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Theme:

**The Control and Elimination of Preventive
Chemotherapy Neglected Tropical Diseases
(PC/NTDs) in Nigeria: Strategy for meeting the
WHO 2030 Elimination goals**

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Feasibility of Helminth Worm Burden as a Marker for Assessing the Impact and Success of Water, Sanitation, and Hygiene Interventions (WASH) for the Control of Neglected Tropical Diseases

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Abstract

The Neglected Tropical Diseases (NTDs), most notably, helminthiasis thrives in tropical settings, where access to improved sanitation, potable water source, and personal and domestic hygiene facilities are limited or lacking. Ensuring increased and adequate access to improved Water, Sanitation and Hygiene (WASH) facilities has been flagged as a complementary tool for ongoing control and elimination efforts. However, evidence demonstrating the impacts of WASH investments on NTDs is scanty. Available integrated database on WASH and NTDs are collected using different tools at varying spatial scales, and in most cases without georeferencing details. These datasets are thus misaligned, making it difficult for geostatistical and modelling analysis that are useful for impact assessments. Therefore, our review suggests; (1) adequate georeferencing of WASH and NTDs sector data, (2) revision and standardization of data collection tools on access and usage of WASH resources, and incorporation of indicators aimed at assessing the risk of helminthiasis, and (3) including standardized WASH assessment questionnaires in epidemiological surveys on helminthiasis. We propose the collection of WASH-NTDs data at the same spatial resolution favors robust geostatistical analysis, making it possible to evaluate and monitor the impact of WASH investments on helminthiasis burden.

Keywords: Water, Sanitation, Hygiene, Interventions, NTDs, Helminth, Feasibility, worm burden, marker, Impacts

Introduction

Endorsed by the United Nations General Assembly in 1980, initiatives focusing on providing access to water and sanitation facilities have gained momentum, primarily targeting the enhancement of

health and well-being within marginalized communities [1]. Efforts to enhance water, sanitation, and hygiene (WASH) conditions in low- and middle-income countries (LMICs) are directed towards promoting fair access to clean water and sufficient sanitation, especially at the household

level. Additionally, these initiatives aim to enhance hygiene education among residents in underserved rural and urban areas [2]. The standards for evaluating WASH intervention performance have been proposed over a decade ago, with emphasis on adequacy, quality, equitable access, and coverage [3]. Importantly, a substantial body of research has highlighted various indirect impacts of WASH interventions on public health, specifically in reducing the prevalence of diarrhea, intestinal protozoan infections such as entamebiasis and giardiasis, as well as Neglected Tropical Diseases (NTDs), including dracunculiasis (Guinea worm disease), schistosomiasis, soil-transmitted helminthiasis, and trachoma [4-16]. [Table 1].

Helminthiasis, a Neglected Tropical Disease (NTD), poses one of the most extensive health threats among these conditions and has particularly detrimental effects on the physical and cognitive development of children. Alarmingly, over five billion individuals are susceptible to contracting infections caused by nematodes, such as *Ascaris lumbricoides*, hookworm, and *Trichuris trichiura*, which are commonly known as soil-transmitted helminths. Moreover, at present, over a billion people are afflicted by these infections [17]. Social-ecological systems govern the transmission of soil-transmitted helminths and other neglected helminth infections; particularly poor sanitation, and inadequate personal and domestic hygiene coupled with unsuitable environments [18, 19]. Put simply, any infected member of a community who engages in open defecation is a potential carrier/source of infection. Parasitic worms can be further transmitted either actively (through penetration of infective larvae, such as in the case of hookworms) or passively (through ingestion of helminth eggs/larva on contaminated food and water) to other community members, especially in areas where WASH practices and facilities are inadequate or entirely lacking.

The provision of improved WASH resources has been posited as a necessary step towards interrupting the cycle of disease transmission [20]. However, access to such resources without adhering to strict hygiene standards and sustainable usage may yield limited intervention effect [20]. Summarily, access to, and usage of a well-maintained community and household-based water sources could lead to improved hygiene and decreased ingestion of helminth ova that exist in the environment, while the provision and usage of improved sanitary facilities

will prevent helminth ova from reaching the soil via faeces [1]. In addition, good personal hygiene at critical times (e.g., handwashing with soap after defecation and before food consumption, wearing of footwear) and domestic hygiene (protection of drinking water) are key messages in any hygiene education program directed at the control of human helminthiasis and are primarily achievable when there are accessible sources of safe and adequate water supply resources [21-23]. Hence, the links between WASH and helminthiasis are intertwined. However, prior assessments of WASH interventions on human health have rarely considered the inclusion of helminthiasis as a disease of priority, unlike diarrhoea.

Therefore, we recommend that efforts targeted at determining the impacts of WASH interventions on human health should include an assessment of the burden of helminthiasis in communities, especially with the growing recognition that a significant reduction in the burden of helminthiasis can be achieved if WASH interventions are tailored to specific settings and sustained over time [8-12]. Moreover, the value of WASH interventions would be better appreciated if implemented in the context of preventing, gaining, and sustaining the control of helminthiasis with the ultimate aim of interrupting transmission. Consequently, the implementation of Water, Sanitation, and Hygiene (WASH) interventions could serve as a supplementary approach to preventive chemotherapy. These strategies involve periodic, large-scale distribution of anthelmintic drugs to populations at risk, without the need for prior individual diagnoses. By doing so, WASH interventions can help reduce both the financial burden and the frequency of annual treatments with anthelmintic drugs, such as albendazole, ivermectin, mebendazole, and praziquantel.

Barriers Limiting Uptake of WASH Interventions In NTD Control

Despite the promising health benefits of WASH interventions, there are several barriers to their uptake in the health sector. First, WASH interventions are strictly bound within the environmental and water sectors, whose primary focus is to ensure an accessible and equitable supply of WASH resources [8]. The challenges of engaging partners and ministries with different priorities have been acknowledged in various public health initiatives, including those addressing health equity,

non-communicable disease prevention, tobacco control, and environmental health [25-28]. As early as 2010 and 2012, experts from diverse sectors emphasized the numerous opportunities for collaboration in interventions targeting multiple diseases and involving various sectors to prevent and control Neglected Tropical Diseases (NTDs) [8, 29]. Therefore, it is crucial to promote ongoing communication between sectors and foster willingness to address issues beyond the immediate concerns of each sector when identifying and executing joint initiatives [30].

Second, there is a lack of rigorous experimental evidence of the precise impact of existing WASH components (water, sanitation, or hygiene) on helminth infections [8,10,12], which is required for enhanced multi-sectoral cooperation. Nevertheless, given the current synergy needed between the environment, water, and health sectors, there is a need for these sectors to work more closely together and develop common tools to evaluate and measure the success of their interventions [8]. The tools that have been developed can contribute significantly to the ongoing dialogue regarding the implementation of Goal 3.3 of the Sustainable Development Goals (SDGs), which aims to "end the epidemics of HIV, tuberculosis, malaria, and neglected tropical diseases" by 2030 [31].

Furthermore, there is growing recognition of the necessity for standardized indicators and tools to gather and analyse high-quality data related to both Water, Sanitation, and Hygiene (WASH) and Neglected Tropical Diseases (NTDs) [32]. However, some key questions remain: What kinds of tools need to be developed? What indicators should be considered? How can the burden of helminthiasis be captured using existing tools to measure the success and impact of WASH interventions for helminthiasis?

Integrating WASH and NTDs Data for Disease Control

We conjecture that the extraction of helminth infection prevalence data from readily available sources, such as the Global Neglected Tropical Diseases (GNTD) database (<http://www.gntd.org>) [33] and the Global Atlas of Helminth Infections (GAHI; <http://www.thiswormyworld.org>) [34], linked with available WASH intervention data from the USAID Demographic and Health Survey (DHS; <http://www.dhsprogram.com/>) and UNICEF

Multiple Indicator Cluster Survey (MICS; <http://mics.unicef.org/>) to investigate the impact of WASH sector activities in helminthiasis-profiled areas is feasible (Figure 1). These two databases can be utilized for spatially explicit disease risk/WASH resource profiling and predictive mapping, which provides an estimate of uncertainty [35-37]. However, as promising as this idea may appear, prediction uncertainty may mask the relationship between WASH and helminthiasis because both databases contain location-specific data generated at different spatial scales and times [38,39].

Furthermore, data on WASH sector activities are usually classified and poorly georeferenced. Thus far, very few large-scale (i.e., national) surveys have collected geo-referenced helminthiasis and WASH data at the household level. Because of this caveat, the available geostatistical analyses are only able to relate aggregated helminthiasis risk and WASH indicators at the cluster level in the models. To overcome this incompatibility of the WASH and helminthiasis databases for geostatistical analysis, we propose the need to develop databases that permit the collection of both helminthiasis risk and WASH indicators at the same spatial and temporal scale/time either at the household and/or community levels concurrently for any geostatistical investigation.

Given the potential synergy between the WASH and NTD in developing tools to evaluate and measure the success of different interventions [8], we propose that standardized national survey tools, such as the DHS or MICS, consider incorporating a specific WASH and helminthiasis module (Supplementary File 1). Currently, the Water, Sanitation, and Hygiene (WASH) sector relies on various survey sources to gather information for policy development, program planning, and implementation. These sources include national censuses, Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS), and child labour surveys, among others [40]. Among these sources, DHS is often preferred because it offers an up-to-date household-level data collection method that helps policymakers and program managers design and monitor health and family planning programs [40]. The DHS employs model questionnaires developed by the MEASURE DHS program, which can be adapted to a country's specific requirements through collaboration with government agencies, ministries, NGOs, and international donors [40]. These questionnaires included the household questionnaire, women's questionnaire, and man's

questionnaire, covering socioeconomic status, water and sanitation resources, fertility preferences, family planning, HIV/AIDS awareness, female genital mutilation, domestic violence, and more for women aged 15-49 years and children under five years old [40]. The DHS also provides estimates of key indicators for both rural and urban populations.

The current Water, Sanitation, and Hygiene (WASH) indicators included in the Demographic and Health Surveys (DHS) primarily focus on (i) the type of water source and (ii) the presence and type of toilet facilities in households along with their proximity to the household [40]. Although these indicators provide valuable information, they are not comprehensive enough to assess WASH resource utilization and its impact on controlling helminthiasis. Essential indicators, such as the conditions, adequacy and usage of water sources and toilet facilities are currently absent from the DHS database [3]. Including these additional indicators is necessary to enhance the capacity of DHS to comprehensively assess and address WASH-related issues.

In this opinion piece, we suggest a new collection tool for WASH and helminthiasis data to address the gaps in information related to coverage, accessibility, and conditions of Water, Sanitation, and Hygiene (WASH) resources at the community and household levels (see Supplementary File 1). We propose that the head of household is the most suitable respondent for these questions. However, it is important to note that a trained interviewer conducting the survey should also visually inspect certain water supply and toilet resources before finalizing the interview. These WASH-related questions can be integrated into the existing DHS survey tool to enhance the comprehensiveness of the data collection.

Helminthiasis-specific Questionnaire As A Rapid Burden Marker

The importance of rapid assessment tools, such as symptomatology questionnaires, for community diagnosis of urogenital schistosomiasis, river blindness, eye worm and lymphatic filariasis is not uncommon [41]. However, common intestinal helminths such as *Ascaris lumbricoides*, hookworm, and *Trichuris trichiura* do not have visible specific and sensitive symptoms like blood in the urine for urogenital schistosomiasis, migrating eye worm for *Loa loa*, nodules for *Onchocerca volvulus*, or hydrocele for advanced lymphatic filariasis, to

mention a few. Therefore, we propose the inclusion of a helminthiasis-specific questionnaire to assess disease burden. The outcome of using such a tool can be further verified by parasitological examination of stool specimens to determine the prevalence and intensity levels in surveyed communities. Assessing the disease burden, especially for helminthiasis, using our proposed strategy might be indirectly impossible or more so, affected by recall bias. Nevertheless, potential risk factors for helminth infections, mostly in the form of poor WASH resources, can provide insights high odds of infection areas with collection and laboratory assessment of stool specimens.

Taking these factors into account, we recommend the incorporation of questions that center on behavioral risk factors and individuals' history of helminth infections within the six months leading up to the interview, including any previous deworming activities. Gathering information related to risk factors, rather than focusing solely on infection rates or disease burden, has greater relevance for policymaking. This approach enables more direct targeting of interventions to modify and reduce the exposure to these risk factors. [42]. Supplementary File 1 shows the helminthiasis-related questions proposed to be included in the DHS and a guide on how to administer a questionnaire by trained interviewers to all consenting members of a household. These additional questions could then be pilot-tested before conducting a national DHS survey. Data obtained from this pilot study might provide useful real-time insights into the WASH profile, helminthiasis history, and behavioural risk factors of the surveyed communities.

As we proposed the inclusion of a few specific questions for rapid WASH and helminthiasis assessments in future DHS, it is also necessary that planned and future surveys for helminthiasis burden using parasitological methods should also incorporate a WASH-specific questionnaire. For example, Transmission Assessment Surveys (TAS) are currently underway to determine whether mass drug administration should be halted as part of the global lymphatic filariasis elimination program [43].

Conclusions

Our opinion paper proposes a unified strategy for evaluating the impact of WASH investments on helminthiasis burden, and *vice versa*. Our study aimed to promote the collection of appropriately

georeferenced WASH and helminth data using revised and standardized tools for possible geostatistical and modelling analyses. We propose the inclusion of well-thought-through questions about helminthiasis and WASH in future DHS. The incorporation of helminthiasis burden among other indicators provides an opportunity to evaluate the progress and impact of WASH interventions on health outcomes, specifically helminthiasis burden. Supporting the consideration of our proposed approach in future intersectoral deliberations would be an important leap toward managing WASH resources while combating helminthiasis.

Abbreviations

WASH: Water, Sanitation, and Hygiene
 NTDs: Neglected Tropical Diseases
 DHS: Demographic Health Surveys

LMICs: Low-Middle Income Countries
 SDGs: Sustainable Development Goals
 GNTD: Global Neglected Tropical Disease
 GAHI: Global Atlas of Helminth Infections
 MICS: Multiple Indicator Cluster Surveys
 NGOs: Non-Governmental Organizations
 TAS: Transmission Assessment Surveys

Declarations

Ethical Approval and Consent to Participate
 Not Applicable

Consent for Publication

Not Applicable

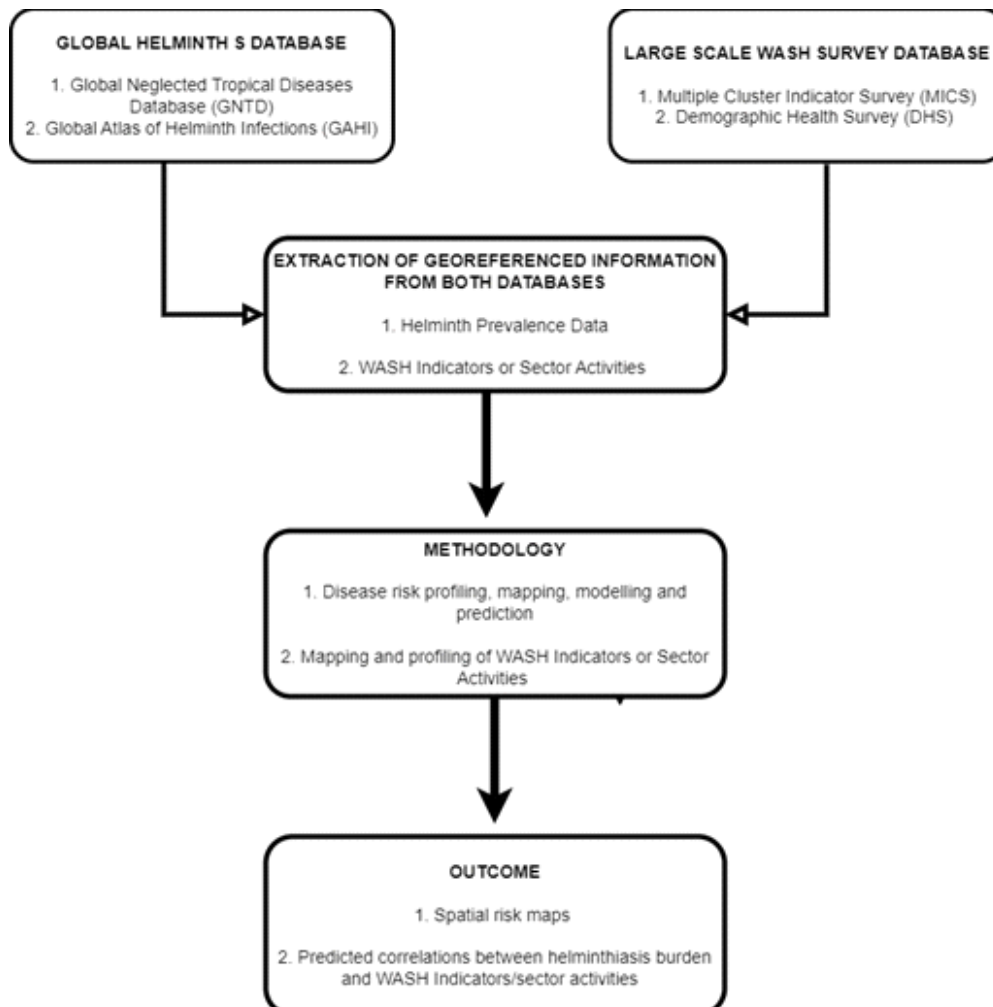
Availability of Data and Materials

Not Applicable

Competing Interest

Figure caption

Figure 1. Proposed flowchart for the use of helminthiasis burden in measuring the success and impacts of water, sanitation, and hygiene (WASH) interventions in endemic communities



The authors declare that they have no competing interests.

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Authors' Contributions

UFE conceptualized this idea. HMO wrote the first

draft of this manuscript. UFE, and HMO, contributed to the development of the manuscript. All authors have read and approved the final manuscript.

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Tables

Table 1: Abridged list of studies showing how WASH interventions impact intestinal protozoa and helminth infections

Title of article	Study design	Findings	Reference Number
Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma	Meta-analysis	Water for personal and domestic hygiene was important in reducing rates of ascariasis, diarrhoea, schistosomiasis and trachoma. Sanitation facilities decreased diarrhoea morbidity and mortality and the severity of hookworm infection	1
The impact of a school-based hygiene, water quality, and sanitation intervention on soil-transmitted helminth reinfection: a cluster-randomized trial	Cluster randomized trial	The impact of the intervention was found to be significant in <i>Ascaris lumbricoides</i> reduction, while no significant impact was found on <i>Trichuris trichiura</i> and hookworm reinfection.	10
Impact of health education on soil-transmitted helminth infection in school children of the Peruvian Amazon: A cluster-randomized trial	Cluster randomized trial	A school-based health hygiene education intervention was effective in increasing STH knowledge and reducing <i>Ascaris lumbricoides</i> infection	11
Effect of sanitation on soil-transmitted helminth infections: A systematic review and meta-analysis	Systematic review and meta-analysis	Availability of sanitation facilities was associated with significant protection against infection with soil-transmitted helminths	12
Water, Sanitation and Hygiene and Soil-transmitted Infection: A systematic review and Meta-analysis	Systematic review and meta-analysis	Water, Sanitation and Hygiene access and practices are associated with reduced odds of STH infection	13
Effect of Sanitation and Water Treatment on intestinal protozoa infection: A systematic review and Meta-analysis	Systematic review and meta-analysis	Availability and use of sanitation facilities and water treatment are associated with lower odds of intestinal protozoa infections	15
Efficacy of Handwashing with Soap and Nail Clipping on Intestinal Parasitic Infections in School-Aged Children: A Factorial Cluster Randomized Controlled Trial	Factorial Cluster Randomized Controlled Trial	Handwashing with soap at critical times and weekly nail clipping significantly decreased intestinal parasite reinfection rates	16

Supplementary File 1**Module 1: Proposed Indicators for WASH assessment module in DHS Guide:**

Questionnaire 1 is to be administered to the head of the household by a trained interviewer. The interviewer needs to observe for some WASH resources particularly those with questions tagged with "report as seen."

Proposed Indicators for the WASH Assessment Module in DHS**Referencing details:**

Country: Region: State:
 Community: Household number:
 Latitude: Longitude: Altitude:

 Name of Household Head:..... Gender Age:
 Number of inhabitants: Number of wives: Number of children:

Water Conditions

- **1. Type of water source** (a) Public tap
 (b) stream/river
 (c) Hand pump borehole
 (d) Protected dug well
 (e) Unprotected dug well
 (f) rainwater
 (g) others (specify)
- 2. How many times do you get water**
 (a) daily (b) twice a week (c) others (specify)
- 3. What do you get this water for (tick applicable options);**
 (a) Drinking (b) Cooking (c) Washing (d) Others
- 4. Condition of water supply (Report as observed, is it functioning or abandoned?)**
- 5. Estimated time taken from home to the water source** (a) 5-10 min (b) 11-20 min (c) 21min-1hour (d) more than 1 hour
- 6. Has your ward ever complained about going to the source before** (a) yes (b) no
- 7. If yes, why?**

Toilet types and conditions****1. Types of toilet facility**

- (a) Flush/Pour Flush Toilet (indicate type)
 (b) Ventilated Improved pit
 (c) Pit latrine without a slab
 (d) Pit latrine with slab (e) open defecation in a nearby bush (f) others
- 2. How many toilets do you have in your house (report as seen).....**
- 3. Presence of gender-segregated toilets** (a) yes (b) no
- 4. Condition of toilets (Report as observed):** (a) clean (no faeces around hole/no flies/ no smell)

(b) dirty (faeces around hole/flies/smell) (c) presence of lid (d) absence of lid

5. Usage of toilet (Report as observed): (a) in use (b) abandoned

Hygiene component

1. Handwashing facilities in toilets, if yes what type (report as seen):
2. Do you wash your hands after using the toilets (a) yes (b) no
3. If yes, with what (a) water (b) water and soap (c) ash
4. Soaps in toilets (Report as observed, if yes what type):
5. Presence of domestic animals as pets (Report as observed, if yes what kind).....
6. Presence of refuse dumping site around household premises (Report as observed, if yes estimate the distance and provide information on the kind of refuse on the dumping site)
7. Have you received any health education message before at home/community (a) yes (b) no
8. Have you received any health education messages on radio or TV before (a) yes (b) no

WASH Inclusiveness:

1. Any disabled person in the household?
2. If yes, who (give number and type of impairment)?
3. Is there an inclusive WASH resource for this person in the household? Describe if yes.

****EXISTING WASH INDICATORS IN DHS**

Module 2: Proposed Indicators for helminthiasis assessment module in DHS

Guide: Questionnaire 2 is to be administered by a trained interviewer to consenting members of the visited household.

Proposed Indicators for Helminthiasis Assessment Module in DHS

Referencing details:

Country:	Region:	State:
Community:	Household number:	
Latitude:	Longitude:	Altitude:

 Name of Household Head:..... Gender..... Age:
 Name of Respondent: Gender..... Age:

Disease History

1. Have you ever seen blood in your stool before (if yes, when)?
 2. Have you ever seen mucus in your stool before (if yes, when)?
 3. Have you ever excreted worms in your stool before (if yes, when)?
 4. Have you ever experienced rectal prolapse before (if yes, when)a?
 5. Have you ever experienced blood in your urine before (if yes, when)?
 6. Do you have any enlarged or swollen stomach (if yes, when)?
 7. Do you experience regular stomach upset/disorders (if yes, when)?
 8. Have you used a deworming tablet in the last 3-6 months (if yes, when and which type)?
- a: rectal prolapse described as protrusion of the last part of the intestine through the anus
-

Behavioural risk factors

1. Do you practice finger-sucking (Yes/No)?
2. Do you bite nails (Yes/No)?
3. Do you pick food or objects from the ground (Yes/No)?
4. Do you trim your fingernails regularly (Report as observed) (Yes/No)?
5. Do you use your footwear regularly (Yes/No)?
6. Do you practice open defecation (Yes/No)?
7. *What materials do you use for anal cleaning after using the toilet: (Please specify).....

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