped water in their yards, while 1.9% accessed water from a neighbor's tap and 4.5% accessed it from a communal tap (Statistics South Africa, 2017a; Statistics South Africa, 2017b). A year later, an estimated 11% of South African households, primarily in peri-urban areas, still lacked water supplies on their premises. Additionally, 18% relied on poorly ventilated pit latrines without access to running water (Statistics South Africa, 2017a; Statistics South Africa, 2017b). These deficiencies are aggravated by the absence of formal property rights in most of SA's PUAs. This submission is supported by observations from many authors, whose findings indicate that one of the main challenges facing the provision of sustainable WASH is the lack of standard municipal services (Durand-Lasserve et al., 2007; Qadir et al., 2010; Zhang et al., 2023). Because these areas are widely considered to be illegal, they always end up being viewed as underserved compared to the planned urban centers. This bias explains why most of the PUAs are persistently susceptible to wide-spread prevalence of waterborne diseases and challenging health problems (Santra and Bhadury, 2024). In attempting to address these challenges, SA has adopted a multifaceted approach that is premised on government-led initiatives, community engagement, and support by non-governmental organizations.

Selected examples of these initiatives include government-funded implementation of planned interventions through the National Water and Sanitation Master Plan which focus on upgrading aging infrastructure, expanding access to WASH services in illegal settlements, and promoting the uptake of efficient water use practices (Naidoo et al., 2016; Bazaanah and Mothapo, 2024). These initiatives include investments in technology and innovation, development of cost-effective and environmentally friendly water purification systems, and the adoption and upscaling of sound waste management solutions (Siddique, 2021) and, the harnessing and mobilization of funding by exploring and expanding partnerships with international agencies and the private sector (Naidoo et al., 2016; Carbonell et al., 2023). Community-based programs also play a crucial role by educating residents about water conservation and hygiene practices, aiming to build long-term resilience and sustainable access to WASH services

(Adeyeye et al., 2020). Despite these efforts, inadequate WASH services in PUAs remain a critical concern (National Planning Commission, 2012; Aydamo et al., 2024; John and Ajibade, 2024), that requires the formulation and implementation of more targeted policies and community-led strategies to ensure equitable access to these essential services. Our aim was to explore views on the challenges, prospects and opportunities related to sustainable access to potable water and sanitation in Nompumelelo, South Africa. This exploration aimed to provide valuable insights into how the identified constraints can be addressed.

Methodology

Study area

Nompumelelo, in Ward 15, East London, is a township with a predominantly isiXhosa speaking population and a mix of low to middle income households (Penn and Watermeyer, 2018). This study area was preferred due to its high population density, limited access to basic services and socio-economic challenges (Buku, 2014; IOL, 2021). In addition, its unique cultural and demographic characteristics, including informal settlements and community life, provide valuable insights into urbanization and community development (Penn and Watermeyer, 2018). Nompumelelo is bounded by the N2 motorway to the north, Mdantsane township to the south, the Buffalo River to the east and Amalinda township to the west and has urban characteristics including informal and formal settlements, limited green space and variable access to basic services (Buku, 2014). Nompumelelo is situated in the peripheries of East London, Eastern Cape province, SA (Figure 1).

This village was selected because of its potential representativeness of the challenges confronting sustainable access to WASH services in SA's PUAs and its established susceptibility to persistent shortages of potable water (Munyai, 2023). The village was also selected because it has a diverse population with various socio-economic backgrounds (Munyai, 2023; Ndasana et al., 2022) which make it ideal for the nuanced exploration and assessment of perspectives on water and sanitation challenges in PUAs. The township has an estimated population of approximately 20,187 residents and around 7,448 households (Wazimap, 2016). This approach was preferred because it creates space for the formulation of informed interventions that can be upscaled to other PUAs where the livelihoods of communities are being undermined by similar service delivery constraints. The history of community activism and engagement with local governance provides an important framework for studying sustainable solutions to enhance, develop, and deliver viable WASH services, as proposed by Ndasana et al. (2022).

Design

This research employs sequential exploration mixed methods design, integrating a case study of Nompumelelo's WASH services with a cross-sectional survey. The quantitative component precedes the quantitative phase, with in-depth interviews used to gather stakeholder perspectives, which then inform the development of the survey instrument. The subsequent sections outline the processes of sampling, data collection, ethical considerations, and data analysis and presentation.



FIGURE 1
Location of Nompumelelo in East London, Eastern Cape province, South Africa.

Sampling methods

A multistage sampling design was systematically used to compile wide-ranging insights on the limitations confronting our abilities to address the ongoing challenges of WASH service delivery failures. Initially, 15 key informants (KIs) were purposefully selected from a sampling universe of 24 potential participants, including municipal officials, community leaders, youth, women representatives, NGOs and long-standing representatives of local communities in this environment with this reasoning being informed by the fact the last latter are better able offer reliable insights on previous and ongoing challenges. This segregation was purposefully structured to ensure the inclusion of informants whose contributions were judged to be useful in providing valuable insights as suggested by [Pandey and Pandey \(2021\)](#) who posit that we can only share what is shareable. In phase two of this investigation, 264 community members from a total sampling universe of about 20,187 were systematically chosen based on their availability and willingness to participate in this survey ([Wazimap, 2016](#)). The survey focused on individuals aged 18 and older, in line with ethical guidelines after screening them from a sampling universe of 264 participants. This approach was reasoned to be helpful because it accommodates the cooptation of in-depth insights from KIs who include but are not limited to informed community-based incumbents following suggestions by [Döringer \(2021\)](#).

Ethical consideration

Prior to participating, participants were informed about the purpose of the study to ensure that they were well informed about their rights. During this investigative phase, all participants were also made aware of their right to withdraw from participation at any time with all issues pertaining to ethical considerations, confidentiality and

beneficence being thoroughly explained to the participants. This was confirmed both in writing and verbally.

Data collection

Data collection was conducted in two phases. The first phase involved semi-structured interview guides that were populated containing well structured, probing questions designed to systematically gather and objectively analyse unbiased responses. These guides combined open- and closed-ended questions to encourage respondents to voluntarily share their experiences while also providing structured responses for analysis. Data saturation was achieved before all 24 participants were interviewed, indicating that additional responses would not provide new insights. In the second phase, data was collected through matrix questionnaires on the drivers and challenges confronting access to potable water and sanitation service that were distributed to purposefully targeted respondents who were guided on how to complete the matrix questionnaires. Triangulation these methods ensured comprehensive understanding of the issues by cross-verifying qualitative and quantitative data, as recommended by [Döringer \(2021\)](#) and [Smit \(2021\)](#).

Data analysis

Qualitative data from key informant interviews were analysed using ATLAS.ti.24 software which is specifically designed for managing large volumes of qualitative data ([González-Prieto et al., 2020](#)). Data analysis began after data collection and transcription, followed by importing the data files into ATLAS.ti 24 ([Muchaku, 2024](#)). The software facilitated coding and cross-linking, enabling the identification of themes and patterns to be analysed. The analysed data is then visualized in the form of a flowchart that illustrates the

thematic relationships and conceptual frameworks that emerge from the qualitative data analysis. Its ability to rigorously manage and analyse qualitative data was helpful in generating informative insights with this assertion being supported by other researchers in the likes of Smit (2021); and by Adeyeye et al. (2020). The compiled matrix questionnaire-based data were analyzed and presented as matrix score, because it offers robust tools for the reliable analysis of multi-sourced data (Kumar, 2023). The conjunctive use of these two software tools enabled a rigorous and comprehensive analysis. This approach facilitated the integration of qualitative and quantitative data, allowing us to propose solutions to the challenges identified in Nompumelelo and similar communities elsewhere.

Results and discussion

This is structured in such a way that the results are presented clearly and concisely. Results are presented visual (Figure 2) and tabular formats (Tables 1, 2) to enhance clarity. Figure 2 illustrates the thematic analysis of the perceptions collected from the key informants (KIs), while Table 1 summarizes the perceptions of the public on the challenges of access to potable water and sanitation services and shows the percentage frequency of responses. Table 2 further breaks down the public's perceptions and shows the percentage frequencies in relation to access to drinking water. The discussion that follows integrates these findings by interpreting the data, identifying key patterns and relationships, and exploring their implications for WASH services in Nompumelelo.

In the ATLAS.ti flow chart diagram above, identifiers such as 1.1, 6.1, 5.1, and 2.1 correspond to specific quotations linked to documents. The first number indicates the document number, while the second number identifies the quotation within that document. For instance, 6.1 refers to the first quotation from document 6 in the project. Additionally, the letter "p" often signifies the paragraph number from

which the quote was sourced. These references facilitate the systematic organisation and retrieval of qualitative data for analysis.

Limited access to potable water

Key informants consistently identified limited access to drinkable water as a critical challenge in Nompumelelo, particularly for young women and girls who are responsible for collecting water. This issue is clearly shown in Figure 2, which demonstrates the significant impact of inadequate water access on people's lives, as confirmed by key informant 8. The severity of the problem is further evidenced by a substantial number of the respondents (89.7%) in the survey who reported limited access to potable water (Table 1) with this perception being attributed to the combined effects of natural and human induced factors by 40% of the respondents (Table 2). Residents often travel long distances to communal taps shared by multiple households. This results in long queues, increasing tensions within the community. This results in long queues, increasing tensions within the community. Similar challenges have been observed in other PUAs in Limpopo, where apart from relying on inadequate supplies from periodic water tanks, most of the residents walk long distances to access water from taps which are not dependable (Adeyeye et al., 2020). Interestingly, 2.1% of the respondents disagreed, 3.5% strongly disagreed and 5.7% were uncertain. These tangential views suggest that although water scarcity is a major problem, there is a small segment of the community that is not affected.

Several factors may explain this divergence, as observed in other peri-urban areas worldwide and in SA. These include disparities in access to water storage facilities, the ability of wealthier households to self-provide, varying household water demands, and differences in lifestyles (Popkin, 2006). The overwhelming predominance of housing structures also makes it difficult to collect roof-water, and the costs of rainwater harvesting systems are often prohibitive (Adeyeye et al.,

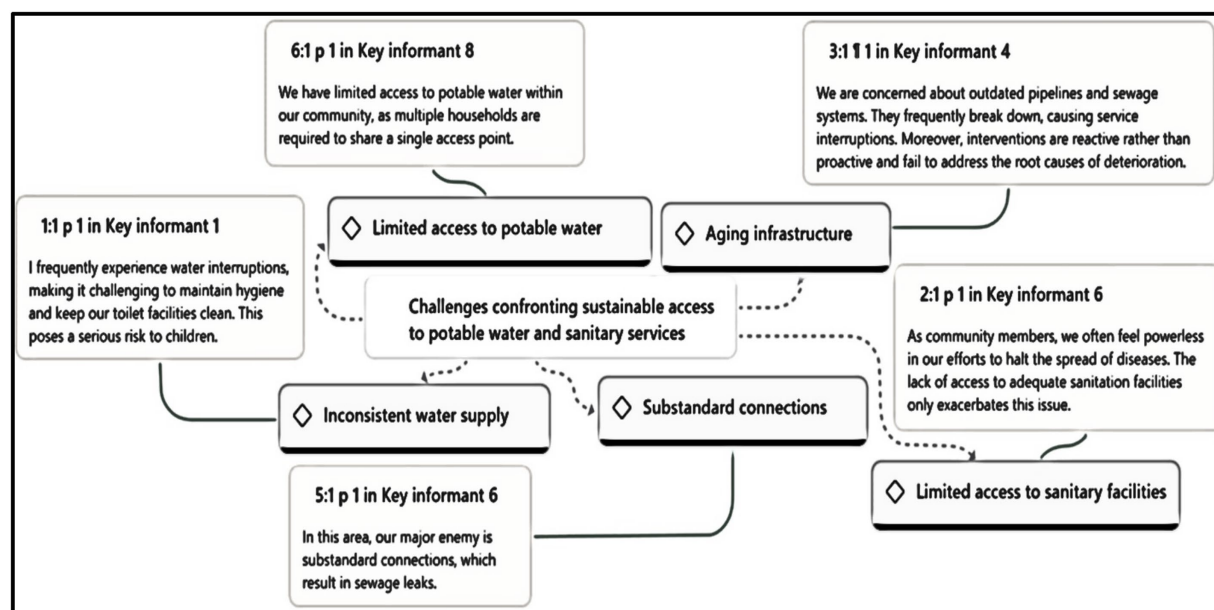


FIGURE 2
Challenges confronting sustainable access to potable water access and sanitation services.

TABLE 1 Public perceptions and the frequency of challenges concerning access to potable water and sanitation services.

Nature of challenge	Specific percentage responses					Overall perception on agreeing & disagreeing	
	A	B	C	D	E	Agree = (B + C)	Disagree = (D + E)
• Limited access to potable water	5.7	46.4	43.3	2.1	3.5	89.7	5.6
• Limited access to sanitary facilities	7.8	34.3	40.2	8.7	9.0	74.5	17.7
• Substandard connections cause sewage leaks	22.9	32.6	31.4	2.1	11.0	64.0	13.1
• Aging infrastructure	24.7	33.4	28.5	1.4	12.0	61.9	13.4
• Inconsistent water supply	11.1	28.9	19.0	13.0	18.0	47.9	31.0

A = Uncertain, B = Strongly agree, C = Agree, D = Strongly disagree, E = Disagree.

TABLE 2 Percentage frequencies of public perceptions on challenges confronting access to potable water.

Challenge investigated	% responses
• Water scarcity is driven by natural environmental changes	17
• Human activities are to blame for the potable water shortage	25
• Water scarcity is the combined outcome of natural and human factors	40
• There are no challenges in accessing adequate potable water and sanitary services.	6
• There is insufficient evidence pointing to inadequate access to water and sanitary services	12

2020). These challenges, combined with differences in community capacity, limits resident's ability to advocate for publicly provided water and participate in community-based self-help initiatives. However, the most prevalent perception is that limited access to water is one of the major challenges facing a considerable proportion of residents in this area. This challenge is not unique to Nompumelelo, as similar issues have been observed in other regions. Studies in Indonesia and Zambia, for example, also highlight how inconsistent water supply in peri-urban areas hinders effective sanitation services (Thomas-Possee et al., 2024; Utami et al., 2024). Schools are among the most affected by the lack of potable water. Insufficient clean water poses significant health risks and creates unhygienic conditions, disrupting learning environments and jeopardizing student well-being.

Inconsistent water supply

Inconsistent water supply is one of the major challenges in Nompumelelo as reported by KIs from various sectors. This challenge has significantly impacted daily life. Health workers report that frequent water interruptions hinder hygiene practices and disrupt essential healthcare operations. The seriousness of this challenge by is demonstrated by one key informant's submissions who reported that inconsistent water supply poses to sanitary services and the health of children (Figure 2). Tables 1, 2 further highlight the gravity of this issue, which is particularly acute during peak usage periods, such as weekends, leading to widespread frustration among community members. This local experience reflects broader observed in Indonesia and Zambia, where studies have shown that inconsistent water supply in peri-urban areas significantly impedes sanitation service delivery (Thomas-Possee et al., 2024; Utami et al., 2024). The impact on

education is equally concerning, as noted by teachers in their perceptions and experiences on access to potable water by reiterating that unreliable water supply also severely hampers efforts to maintain a clean and safe learning environment in schools. Survey results further illustrate this challenge, with 47.9% of participants identifying inconsistent access to water as their most pressing concern (Table 1). However, 31% did not view it as a major issue, while 11.1% remained neutral. These mixed perceptions suggest disparities in access to potable water, influenced by factors such as households' water storage capacity, economic ability to secure alternative water sources and differences in daily water needs.

Limited access to sanitary facilities

The results of this study show that most of the households in Nompumelelo's informal settlements (74.5%) have limited access to standard sanitation facilities (Table 1). This poses risks to public health and safety, with young women and girls being subjected to sexual abuse as they queuing for water. This assertion is supported by the submissions of most respondents who reported that using crowded and poorly maintained communal toilets fails to meet sanitation requirements and creates unsafe environments. Respondents also noted the unhygienic state of their toilets due to poor delivery service, which increases their exposure to water-borne diseases. This issue is further aggravated by poor communication and inefficient refuse disposal services. Research by Adeyeye et al. (2020) and by Ngasala et al. (2022) highlights the correlation between inadequate sanitation facilities and health problems among vulnerable populations. This concern is shared by 74.5% of participants, who perceive limited access to sanitary facilities as a significant issue (Table 2). The level of agreement underscores the urgent need for targeted interventions. The repeated occurrence of public protests reflect growing dissatisfaction with inadequate sanitation, as Nel et al. (2023) observe that substandard sanitation facilities consistently lead to increased discontent and demands for improved infrastructure.

Unexpectedly however, 17.7% of participants expressed disagreement with the notion that access to sanitation services is a major problem (Table 1). This minority perspective appears to be based on variations in personal experiences as observed in other informal settlements by Drechsel et al. (2022). In support of this view, one health worker stated, "We run the risk of missing the forest because there are too many trees." This suggests that addressing sanitation challenges requires considering multiple interconnected factors. This observation is important because it is indicative of broad-based functional system failures, which include inadequate infrastructural

investment, neglect of informal settlements and many others. Therefore, addressing these challenges requires comprehensive, holistic and inclusive solutions that prioritize the safety, dignity, and health of all residents.

Aging infrastructure

Community leaders and health workers consistently identified the aging infrastructure in Nompumelelo as a major barrier to the meaningful realization of sustainable water and sanitation access. [Figure 2](#) presents a case-study based submission from one of the respondents (informant 4), which captures some of the concerns about persistent infrastructure challenges. This submission underscores the long-standing systemic challenges confronting some of the residents in this area. The outdated water pipelines and their concomitant sewage systems not only experience frequent breakdowns but also cause prolonged service disruptions that significantly impact low-income households. Although efforts are being made to address this challenge, community leaders are concerned that these measures are reactive and rather than proactive. This concern aligns with [Silver \(2021\)](#), who notes that many PUAs face challenges in addressing the underlying causes of most failures in the functioning of water delivery infrastructure. Similarly, [Salihu et al. \(2022\)](#), report that outdated pipelines cannot withstand increasing pressure from rising sewage volumes due to population growth. This finding is corroborated by 61.9% of this survey's respondents, who pointed out that aging infrastructure is a critical issue ([Table 1](#)). The convergence of qualitative insights and quantitative evidence underscores the urgent need for a comprehensive overhaul of Nompumelelo's water delivery infrastructure. This overhaul must prioritize long term-based planning to address the systemic challenges residents continue to face.

Substandard connections

During key informant interviews, respondents highlighted a major challenge in PUAs related to difficulties in accessing clean water and sanitary services due to poor and illegal plumbing connections. Many of these connections are often made by individuals without proper plumbing training, leading to haphazard and substandard makeshift systems. [Figure 2](#) illustrates these deficiencies and survey data 64% of the respondents identified substandard connections as major cause of recurrent sewage leaks. In contrast, a marginal 13.1% disagreed or strongly disagreed, while 22.9% remained neutral. This recognition of infrastructural deficiencies align with findings from other PUAs worldwide ([Adeyeye et al., 2020](#); [Babar et al., 2020](#)). These frequent leaks not only heighten the risk of disease outbreaks but also reflect systematic neglect in service delivery, largely due to insufficient investment and poor coordination of adaptive strategies ([Ngasala et al., 2022](#); [Silver, 2021](#); [Salihu et al., 2022](#)). Addressing these challenges requires a coordinated effort to upgrade infrastructure and align interventions with the sustainable development goals (SDGs) to ensure the sustainable management of finite water resources.

Health implications

Health workers in Nompumelelo highlighted the severe health risks posed by inadequate water and sanitation services, which contribute to the community's ongoing struggles. According to their view, outbreaks of waterborne diseases, such as diarrhea and cholera, are common during periods of water scarcity. This finding aligns with [Clasen et al. \(2015\)](#), who note that improved water quality significantly reduces the incidence of diarrheal and other waterborne diseases in low-income areas. Similarly, [Prüss-Ustün et al. \(2014\)](#) posit that inadequate access to safe drinking water is a major contributor to the global burden of waterborne illnesses, particularly in vulnerable communities. The lack of proper sanitation facilities further exacerbates the spread of these diseases, putting additional strain on overwhelmed healthcare systems, which struggle to cope with the ever-increasing numbers of patients ([Figure 2](#)). This scenario is reflected by the recurring outbreaks of skin infections and other unhygienic-related diseases among the vulnerable groups such as youths and elderly. The urgent need for innovative strategies to provide sustainable and shareable access to standard WASH services is evident from these findings.

Prospects for improvement

Government and NGO interventions

Key informants highlighted ongoing efforts by government agencies and non-governmental organizations (NGOs) to improve access to potable water and sanitation services in Nompumelelo. Recent projects in this domain include the installation of new pipelines and the construction of additional communal toilets. However, these efforts are undermined by delays in completing supporting infrastructure, inadequate maintenance and insufficient service coverage. [Giné-Garriga et al. \(2015\)](#) provide informative insights on how this trend leads to neglect and inadequate resource allocation, with the same observation echoed by [McGranahan \(2016\)](#), who argues that rapid population growth in PUAs outpaces the development of essential services. These challenges are further aggravated by governance inefficiencies, socio-economic disparities, and logistical obstacles. Addressing these systemic issues requires a comprehensive approach that includes regular monitoring of services delivery, proactive maintenance and adaptive management strategies informed by objective data. This reasoning explains why it is necessary to ensure consistent maintenance of infrastructure and expand coverage.

Community involvement

Primary data shows that Nompumelelo's residents need more pro-active decision-making processes on how to dispose of wastewater and sewage. Community leaders are of the opinion that involving residents in the planning and implementation phases of projects is helpful in enhancing the alignment of different interventions. The importance of doing this is demonstrated by the voluntary and selfless willingness of this village's community to actively participate in decision-making processes when given the opportunity to do so. Scholars such as [Xu and Tang \(2020\)](#) and [Kulal et al. \(2024\)](#) emphasize the importance of community participation in decision-making, noting that this involvement leads to more effective and equitable outcomes in the day-to-day delivery of public services. The salience of this approach is

demonstrated by community-based engagements that foster the identification of critical local-specific issues that require the implementation of bottom-up intervention strategies. Teachers and health workers, for example, play an important role by facilitating the mobilization and participation of individual members of the community. This approach is helpful because it ensures participatory representation when dissecting, interrogating, and addressing specific issues. Implementing structured consultation processes through community meetings and feedback surveys can go a long way in providing useful insights and actionable interventions (Geekiyange et al., 2020) that help to overcome deep-rooted barriers that undermine the delivery of critical services. By creating a participatory framework that integrates feedback into project planning and implementation, it becomes easier to advance the uptake of informed coping and adaptation strategies that address the major challenges confronting PUAs like Nompumelelo.

Educational campaigns

Teachers and community leaders in Nompumelelo emphasized the critical role of education in enhancing the uptake of sound water and sanitation practices. This is clearly demonstrated by their expression of the need to launch targeted educational campaigns that increase awareness on the importance of water conservation, proper sanitation, and hygiene. Examples of these campaigns include workshops, school-based programs, and the circulation of informational materials that are tailored to meet the needs of specific target groups like children, adults, and local leaders (Victor et al., 2015). Evidence of the potency of these initiatives from different communities worldwide suggests that well-designed educational programs can lead to significant improvements in hygiene practices and reductions in water shortage-related diseases (Yoshida et al., 2008; Victor et al., 2015). The effective implementation of such campaigns requires inclusive approaches that acknowledge the importance of getting everybody involved. Strategies like partnering with local organizations, utilizing multimedia platforms, and conducting regular assessments are selected examples of this can be accomplished.

Opportunities for sustainable solutions

Public-private partnerships

Key informants highlighted public-private partnerships (PPPs) as promising strategies for addressing water and sanitation challenges in Nompumelelo. Community leaders and health workers emphasized that such collaborations can facilitate funding and expertise mobilization. Similar PPP initiatives in other PUAs such as those in Johannesburg, have demonstrated that private sector involvement can enhance service delivery and infrastructure development (Akomea-Frimpong et al., 2023). However, successful implementation in Nompumelelo would require careful planning and management. A key concern is the potential conflict of interest as private entities often prioritize profitability, while public institutions focus on social welfare (Batidzirai et al., 2021). Developing balanced agreements that ensure affordability while maintaining service efficiency is essential. To maximize the benefits of PPPs, it is crucial to align these partnerships with community needs, ensure transparency, and implement mechanisms for conflict resolution. Additionally, engaging local stakeholders and tailoring interventions to specific challenges can improve project sustainability. Clear objectives, performance metrics,

and oversight mechanisms should be established to enhance accountability and ensure long-term success.

Technological innovations

Health workers and community leaders in Nompumelelo have been exploring how technological innovations can be used to improve water and sanitation services. They have proposed the adoption of low-cost, sustainable technologies, such as solar-powered water purification systems and eco-friendly composting toilets, that can be implemented and used by the community. Solar-powered water purification systems have already been successfully used in other resource-limited settings to provide clean drinking water, while composting toilets can help reduce dependence on traditional sewage infrastructure and minimize adverse environmental impacts (Reyneke et al., 2023). Examples of areas where this has been done include in rural India (Elewa, 2024; Kumar et al., 2024) and in Kenya (Da Silva et al., 2020). However, the implementation of these innovative solutions in Nompumelelo requires careful consideration of their feasibility and systematic assessment of how possible challenges that may emerge from their use will be addressed. Issues like initial costs, maintenance requirements, community training, and long-term sustainability must be considered in advance to ensure the successful adoption of these solutions. Accomplishing this requires the engagement of local stakeholders in identifying their needs, broad-based provisioning of technical support, and the establishment of implementable maintenance plans that. This approach can be further strengthened by evaluating pilot projects and collecting data on their performance to determine their viability before upscaling them to other households in the broader community. Doing this is helpful because it ensures that the proposed technologies are socially acceptable, suitable, effective and sustainable.

Capacity building and training

The results show that there several challenges that need to be addressed through different interventions like capacity building and establishment of training programs that empower this village's residents by enabling them to effectively manage and maintain their water and sanitation facilities. Challenges like poor maintenance for example can be effectively addressed through self-help programmes, the comprehensive training of local youth, with a focus on providing essential maintenance skills, basic repair techniques, and how to manage existing infrastructure (Stanca et al., 2022; da Mata, 2023). These training programs could include hands-on workshops, certification courses, and partnerships with technical experts who can provide useful knowledge by sharing their experiences and skills (Huang et al., 2022; da Mata, 2023). This participatory approach can go a long way in offering sustainable solutions because it fosters a sense of ownership, accountability, and responsible stewardship (Stanca et al., 2022). Health workers and teachers for example are increasingly favoring initiatives that involve local communities not only because they are potentially capable of creating job opportunities but also because they enhance the assimilation of useful skills which can be tapped to sustainably provide the required water and sanitation services. Successful implementation, however, requires careful planning and addressing strategies on how to mobilize funding and how to design an effective curriculum that ensures community engagement and delivery of appropriately informed and useful skills (Huang et al., 2022). Developing partnerships with local organizations

and institutions can provide additional support and resources. Regular evaluations and feedback on the performance of these initiatives will also help in objectively determining their assessing the effectiveness and how operational flaws and breakdowns in some of these training programs can be addressed.

Addressing the challenges

The results of the key informant (KI) interviews underscore the urgent need to address the persistent problems of inconsistent water supply, aging infrastructure, and inadequate sanitation facilities in Nompumelelo. Addressing these challenges requires a comprehensive, integrated approach that provides sustainable, long-term solutions. The potential health risks, such as waterborne disease outbreaks, highlight the critical link between water, sanitation, and community wellbeing. Solutions must be tailored to local conditions and focus on improving infrastructure to ensure the continued provision of clean water and reliable sanitation services. To meet these needs, plans for new services and maintenance of existing infrastructure must prioritize safety and privacy, especially for women, children, and the elderly. A coordinated effort between government agencies, non-governmental organizations (NGOs) and local leaders will ensure that the solutions are community-driven and address the specific challenges in Nompumelelo.

Leveraging prospects for improvement

The potential for significant improvement in Nompumelelo's water and sanitation infrastructure depends on effective implementation and active community participation. Government and NGO efforts need to be accelerated, closely monitored and continuously adapted to the evolving needs of the community (Stanca et al., 2022; da Mata, 2023). Promoting local ownership through community-led advisory committees and feedback mechanisms will strengthen accountability and ensure that initiatives are effectively managed and sustained (Stanca et al., 2022). Awareness campaigns provide an excellent opportunity to promote behavioral change in relation to water and sanitation conservation. Following successful examples such as the community-led sanitation initiatives in Kenya and the public-private partnerships in Cape Town, these campaigns should focus on practical solutions and shared responsibility (Harris, 2012; Swart et al., 2024). Collaborating with schools, health facilities and community organisations will maximise reach and create a culture of care and responsibility. The impact of these initiatives can be assessed through key indicators such as improvement in hygiene practises, reduction in waterborne diseases and reliability of clean water and sanitation facilities.

Rethinking sustainable solutions

Addressing water and sanitation challenges in Nompumelelo requires a multi-faceted approach that integrates public-private partnerships (PPPs), technological innovations, and community-driven capacity building. PPPs can leverage private sector investment and expertise, accelerating infrastructure development while ensuring cost-effective, sustainable solutions (Akomea-Frimpong et al., 2023). For instance, solar-powered water purification systems have proven effective in resource-limited settings, offering long-term affordability and environmental benefits. Additionally, drawing lessons from successful urban initiatives globally and examining the link between WASH conditions and public health can help set evidence-based priorities for innovation and policy development (Haque and Freeman,

2021). Furthermore, building local capacity is fundamental to long-term sustainability. Recent studies highlight the potential of AI-driven decision-making tools in optimizing water treatment processes and operational efficiency (Yusuf et al., 2020). Implementing training programs focused on equipping community members with technical skills for managing and maintaining WASH infrastructure can create local economic opportunities while enhancing system resilience. Establishing training centers and providing ongoing technical support will ensure that the community remains self-sufficient and capable of maintaining its infrastructure over time. In addition to technological and capacity-building efforts, addressing intra-city inequalities is crucial for ensuring equitable WASH access. Disparities in housing conditions, economic status, and education levels significantly impact WASH service delivery. Therefore, urban policies should prioritize both efficiency and equity, ensuring that improved services benefit all residents, particularly those in marginalized areas (Saroj et al., 2020). This approach not only enhances sustainability but also fosters social inclusion, empowering residents, especially the youth, through skill development and job creation. By integrating inclusive urban policies, innovative technologies, and community-centered approaches, Nompumelelo can serve as a model for sustainable WASH service delivery, inspiring similar initiatives in other peri-urban areas.

Conclusion

Addressing the challenges of sustainable access to potable water and sanitation in Nompumelelo requires a strategic and well-defined approach. These complex issues demand targeted solutions, including community-driven initiatives, effective public-private partnerships (PPPs), and robust education and capacity-building programs. However, the success of these strategies depends on their practical implementation, which must be clearly outlined through a structured action plan with well-defined timelines, responsibilities, and measurable objectives. A key component of this approach is the establishment of a local advisory committee to facilitate community engagement. This committee should include representatives from local leadership, health workers, NGOs, and key government agencies, ensuring inclusive decision-making and shared responsibility. Its primary functions should include identifying priority issues, coordinating stakeholder participation, monitoring project implementation, and enforcing accountability in service delivery. Clear governance structures, decision-making protocols, and regular review mechanisms will be necessary to maximize its effectiveness. In addition, pilot projects should be launched to assess the feasibility of PPP models and technological innovations before broader implementation. These projects should be designed with clear evaluation criteria, including cost-effectiveness, scalability, and community acceptance, to ensure informed decision-making on long-term investments. To sustain progress, it is crucial to address potential barriers such as funding constraints, weak community engagement, and technological mismatches. Diversifying funding sources, conducting continuous stakeholder consultations, and providing long-term technical support will be critical in overcoming these challenges. By proactively implementing these strategies, Nompumelelo can develop a replicable model for sustainable water and sanitation service delivery, offering valuable insights for other peri-urban areas (PUAs). Finally, further research is needed to develop innovative,

evidence-based solutions that enhance the scalability and long-term sustainability of these interventions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent was obtained from the [patients/ participants OR patients/participants legal guardian/next of kin] to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

SM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. LZ: Investigation, Methodology, Resources, Project administration, Conceptualization, Supervision, Writing – review & editing.

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