Strategic Interventions for Sustainable Wastewater Management: A Case Study of Georgetown, Guyana

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Abstract:
The lack of a thorough, integrated, and coordinated wastewater management system in Guyana is currently a pressing issue that must be addressed given the country's expanding urban population and environmental stresses. The Laing Canal and the mouth of the Demerara River receive "untreated" discharges from the outdated and insufficient Tucville sewage system and Central Georgetown sewage respectively. Operational shortcomings exacerbate these effects. Inappropriate fat oil and grease disposal from commercial facilities sometimes lead to sanitary overflows, sewer obstructions, contamination of surface and potentially drinking water sources. Untreated or improperly managed biosolids can enter delicate ecosystems due to a crucial gap in fecal sludge governance, which is reflected in the lack of environmentally sound management procedures for sludge collected from septic tanks. Collectively, these failures exacerbate environmental degradation, elevate public health risks, and undermine the sustainability of wastewater management systems.
Semi-structured interviews with pertinent Guyana Water Incorporated, Environmental Protection Agency, hotel and food establishment representatives, lecturer and independent waste disposal service personnels highlighted the problems with the centralized facilities and provided solutions for better wastewater management. Data were evaluated utilizing a framework analysis approach to enable a systematic and transparent interpretation.
The findings show that Guyana's wastewater management difficulties are systemic and multifaceted, resulting from a combination of infrastructure constraints, poor regulatory enforcement, inadequate maintenance practices, inadequate financial investment, and low public awareness. These interrelated shortcomings impede system performance and progress toward sustainable water management.
In response, the study suggests a holistic approach that focuses on coordinated efforts across governance, infrastructure, and behavioral domains. Priorities consist of strengthening regulatory frameworks and enforcement mechanisms, investing in advanced treatment technologies, improving institutional capacity, raising public awareness and behavior change, and combining resource recovery and wastewater reuse techniques.
Overall, the study shows that attaining sustainable wastewater management in Guyana necessitates a shift from fragmented, reactive techniques to coordinated, system-based strategies that correspond with Sustainable Development Goal (SDG) 6.3. The findings establish a context-specific, evidence-based framework for policy development and give transferable perspectives for other underdeveloped and resource-constrained locations.

Key Words: Strategic Intervention, Sustainable, Wastewater Management

HIGHLIGHTS

- Raises awareness of wastewater issues
- Provides a framework for wastewater management in Guyana

INTRODUCTION

Water resources worldwide are increasingly threatened by the combined pressures of population growth, rapid urbanization, industrial expansion, agricultural intensification, and climate change (Mishra, 2023; Roopnarine

et al., 2023). These pressures have significantly increased wastewater (WW) generation, placing considerable strain on environmental systems and aquatic ecosystems (Pandey et al., 2022). In many developing regions, inadequate wastewater management (WWM) has resulted in the widespread discharge of untreated or partially treated effluent into natural water bodies, contributing to declining water quality, ecosystem degradation, and heightened public health risks (Voulvoulis, 2018).

Coastal habitats are especially vulnerable to the effects of poor WWM since they serve as important socioeconomic and ecological resources. Untreated domestic and industrial wastewater is a significant contribution to coastal water pollution worldwide (Braga et al., 2000; Aslan-Yilmaz et al., 2004; Mozetič et al., 2008). The introduction of nutrients such as nitrogen and phosphorus from wastewater discharges causes eutrophication and hypoxia, resulting in biodiversity loss, altered ecosystem functioning, and poor water quality (Diaz & Rosenberg, 2008; Powley et al., 2016). These effects not only endanger marine ecosystems, but also undermine important human activities such as fishing, tourism, recreation, and coastal protection (Prouty et al., 2018).

In response to these challenges, global efforts have shifted toward sustainable wastewater management practices, particularly Sustainable Development Goal (SDG) 6.3, which calls for pollution reduction, untreated wastewater discharge minimization, and safe reuse and recycling. Wastewater reuse has evolved as a viable option for dealing with water constraint while increasing resource efficiency, with treated wastewater providing as an alternative supply for agricultural, industrial, and environmental uses (Demir et al., 2017; Ulusoy et al., 2024). Despite technological advances, the efficiency of WWM systems is still limited in many developing contexts due to a combination of infrastructural, institutional, financial, and behavioral hurdles (Edokpayi et al., 2017; Baptiste, 2017).

These issues are especially acute in the Caribbean region, notably Guyana, due to inadequate infrastructural development and governance constraints. According to GWI (2017), Georgetown's wastewater services are mostly provided by Guyana Water Incorporated (GWI), which relies on aging and inadequate systems such as the Central Georgetown sewer system (built in 1929) and the Tucville treatment facility (built in 1970). These systems are either non-functional or operate below capacity, resulting in the discharge of untreated or inadequately treated effluent into canals, rivers, and coastal waterways. Industrial effluents are also released into surface water bodies, aggravating environmental pollution and ecological degradation.

An additional operational challenge arises is that occasionally, fats and oils from tissues, wipes, and restaurants clog the sewer systems, causing overflows when waste is purposefully dumped in the chambers. According to Hussain et al. (2014), fats oil, and grease (FOG) frequently builds up and deposits on the sewers inside walls, blocking pipes and reducing WW flow, which lowers the sewer system's capacity. FOG buildup can trigger sewer systems to corrode under anaerobic conditions, reducing their lifespan and requiring earlier repairs and replacements.

A further systemic concern is that even though most homes use septic tanks, there are no inspections to make sure they are constructed, operated, and desludged in compliance with the Guyana Standard Code of Practice for the design and construction of septic tanks and related secondary treatment and disposal systems (GCP 26: 2007), which is issued by the Guyana National Bureau of Standards (GNBS). Consequently, desludging practices are determined at the discretion of homeowners rather than being conducted in accordance with the prescribed intervals. This discretionary approach results in periodic and delayed desludging thus increasing the risk of septic effluent flowing into open drains, causing detrimental environmental consequences; the overflow of pathogen-laden supernatants pollutes surface and groundwater, according to Mehta et al. (2019).

These issues are exacerbated by institutional fragmentation and insufficient enforcement capacity. Although regulatory frameworks exist, their execution is limited by financial and technical constraints, as well as unclear institutional roles and responsibilities (Baptiste, 2017; Cashman, 2012). As a result, Guyana's wastewater management is represented by systemic failure, infrastructural inadequacies, poor behavioral

habits, governance gaps, and financial limitations all contributing to environmental degradation and public health hazards.
Given that a large proportion of the population lives on the low-lying coastal plain, poor WWM has serious ramifications for water quality, environmental integrity, and human health. These conditions are incompatible with the goals of SDG 6.3, emphasizing the critical need for integrated and sustainable wastewater management approaches.

Against this backdrop, this report provides a critical and comprehensive examination of Guyana's wastewater management, with an emphasis on onsite systems, centralized infrastructure, and faecal sludge management procedures. The study's goal is to identify the fundamental reasons of system inefficiencies and propose a strategy framework for sustainable wastewater management that integrates technological, institutional, and behavioral interventions.

Study Area
Georgetown, the capital and most populated town of Guyana, and is situated on the northeastern Atlantic coast of South America (Edwards et al., 2005). Covering an area of around 30 km^2, the neotropical city is home to 14.3% (~125,683) of Guyana's total population and is distinguished by a wide range of socioeconomic and ethnic backgrounds (Bureau of Statistics, 2022). Georgetown serves as the center of industry, commerce, and international trade in addition to serving as the seat of government and like many developing-nation cities, suffers from a number of socioeconomic issues, such as pervasive poverty, high unemployment, inadequate infrastructure, and a variety of environmental issues, such as poor sanitation, garbage disposal, and flooding, the latter of which is more serious due to the city's physical environmental features, particularly its closeness to the Demerara River and the ocean, as well as its position below sea level (Edwards et al., 2005).

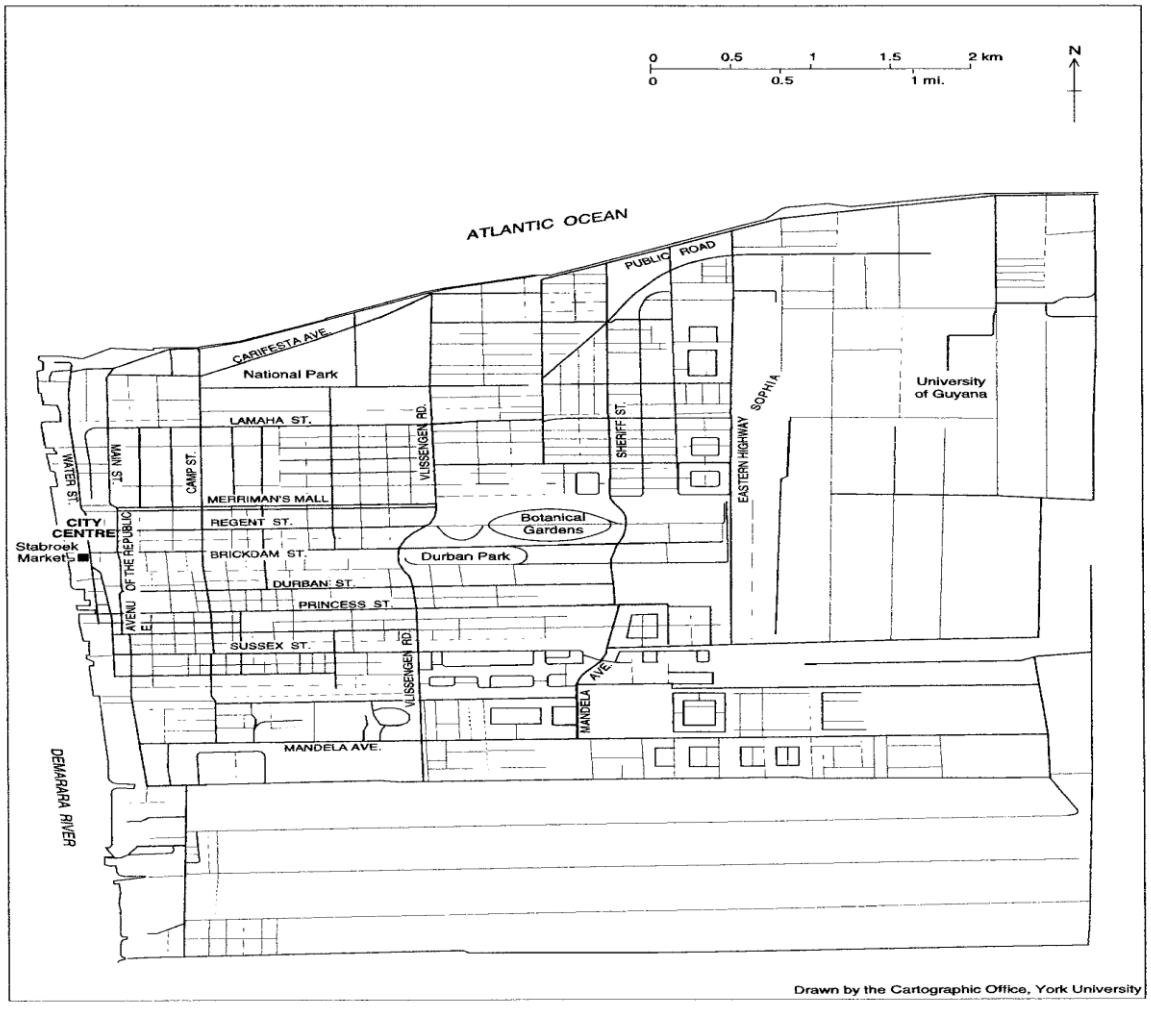

Figure 1: Georgetown Guyana (Source: Edwards et. al, 2005)

METHODOLOGY

Data Collection

A selective sample technique was used to recruit participants in Guyana who has specialized expertise and direct experience in wastewater management (WWM). Rather than aiming for numerical representativeness, the study focused on important informants in key positions in pertinent sectors such as government, private wastewater services, academia, and the hospitality industry. Such a strategy ensures that participants have unique, context-specific insights necessary to fulfill the research goals.

The final sample included six persons: a senior engineer from Guyana Water Incorporated (GWI), a senior environmental officer from the Environmental Protection Agency (EPA), representatives from two private wastewater disposal services, a hotel/restaurant employee, and an environmental science lecturer. All participants had advanced academic degrees or more than 10 years of professional experience, indicating a high level of domain understanding.

The relatively small sample size is supported by the concept of "information power," which holds that the more relevant and specific the information provided by participants, the fewer participants are needed (Malterud et al., 2016). Participants in this study were carefully chosen for their depth of expertise and direct involvement in WWM systems, yielding rich, detailed data that could be used to answer the research objectives.

Data saturation was achieved when no new themes emerged throughout the analysis, as per qualitative research guidelines (Bekhet & Zauszniewski, 2012). As a result, the sample size was deemed sufficient to provide relevant and credible findings.

Unstructured interviews were done for a duration of approximately 45 to 60 minutes and provided information for finding solutions to the issues. Questions covering the following areas were incorporated in the interview:

- Demographic data such as gender, age, degree attained, occupation, years of experience,
- Issues with the current wastewater collection and disposal systems in Georgetown,
- Factors attributed to the current state of the wastewater facilities,
- Human health and environmental risks associated with the usage of the facilities,
- Wastewater treatment, discharge standards and implementation of wastewater reuse,
- Policy, institutional, and legal frameworks used for the provision of safe wastewater collection and disposal services in different categories of business,
- Strategic interventions for achieving Sustainable Development Goals in sanitation are attainable in Guyana by 2030.

Emails inviting the individuals to participate in the study were issued. Following their receipt of pertinent information and confirmation that they understood the study well, consent was obtained, and the interviews were held on the scheduled dates. UREC granted ethics approval prior to the data collection phase. The cornerstone for approval has been the based on protection, anonymity, and confidentiality. To guarantee the accuracy and caliber of the current study, credibility, transferability, dependability, and confirmability were employed.

Transferability: Reaching saturation (Casey and Murphy 2009, as mentioned in Bekhet and Zauszniewski, 2012) enables you to attain "applicability" (also known as "transferability" in qualitative research). This was obtained in this study by collecting new data without new themes emerging.

Credibility: By employing quotations that authentically conveyed the experiences of individuals (Guba and Lincoln 1989 as referenced in Bekhet & Zauszniewski, 2012), credibility and truth were attained ('internal validity' in quantitative research).

Dependability: Dependability is defined as the scrutiny and documenting of data, procedures, and researcher judgments (Lotfi et al., 2022, cited in Ghanbari et al., 2024). To depend on the study outcomes, the interviews were recorded and then transcribed.

Confirmability: Confirmability refers to the parallel assessment of outcomes and reflexivity (Lotfi et al., 2022, as cited in Ghanbari et al., 2024). The results were verified using a variety of approaches, including document examination, interviews, and interview recordings.

Data Analysis

The qualitative data were examined using a framework analysis approach, which allowed for both deductive (a priori) and inductive (emergent) theme creation. The analysis was conducted in five stages: familiarization, coding, establishing a theme framework, charting, and interpretation (Smith & Firth, 2011).

Interview transcripts were initially read several times to establish immersion in the data. Initial codes were then produced using both the study objectives and reoccurring patterns in the data. These codes were methodically organized into bigger categories, which were then developed into analytical themes via an iterative process of comparison and abstraction.

To increase transparency, a coding tree was created to show the progress from raw data to final themes. This process provided a clear audit trail connecting responses from participants to the study's conclusions.

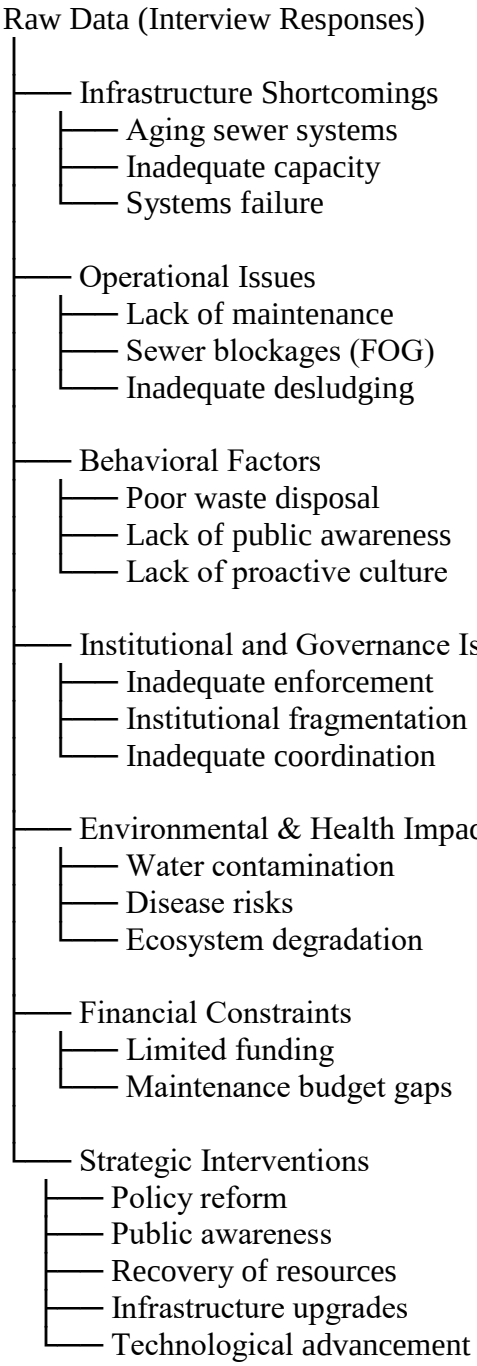

Figure 2: Coding Tree showing Progress from Raw Data to Final Themes

Given that the coding was done by a single researcher, no formal inter-coder reliability testing was performed. However, methodological rigor was guaranteed via:

- Systematic coding processes.
- Iterative review of transcripts.
- Uniform coding frameworks.
- Triangulation with secondary data sources.

This technique is congruent with qualitative research norms, which emphasize transparency and reflexivity over statistical agreement (Guba & Lincoln, 1989 as cited in Bekhet & Zauszniewski, 2012).

RESULTS AND DISCUSSION

Wastewater Management: A Systematic, Interconnected Problem

The results show that Georgetown's wastewater management (WWM) is characterized by a systematic and interconnected set of failures covering infrastructure, behavior, and governance rather than individual operational deficiencies. Problems including insufficient infrastructure, inadequate enforcement, poor maintenance, and low public awareness combined to create enduring system inefficiencies rather than operating as isolated problems.

Data from interviews frequently indicate operational constraints and the deteriorating status of infrastructure. One participant highlighted capacity issues associated with urban growth by emphasizing that "the Central and Tucville wastewater facilities are insufficient for handling the city's current population." However, the research indicates that system underperformance cannot be entirely explained by infrastructure constraints alone. Rather, institutional and behavioral factors—specifically, poor enforcement and irregular maintenance—compound these limitations.

This is consistent with previous research showing that operational management and governance capacity, rather than infrastructure alone, influence wastewater system performance in developing environments (Edokpayi et al., 2017; Baptiste, 2017). Therefore, it is appropriate to think of Guyana's WWM problems as structurally ingrained, where many component failures reinforce the others.

Behavioral Pattern and Infrastructure Failure

The study's key result is that user behavior has a substantial role in contributing to infrastructure failure, particularly when it comes to fat, oil, and grease (FOG) disposal. Interviewees regularly cited commercial establishments' inappropriate disposal procedures as a primary cause of sewer clogs and overflows. According to one participant, fats, oils, and grease from restaurants can clog sewer systems and cause overflows.

While FOG formation is well acknowledged as a cause of sewer inefficiencies (Husain et al., 2014; Wallace et al., 2017), the findings expand on this understanding by emphasizing the importance of poor enforcement and maintenance procedures. Several participants noted that, while grease traps may exist, they are frequently inadequately maintained, allowing detrimental activities to continue.

Crucially, organizational and regulatory factors influence these behaviors rather than being solely personal decisions. "Some establishments may have grease traps, but they are improperly maintained," as one respondent stated, suggesting oversight and noncompliance issues. This is consistent with a larger body of research that suggests institutional structures and enforcement mechanisms have an impact on environmental behaviors (Bhaduri et al., 2016).

As a result, in this instance, infrastructure failure reflects a behavior–governance relationship in which inadequate regulatory control and behavioral conformity compromise technological systems.

Institutional and Governance Issues

Results also show that wastewater management is hampered by institutional fragmentation and poor regulatory compliance, which reduce the effectiveness of existing systems. Interviewees regularly mentioned

a lack of cooperation among key entities in charge of water and sanitation. One participant inquired, "Who is responsible for ensuring that septic tanks are constructed in accordance with standards?" Another noticed a lack of collaboration among authorities such as GWI, the Bureau of Standards, and the Public Health Department.

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Furthermore, participants stressed the importance of better policy frameworks and enforcement measures. One interviewee noted that "the regulatory body needs to be operational," expressing concern about the inadequate implementation of current policies. This validates Baptiste's (2017) findings, which identify institutional and budgetary restrictions as important hurdles to efficient water governance in Guyana.
These findings imply that enhancing WWM necessitates not just policy formation, but also institutional alignment and operational capacity to ensure that regulatory frameworks are properly implemented.

Fecal Sludge Management
One of the most noteworthy discoveries is that faecal sludge management (FSM) is a crucial point of failure in the system. Interview data revealed that sludges are frequently disposed of without proper treatment, such as discharging at outfalls or along shorelines. This implies a failure in the last stages of the wastewater management process.

From a systems perspective, this reflects a failure in the wastewater value chain, as upstream collection and conveyance are rendered useless due to a lack of safe treatment and disposal. As a result, wastewater systems serve not as containment devices, but as routes for environmental contamination.

This finding aligns with global research indicating that ineffective sludge management contributes to the discharge of pathogens, nutrients, and pollutants into aquatic environments (Voulvoulis, 2018). The ramifications are especially important in coastal areas, where untreated discharges can harm marine ecosystems, fisheries, and public health.

Additionally, the reliability and validity of the results are reinforced by the uniformity of participant responses and the triangulation of interview data with secondary sources. The results give analytical generalizability and transferable insights for similar developing and resource-constrained environments, even though they might not be quantitatively generalizable.

Implications for Accomplishing SDG 6.3
The Sustainable Development Goal (SDG) 6.3, which focuses on enhancing water quality by reducing pollution and limiting untreated wastewater discharge, is directly impacted by the systemic issues identified in this study. Current methods are incompatible with SDG targets, as evidenced by the persistence of untreated discharges, infrastructural failures, and sludge mismanagement.

Significantly, the results show that infrastructure investment alone is not enough to achieve SDG 6.3. One participant pointed out that "developing a culture of being proactive" is crucial for sustainable wastewater treatment, emphasizing the importance of both technical solutions and behavioral change.

This bolster international data indicating that integrated strategies combining infrastructure, governance, and behavioral interventions are necessary to advance SDG targets (Delanka-Pedige et al., 2021). WWM must be viewed in this context as a multi-level system, where advancements in one area necessitate alignment in others.

CONCLUSION

This study shows that wastewater management (WWM) in Guyana is hampered not by discrete technological shortcomings, but by systemic, interrelated problems in infrastructure, government, behavior, and financing. Research from Georgetown demonstrates that obsolete and inadequate systems, inconsistent maintenance, limited regulatory enforcement, fragmented institutional roles, and unsafe sludge disposal practices all contribute to continual unregulated discharges and repeated system failures. These conditions can have a direct impact on the ecosystem and public health, especially through nutrient loading, pathogen exposure, and coastal and surface water contamination.

By combining empirical findings with international evidence, the study reframes WWM as an integrated, multi-level system in which user practices, organizational capacity, and policy coherence all contribute to outcomes. A major result is that gaps in the wastewater value chain, particularly the lack of adequate faecal sludge management rendering collection and conveyance as ineffective.

These dynamics pose a substantial roadblock to reaching Sustainable Development Goal (SDG) 6.3, which aims to reduce untreated wastewater and enhance water quality. Progress, therefore, necessitates a transition from reactive, fragmented interventions to a coordinated and systemic approach. The study proposes an integrated framework based on: (i) enforceable regulatory frameworks and institutional coordination; (ii) continual public awareness and behavior change; (iii) targeted infrastructure improvement and maintenance; (iv) regulated faecal sludge treatment and disposal; (v) resource recovery and safe reuse; and (vi) long-term financing mechanisms. Importantly, these elements ought to be integrated as mutually reinforcing components of a unified system.

To summarize, attaining effective WWM in Guyana—and other resource-constrained settings—requires integrating behavioral, institutional, and infrastructural dimensions to restore the integrity of the wastewater value chain. Such alignment is required to achieve measurable improvements in water quality, protect public health, and put SDG 6.3 into motion.

ACKNOWLEDGEMENTS

The author would also like to express her sincere gratitude to Dr, David Mulenga from Unicaf University, Zambia for his guidance and support throughout this study.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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