SMJ- Sohag Medical Journal, Vol. 29 No(1) 2025

Print ISSN1687-8353 Online ISSN2682-4159

Original Article

Prevalence and Effects of Waterborne Illnesses among Students in Rural and Urban Schools in Iringa, Tanzania: A Comparative Study

Magwe, Edward Augustine

*Department of Pharmaceutical Sciences, Institute of Health and Allied Sciences, Ruaha Catholic University, P.O. Box 774 Iringa, Tanzania

Abstract

Background: The prevalence of waterborne illnesses among students in rural and urban schools is a significant public health issue, especially in developing regions with limited access to clean water and sanitation. In Tanzania, research shows that rural populations still face significant challenges despite improved water access, impacting efforts to control waterborne diseases.

Objectives: This study assessed the prevalence of reported waterborne illnesses and their effects on students in rural and urban primary and secondary schools in Iringa, Tanzania.

Patients and Methods: This study, conducted from July 4 to July 25, 2024, used a quantitative cross-sectional analytical approach involving 1,536 students. Data was collected through structured questionnaires, and descriptive and comparative results were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. Significant associations were evaluated using P-values from cross-tabulation and further by examined binary logistic regression.

Results: The study found that 17.2% of rural school students suffer from waterborne illnesses, which is higher than the 10.9% prevalence seen in urban school students, both being a moderate prevalence. This study established a significant correlation in rural and urban schools through bivariate analysis ($P < 0.05$); however, binary logistic regression did not support this relationship.

Conclusion: Waterborne illness was more prevalent in rural than urban school students, although both face moderate reported prevalence. This necessitates attention to potential interventions, including equitable resource allocation, to close the rural-urban gap.

Keywords: Prevalence, Waterborne Illnesses, Rural-Urban, Students, Schools.

DOI : 10.21608/smj.2025.336530.1512 **Received:** November 04, 2024 **Accepted:** December 09, 2024

Published: January 01, 2025

Corresponding Author: **Edward Augustine Magwe** **E.mail**: edwardam87@gmail.com

Citation: Edward Augustine Magwe, Prevalence and Effects of Waterborne Illnesses among Students in Rural and Urban Schools in Iringa, Tanzania: A Comparative Study SMJ,2025 Vol. 29 No(1) 2025: 84 -94

Introduction

The prevalence of waterborne illnesses among students in rural and urban schools is a significant public health concern, particularly in developing regions where access to clean drinking water and proper sanitation facilities is often inadequate.[1] Studies have consistently shown that contaminated water sources are a primary contributor to various waterborne diseases, including cholera, typhoid fever, and gastrointestinal infections, which disproportionately affect children and adolescents.[2,3]

The study conducted in Peshawar, Pakistan, revealed that 52% of participants identified waterborne illnesses as a significant health issue in their community, highlighting dissatisfaction with drinking water quality.[1] Similarly, another study emphasized that waterborne diseases are transmitted primarily through the fecal-oral route, often exacerbated by inadequate water treatment practices.[4] This is particularly concerning in rural schools where infrastructure may be lacking, leading to higher rates of illness among students.

The impact of waterborne diseases on school-aged children is further illustrated by findings that indicate schools utilizing surface water sources face a higher risk of infection.[5] This is compounded by the fact that children are more susceptible to the effects of contaminated water, which can lead to severe health outcomes, including dehydration and malnutrition from diarrheal diseases.[6] In regions where water insecurity is prevalent, the threat of waterborne illnesses is expected to escalate due to climate change and its effects on water quality and availability.[7]

Knowledge and personal hygiene practices among students are vital for reducing the risk of waterborne diseases.[8] However, studies in India and Sierra Leone found that although many recognized that clean drinking water could prevent these diseases, a lack of actual hygiene practices highlighted a gap between awareness and behavior.[8,9] This disconnect suggests that educational interventions are necessary to improve hygiene practices among students, thereby reducing the incidence of waterborne illnesses.

In Tanzania, the research found that inadequate storage solutions can lead to the re-contamination of treated drinking water, which poses a significant risk for waterborne diseases. It further emphasized the importance of proper water treatment and storage practices among students in Tanzania, highlighting a crucial aspect of school water management.[2] A cross-sectional study among the Maasai community reported significant WASH challenges in rural than urban areas, affecting efforts to control waterborne diseases like cholera. Also, inadequate sanitation facilities worsen this disparity, increasing disease transmission risks among schoolchildren.[3]

Moreover, another study found that fluctuations in climate conditions can lead to increased contamination risks, which is particularly relevant for rural schools, where reliance on unimproved water sources is common.[10] Another Tanzanian research underscores the effectiveness of ordinary water filters used in Tanzania, noting that their ineffectiveness can lead to persistent waterborne diseases.[11]

This study aimed to assess the prevalence of reported waterborne illnesses and their effects on students in rural and urban schools in Iringa, Tanzania. The results are intended to enhance sanitation facilities and foster greater awareness of hygiene practices among students.

Patients and Methods

Area of study

This research was conducted in the Iringa, Kilolo, and Mufindi districts, which are situated within the Iringa region. The Iringa Region, found in the Southern Highlands zone of Tanzania Mainland, is located south of the Equator between the latitudes of 6°-55’ and 9° 00’ south, and the longitudes of 33° 45’ and 36° 55’ East of Greenwich. It shares its northern borders with the Singida and Dodoma regions, while the Morogoro region lies to the east and the Mbeya region to the west; the Njombe region is located to the south.[12] Three districts were chosen for this study because of their varying economic conditions, geographical features, and population sizes. Iringa municipality, located in the Iringa district, was selected to represent urban schools, given its predominantly urban character. Kilolo and Mufindi districts were selected to represent rural schools due to their predominantly

rural characteristics. Iringa district comprises 151 primary schools and 42 secondary schools, with 50 primary and 30 secondary schools located in Iringa municipality; Kilolo district has 133 primary schools and 44 secondary schools, while Mufindi district contains 162 primary schools and 48 secondary schools.[13-16]

Study design

This research, conducted from July 4 to July 25, 2024, employed a quantitative cross-sectional analytical approach to evaluate the reported prevalence and effects of waterborne diseases among students in rural and urban schools within the Iringa region of Tanzania.

Study population

This research involved students from rural and urban schools in the Iringa region, incorporating public and private schools, day, boarding, mixed schools, and primary and secondary levels. Primary school students from standard 5 to 7 were included, while those from lower grades (standard 1-4) were not part of the study. In secondary education, both O-level students (form 1-4) and high-level students (form 5-6) were included in the research.

Sampling and sample size

An equal number of rural and urban schools were purposefully selected, ensuring a proportionate distribution of private and public institutions, primary and secondary schools, and boarding and day schools. The stratification of rural and urban schools was established to facilitate a structured analysis. Specifically, 32 schools were chosen from rural districts with equal distribution from Kilolo and Mufindi, and 32 schools were selected from Iringa Municipality, representing the urban areas. This resulted in a total of 64 schools in the study. A simple random selection technique was applied to select schools from each stratum, and selecting students from assessed schools.

Subsequently, the Cochran formula was utilized to determine the sample size of students for the rural district of Kilolo, and this calculated size was applied to the second rural district, Mufindi. The total sample size for the rural segment was also replicated for the urban segment.

$$\text{Cochran formula: } N = \frac{Z^2 P(1-P)}{d^2}$$

Where;

N = Minimum sample size

Z = Constant, standard normal deviation (1.96 for 95% Confidence level)

P = Estimated proportion of the population (50% or 0.5) to maximize sample size in the absence of precise prevalence data

d = Acceptable margin of error (5% or 0.05)

$$\text{For Kilolo district: } N = \frac{1.96^2 \times 0.5 \times (1 - 0.5)}{0.05^2} = 384 \text{ students}$$

Thus, the total number of rural schools amounted to 768 students, with a corresponding urban sample size of 768, culminating in an overall total of 1,536 students.

Data collection

Data were collected utilizing structured questionnaires designed to evaluate the prevalence and effects of waterborne illnesses among students in rural and urban schools in Iringa, Tanzania.

Data analysis

Data analysis was conducted using Statistical Package for the Social Sciences **(**SPSS) version 26, which employed descriptive and comparative methods to summarize findings on waterborne illnesses and assessed effects. Frequencies and percentages were calculated, with students reporting illness from water use in the past six months affirming prevalence. Associations between variables were examined using P-values from cross-tabulation, and binary logistic regression analyzed the causes of these associations.

Scoring and definitions of reported prevalence

Prevalence was categorized into three levels. Low prevalence (<10%), indicates minimal concern. Moderate prevalence (10% to <30%), indicates a moderate public health concern, but not extensive. High prevalence (≥30%), indicates a substantial disease burden, necessitating attention to potential interventions.[17]

Ethical considerations

Ruaha Catholic University (RUCU) provided ethical clearance for this research, identified by reference number RU/RPC/RP/2024/14. Authorization to carry out the study was acquired from the regional education officer's office, the respective district education officer, and the school heads and administrators. All data gathered was managed with utmost confidentiality, guaranteeing no details were disclosed.

Results

Socio-demographic characteristics of rural-urban students in schools

In the demographic analysis of students, it was observed that the age group of 13-15 years comprised a significant portion of the enrollment in rural schools, totaling 290 (18.9%) students. Conversely, urban schools exhibited more students aged 10-12 years, with 294 (19.1%) students. The least represented age group in rural schools was those over 18 years, with 21 (1.4%) students, whereas urban schools had fewer students under 10 years, amounting to 28 (1.8%) students.

Female students were substantially represented in rural and urban educational settings, accounting for 399 (26.0%) and 448 (29.2%) students, respectively. Students enrolled in Primary School (Standard 5-7) were predominant in both rural and urban schools, with 385 (25.1%) students in rural areas and 387 (25.2%) students in urban areas, surpassing other educational categories.

Public schools were the primary contributors to student enrollment in both contexts, with 502 (32.7%) students in rural schools and 515 (33.5%) students in urban schools. Additionally, day students represented a significant demographic, with 485 (31.6%) students in rural schools and 589 (38.3%) students in urban schools. A significant association was revealed in age, gender, type of school, and living situation factors, as described in Table 1.

Rural-urban comparison of waterborne disease prevalence among students in schools

The study revealed that the prevalence of waterborne illnesses among rural school students is 17.2%, which is higher than the prevalence of 10.9% observed among urban school students. Both groups exhibit a moderate prevalence, as illustrated in the accompanying figure. Among those who enco-untered illness, a considerable percentage of stu-dents reported experiencing symptoms of waterb-orne illnesses one to two times in the past six months, with 201 (46.5%) in rural schools and 107 (24.8%) in urban schools. In comparison, fewer students reported experiencing symptoms five or more times, with 8 (1.9%) in rural schools and 25 (5.8%) in urban schools. The symptom of stomach cramps was prevalent among students, with 104 (24.1%) in rural schools and 98 (22.7%) in urban schools reporting this particular issue more frequently than other symptoms.

Furthermore, a notable number of students from both rural 114 (26.6%) and urban 73 (17.0%) schools experienced symptoms in less than one hour after consuming water at school. This was followed by a timeframe of one to six hours, where 99 (23.1) of rural students and 52 (12.1%) of urban students

reported similar experiences. The majority of students in both rural 149 (34.7%) and urban 97 (22.6%) schools predominantly utilized tap water as their primary source of drinking water, rather than other available sources. Among those who experienced symptoms, 141 (33.2%) sought medical attention in rural settings compared to 111 (26.1%) in urban locations. A significant relationship was found between location and experiences of waterborne illness, symptoms related to drinking water at school, frequency of symptoms in the past six months, seeking medical attention, satisfaction with hygiene practices, and reporting illness to the school health services unit, as detailed in Table 2.

Predictors associated with the prevalence of waterborne illnesses among students in school

This study identified a significant correlation among three predictor variables: school location (rural and urban), school district (Iringa, Kilolo, and Mufindi), and living situation (boarding and day students), all of which exhibited a P-value <0.05 as detailed in Table 3. A binary logistic regression analysis revealed that living in the Kilolo district reduced the likelihood of not being affected by waterborne illnesses by 41.4% (Odds Ratio = 0.586, 95% CI: 0.429-0.801), while being a boarding student decreased the likelihood of not being affected by 33.8% (Odds Ratio = 0.662, 95% CI: 0.468-0.936), as shown in Table 4.

Table 1: Socio-demographic characteristics of rural-urban students in schools (N = 1536)

Socio-demographic characteristics	**School location**		**Chi-square**	**P-value**
	Rural	**Urban**		
Age				
Under 10 years	42 (2.7)	28 (1.8)		
10-12 years	249 (16.2)	294 (19.1)		
13-15 years	290 (18.9)	243 (15.8)	12.703	**0.013***
16-18 years	166 (10.8)	172 (11.2)		
Over 18 years	21 (1.4)	31 (2.0)		
Gender				
Male	369 (24.0)	320 (20.8)	6.319	**0.012***
Female	399 (26.0)	448 (29.2)		
Level of study				
Primary school (Standard 5-7)	385 (25.1)	387 (25.2)		
Secondary school (Form 1-4)	353 (23.0)	337 (21.9)	3.025	0.22
High school (Form 5-6)	30 (2.0)	44 (2.9)		
Type of school				
Public	502 (32.7)	515 (33.5)	0.492	0.483
Private	266 (17.3)	253 (16.5)		
Living situation				
Boarding student	283 (18.4)	179 (11.7)	33.482	< **0.001***
Day student	485 (31.6)	589 (38.3)		

* P<0.05 is statistically significant

Table 2: Rural-urban comparison of waterborne illness prevalence and effects among students in schools

Questions related to waterborne illness	Responses	School location		Chi-	P-
		Rural	Urban	square	value
Have you experienced waterborne illness symptoms after drinking water at school?	Yes	264 (17.2)	168 (10.9)	29.681	< **0.001***
	No	504 (32.8)	600 (39.1)		
If yes, how many times have you experienced waterborne illness symptoms in the past six months?	1-2 times	201 (46.5)	107 (24.8)		
	3-4 times	55 (12.7)	36 (8.3)	21.123	< **0.001***
	≥ 5 times	8 (1.9)	25 (5.8)		
Which of the following symptoms have you experienced after drinking water around the school community?	Nausea	31 (7.2)	16 (3.7)		
	Vomiting	10 (2.3)	11 (2.5)		
	Diarrhea	34 (7.9)	13 (3.0)		
	Stomach cramps	104 (24.1)	98 (22.7)	22.947	**0.001***
	Fever	16 (3.7)	9 (2.1)		
	Other	2 (0.5)	2 (0.5)		
	Multiple symptoms	67 (15.5)	19 (4.4)		
How long after drinking water did the symptoms appear?	< 1 hour	114 (26.6)	73 (17.0)		
	1-6 hours	99 (23.1)	52 (12.1)	3.351	0.341
	7-24 hours	22 (5.1)	20 (4.7)		
	> 24 hours	27 (6.3)	22 (5.1)		
Which source of drinking water caused illness?	Well	66 (15.4)	51 (11.9)		
	Tape water	149 (34.7)	97 (22.6)	6.004	0.111
	River water	40 (9.3)	13 (3.0)		
	Other	7 (1.6)	6 (1.4)		
Did you seek medical attention for your symptoms?	Yes	141 (33.2)	111 (26.1)	7.786	**0.005***
	No	120 (28.2)	53 (12.5)		
How did the waterborne illness impact your daily activities?	Missed classes	64 (15.0)	42 (9.9)		
	Bed rest	47 (11.0)	25 (5.9)	1.887	0.596
	Hospitalization	25 (5.9)	22 (5.2)		
	No impact	125 (29.3)	76 (17.8)		
How satisfied are you with the hygiene and sanitation practices of water around the school community?	Very satisfied	191 (12.4)	235 (15.3)		
	Satisfied	260 (16.9)	277 (18.0)		
	Neutral	71 (4.6)	64 (4.2)	12.123	**0.016***
	Dissatisfied	165 (10.7)	130 (8.5)		
	Very dissatisfied	81 (5.3)	62 (4.0)		
Have you reported your illness to the school health services unit?	Yes	165 (38.5)	86 (20.0)	7.906	**0.005***
	No	93 (21.7)	85 (19.8)		
If you reported your illness, how satisfied were you with the response?	Very satisfied	63 (22.0)	25 (8.7)		
	Satisfied	68 (23.7)	27 (9.4)		
	Neutral	28 (9.8)	8 (2.8)	3.662	0.454
	Dissatisfied	28 (9.8)	16 (5.6)		
	Very dissatisfied	14 (4.9)	10 (3.5)		

* P<0.05 is statistically significant

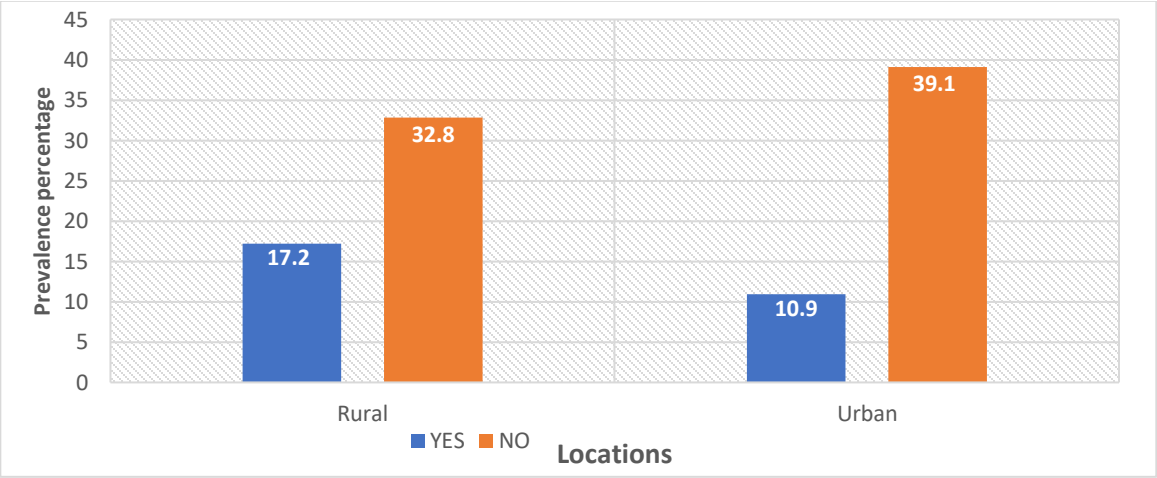

Figure: Rural-urban comparison of waterborne illness prevalence among students in schools

Table 3: Bivariate analysis of predictor factors associated with the prevalence of waterborne illness among students in schools (N = 1536)

Experienced symptoms of waterborne illness after drinking water in school				
Predictor variables	**Yes n (%)**	**No n (%)**	**Chi-square**	**P-value**
Age				
Under 10 years	18 (1.2)	52 (3.4)		
10-12 years	142 (9.2)	401 (26.1)		
13-15 years	167 (10.9)	366 (23.8)	4.678	0.322
16-18 years	93 (6.1)	245 (16.0)		
Over 18 years	12 (0.8)	40 (2.6)		
Gender				
Male	195 (12.7)	494 (32.2)	0.019	0.889
Female	237 (15.4)	610 (39.7)		
Level of study				
Primary school (Standard 5-7)	211 (13.7)	561 (36.5)		
Secondary school (Form 1-4)	204 (13.3)	486 (31.6)	1.920	0.383
High school (Form 5-6)	17 (1.1)	57 (3.7)		
School location				
Urban	168 (10.9)	600 (39.1)	29.681	**< 0.001***
Rural	264 (17.2)	504 (32.8)		
Type of school				
Public	270 (17.6)	747 (48.6)	3.700	0.054
Private	162 (10.5)	357 (23.2)		
School district				
Iringa	168 (10.9)	600 (39.1)		
Kilolo	151 (9.8)	233 (15.2)	38.982	**< 0.001***
Mufindi	113 (7.4)	271 (17.6)		
Living situation				
Boarding student	156 (10.2)	306 (19.9)	10.402	**0.001***
Day student	276 (18.0)	798 (52.0)		

* P<0.05 is statistically significant

Table 4: Binary logistic regression of predictor factors associated with the prevalence of waterborne illness among students in schools (N = 1536)

	YES response (Reference) vs. NO response				
Predictor variables	**B**	**P-value**	**AOR**	**95% CI for AOR**	
				Lower	**Upper**
Age					
Under 10 years	-0.063	0.910	0.939	0.312	2.82
10-12 years	-0.111	0.823	0.895	0.339	2.364
13-15 years	-0.289	0.536	0.749	0.3	1.868
16-18 years	-0.136	0.761	0.873	0.363	2.098
Over 18 years	Reference				
Gender					
Male	0.005	0.969	1.005	0.795	1.27
Female	Reference				
Level of study					
Primary school (Standard 5-7)	-0.323	0.465	0.724	0.305	1.72
Secondary school (Form 1-4)	-0.224	0.571	0.799	0.368	1.737
High school (Form 5-6)	Reference				
School location					
Urban	0.283	0.056	1.327	0.993	1.773
Rural	Reference				
Type of school					
Public	0.06	0.710	1.061	0.775	1.454
Private	Reference				
School district					
Iringa	-	-	-	-	-
Kilolo	-0.534	**0.001**	0.586	0.429	0.801
Mufindi	Reference				
Living situation					
Boarding student	-0.413	**0.020**	0.662	0.468	0.936
Day student	Reference				

* P<0.05 is statistically significant, **B** = Coefficient, degree of freedom (**df**) = 1, **CI**=Confidence Interval, **AOR**=Adjusted Odds Ratio.

Discussion

This comparative study has elucidated significant findings concerning the prevalence of waterborne illnesses among students in rural and urban schools in Iringa, Tanzania. The observed disparities in prevalence rates, symptomatology, healthcare-seeking behaviors, and the impact of socio-demographic factors emphasize how environmental and social contexts influence health outcomes among students.

The research found that 17.2% of rural school students reported suffering from waterborne illnesses, higher than the 10.9% prevalence in urban school students; however, both groups displayed a moderate level of illness. These results align with other studies, which revealed that rural schools had inadequate WASH facilities, which increased the risk of disease transmission.[18-20] Conversely, despite having better access to piped water, urban populations may still face significant risks due to the contamination of water supplies and inadequate waste management systems.[21,22]

Stomach cramps emerged as the most frequently reported symptom among students, slightly higher

in rural schools than urban ones. This aligns with findings in other Tanzanian studies, which reported that rural populations, including schoolchildren, were more vulnerable to waterborne diseases due to inadequate sanitation and hygiene facilities, leading to higher incidences of illnesses such as diarrhea with stomach cramps complaints.[3,23] These studies are consistent with findings from other regions outside of Tanzania, which indicate that urban students have a better understanding of waterborne diseases. However, the actual prevalence of these illnesses is higher in rural areas, where inadequate sanitation and hygiene practices lead to more complaints of stomach cramps. [18, 24]

However, the higher prevalence of stomach cramps in rural students contrasts with findings from a similar study conducted in Bangladesh, which found that abdominal pain and cramps were frequently reported symptoms among urban students affected by waterborne diseases.[25] Such symptoms are typically associated with bacterial or viral infections, which thrive in environments with compromised water sanitation.[25] Another study from Brazil revealed that contamination of urban groundwater had significant health consequences, including dysentery and other diarrheal diseases, which were linked to the consumption of unsafe water.[26]

Ongoing oversight and regular maintenance of urban water infrastructure could help reduce this inequality.

The study found that more students did not seek medical attention for waterborne illness symptoms in rural schools than in urban schools. This aligns with similar studies from Tanzania and Nigeria, which found that urban schoolchildren were more likely to seek medical attention for gastrointestinal symptoms than their rural counterparts because of better access to healthcare facilities, influencing their health-seeking behavior.[27,28]

Additionally, boarding students decreased the odds of not being affected by waterborne illness against the day students. The findings contrast with other studies that revealed that boarding schools typically implement rigorous hygiene practices and provide access to clean drinking water, which significantly reduces the likelihood of waterborne diseases. [5,29]

However, the study of Peguero et al. found that students living in boarding schools often face unique health challenges due to the communal living environment, which can facilitate the spread of infections, similar to this current study.[30]

Furthermore, day students may have more access to home resources, including clean water and sanitation facilities, which can mitigate their risk of contracting waterborne illnesses.

Conclusion

Waterborne illnesses are observed to be more prevalent in rural schools compared to urban settings, although students from both locations reported moderate prevalence. This situation underscores the need for targeted interventions in both settings. Among the symptoms reported by students in both contexts, stomach cramps are the most frequently mentioned. Additionally, rural students demonstrate a higher propensity of not seeking medical assistance for these symptoms than their urban peers. There are significant disparities in the impact of such illnesses when comparing school districts and differences between boarding and day students. This study also found a significant correlation between rural and urban schools through bivariate analysis ($P < 0.05$); however, binary logistic regression did not support this relationship.

Recommendations

Policies must emphasize the equitable allocation of resources to bridge the rural-urban divide. This approach should ensure that rural schools receive sufficient funding to improve water and sanitation facilities. Furthermore, establishing partnerships with health organizations to conduct regular health education sessions in schools could significantly enhance students' comprehension of waterborne diseases and their prevention.

References

1. Mehboob G, Hassan A, Shah S. An Assessment of Community Intervention for Reduction of Waterborne Illnesses in Peshawar, Khyber Pakhtunkhwa, Pakistan. Journal of Development Policy Research & Practice. 2018;2(1):106-119. https://doi.org/10.59926/jodprp.vol02/05

2. Felix GA, Ngasala TM, Mbatta G. Willingness of boarding school students in Tanzania to employ point-of-use water treatment: a case study. J Water Sanit Hyg Dev. 2021;12(1):52-57. https://doi.org/10.2166/washdev.2021.134

3. Jacob B, Kazaura M. Access to safe water, sanitation, and hygiene: a cross-sectional study among the Maasai in Tanzania. Am J Trop Med Hyg. 2021;104(4):1535-1539. https://doi.org/10.4269/ajtmh.20-0134

4. Abdulkadir N, Afolabi RO, Usman HM, Mustapha G, Abubakar UA. Epidemiological studies of waterborne diseases in relation to bacteriological quality of water. Microbiol Res J Int. 2019:1-12. https://doi.org/10.9734/mrji/2019/v28i430141

5. Ahmed J, Wong LP, Chua YP, Channa N, Mahar RB, Yasmin A. et al., Quantitative microbial risk assessment of drinking water quality to predict the risk of waterborne diseases in primary-school children. Int J Environ Res Public Health. 2020;17(8):2774. https://doi.org/10.3390/ijerph17082774

6. Hamilton S, Talbot J, Flint C. The use of open source GIS algorithms, big geographic data, and cluster computing techniques to compile a geospatial database that can be used to evaluate upstream bathing and sanitation behaviours on downstream health outcomes in Indonesia, 2000–2008. Int J Health Geogr. 2018;17(1). https://doi.org/10.1186/s12942-018-0164-6

7. Marcantonio R. Water insecurity, illness and other factors of everyday life: a case study from Choma district, southern province, Zambia. Water SA. 2018;44(4 October). https://doi.org/10.4314/wsa.v44i4.14

8. Patwardhan M, Li S, Miles T, Dere H, Khushalani D, Desai S. Types of health service utilization in Mumbai slums: a community-based survey. BMC Res Notes. 2023;16(1). https://doi.org/10.1186/s13104-023-06557-y

9. Sesay B, Hakizimana J, Elduma A, Gebru G. Knowledge and practices of the adult population on diarrheal diseases, transmission, and prevention in Sierra Leone: a community-based cluster survey. Afr J Health Sci. 2023;36(2):113-123. https://doi.org/10.4314/ajhs.v36i2.3

10. Guo D, Thomas J, Lazaro A, Mahundo C, Lwetoijera D, Mrimi E. et al., Understanding the impacts of short-term climate variability on drinking water source quality: observations from three distinct climatic regions in Tanzania. GeoHealth 2019;3(4):84-103. https://doi.org/10.1029/2018gh000180

11. Komba F, Fabian C, Elimbinzi E, Shao G. Efficiency of common filters for water treatment in Tanzania. Bull Natl Res Cent. 2022;46(1). https://doi.org/10.1186/s42269-022-00888-9

12. Iringa Region (IR). United Republic of Tanzania Office of the President, Regional Administrations and Local Governments. Iringa Region 2024. Available at: https://iringa.go.tz/. Accessed June 23, 2024.

13. Iringa District Council (IDC). United Republic of Tanzania Office of the President, Regional Administrations and Local Governments. Iringa District Council 2024. Available at: https://iringadc.go.tz/. Accessed June 23, 2024.

14. Iringa Municipal Council (IMC). United Republic of Tanzania Office of the President, Regional Administrations and Local Governments. Iringa Municipal Council 2024. Available at: https://iringadc.go.tz/. Accessed June 23, 2024.

15. Kilolo District Council (KDC). United Republic of Tanzania Office of the President, Regional Administrations and Local Governments. Kilolo District Council 2024. Available at: https://kilolodc.go.tz/. Accessed June 23, 2024.

16. Mufindi District Council (MDC). United Republic of Tanzania Office of the President, Regional Administrations and Local Governments. Mufindi District Council 2024. Available at: https://mufindidc.go.tz/. Accessed June 23, 2024.

17. World Health Organization. Preventive chemotherapy in human helminthiasis—Coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and program managers. Geneva: WHO; 2006. Available at: https://iris.who.int/bitstream/handle/10665/43545/9241547103_eng.pdf;jsessionid=A3A54328BA5A95F88B4485C14CFC55A6?sequence=1. Accessed June 25, 2024.

18. Kumar P, Srivastava S, Banerjee A, Banerjee S. Prevalence and predictors of water-borne diseases

among elderly people in India: evidence from longitudinal ageing study in India, 2017–18. BMC Public Health 2022;22(1). https://doi.org/10.1186/s12889-022-13376-6

19. Ohwo O, Agusomu TD. Assessment of water, sanitation and hygiene services in sub-Saharan Africa. Eur Sci J. 2018 Dec 31;14(35):308-26. http://dx.doi.org/10.19044/esj.2018.v14n35p308

20. Stothard J, Campbell S, Osei-Atweneboana M, Durant T, Stanton M, Biritwum N. et al., Towards interruption of schistosomiasis transmission in sub-Saharan Africa: developing an appropriate environmental surveillance framework to guide and to support 'end game' interventions. Infect Dis Poverty. 2017;6(1). https://doi.org/10.1186/s40249-016-0215-9

21. Rahaman M, Kalam A, Al-Mamun M. Unplanned urbanization and health risks of Dhaka city in Bangladesh: uncovering the associations between urban environment and public health. Frontiers in Public Health 2023;11. https://doi.org/10.3389/fpubh.2023.1269362

22. Zerbo A, Delagado R, González P. Conceptual frameworks regarding waterborne diseases in sub-Saharan Africa and the need of for a new approach to urban exposomes. Epidemiol Health. 2021;43:e2021079. https://doi.org/10.4178/epih.e2021079

23. Mrimi E, Palmeirim M, Minja E, Long K, Keiser J. Malnutrition, anemia, micronutrient deficiency and parasitic infections among schoolchildren in rural Tanzania. PLOS Negl Trop Dis. 2022;16(3):e0010261. https://doi.org/10.1371/journal.pntd.0010261

24. Shrestha M, Manandhar N, Joshi S. Study on knowledge and practices of water, sanitation and hygiene among secondary school students. Journal of College of Medical Sciences-Nepal. 2018;14(3):160-165. https://doi.org/10.3126/jcmsn.v14i3.21158

25. Harada H, Fujimori Y, Gomi R, Ahsan M, Fujii S, Sakai A. et al., Pathotyping of escherichia coli isolated from community toilet wastewater and stored drinking water in a slum in Bangladesh. Lett Appl Microbiol. 2018;66(6):542-548. https://doi.org/10.1111/lam.12878

26. Baía C, Vargas T, Ribeiro V, Laureano J, Boyer R, Dorea C. et al., Microbiological contamination of urban groundwater in the Brazilian western Amazon. Water 2022;14(24):4023. https://doi.org/10.3390/w14244023

27. Mboera LE, Rumisha SF, Lyimo EP, Chiduo MG, Mangu CD, Mremi IR. et al., Cause-specific mortality patterns among hospital deaths in Tanzania, 2006-2015. PLoS One. 2018;13(10):e0205833. https://doi.org/10.1371/journal.pone.0205833

28. Aboagye R, Seidu A, Okyere J, Mohammed A, Chattu V, Budu E. et al., Rural-urban disparities in caesarean deliveries in sub-Saharan Africa: a multivariate non-linear decomposition modelling of demographic and health survey data. BMC Pregnancy and Childbirth 2022;22(1). https://doi.org/10.1186/s12884-022-04992-6

29. Aziz A, Akram K, Haq M, Hawaldar I, Rabbani M. Examining the role of clean drinking water plants in mitigating drinking water-induced morbidity. Sustainability 2022;14(15):9644. https://doi.org/10.3390/su14159644

30. Peguero A, Varela K, Marchbanks M, Blake J, Eason J. School punishment and education: racial/ethnic disparities with grade retention and the role of urbanicity. Urban Education 2018;56(2):228-260. https://doi.org/10.1177/0042085918801433