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Home Treatment of Drinking Water in the Peri-Urban Environment of Bumba: Study Protocol

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Summary

Introduction: Consumption of unsafe water is the cause of many diseases, leading to significant morbidity and mortality, particularly among children under five years of age. This situation represents a considerable burden for humanity. Household water treatment appears to be a practical and effective solution to ensure water security for populations, while reducing contamination and microbiological risks in communities without reliable access to safe drinking water. This article presents a study protocol aimed at assessing household drinking water treatment practices and identifying factors associated with these methods in the peri-urban environment of Bumba, Democratic Republic of Congo.

Material and method: A cross-sectional study with analytical aim will be carried out among 422 households during a period from July 1 to November 30, 2023. The data will be collected on the basis of an administered questionnaire and an observation guide. The frequencies and odds ratios (OR) and their 95% confidence interval will be estimated, then the logistic regression by stepwise descending approach will be calculated to analyze the influencing factors.

Expected results: Expected outcomes include a better understanding of households' practices and knowledge regarding drinking water, as well as the determining factors for their treatment behavior.

Conclusion: The findings of this study will highlight the role of knowledge and perceptions in the adoption of water treatment practices, thus contributing to the Sustainable Development Goals for 2030.

Keywords: Treatment; drinking water; peri-urban environment; Bumba

Introduction

Water is a vital resource for human beings, playing a crucial role in health and economic development and the stability of societies [1]. Recognized as a fundamental human right by the United Nations since 2010 [2], access to quality drinking water remains a major global challenge [1, 2]. According to the World Health Organization (WHO) and UNICEF, approximately 2.2 billion people lack access to safe drinking water services, putting them at increased risk of diseases such as diarrhea, cholera and dysentery [3]. This situation is particularly worrying in developing countries, where water supply and sanitation infrastructure is often inadequate, increasing morbidity and mortality, particularly among children under five years of age [4].

In addition to these health challenges, climate change exacerbates global water shortages. The Intergovernmental Panel on Climate Change (IPCC) is warns of impacts of prolonged droughts, floods and other extreme weather events on water supplies [5]. For example, in India, overexploitation of groundwater, combined with droughts, has created a water crisis in several states, requiring emergency interventions [6]. Sustainable solutions include integrated water resources management (IWRM), investment in climate-resilient infrastructure [7] and cross-border cooperation to manage shared basins [8].

In terms of public health, Consumption of unsafe water causes diseases such as cholera, schistosomiasis, typhoid fever, polio, and severe diarrhea. responsible for many deaths each year [9]. According to WHO, approximately 1.5 million deaths annually,, of which more than half(842,000)can be attributed to contaminated water consumption, lack of sanitation and poor hygiene [10].

Of these deaths, approximately 361,000 involved children under five years old [9], while water is a precious natural resource and a necessary element for life on earth [11], and must be drunk without risk to health, free from pathogenic germs (bacteria, viruses) and parasitic organisms, and have a good smell and taste [12]. According to the Global Burden of Disease Study, the health impacts of contaminated water are particularly severe in sub-Saharan Africa and Southeast Asia [13]. These effects extend beyond health, impacting education, food security and economic stability in vulnerable communities [14, 15].

Regional disparities in access to drinking water are influenced by several factors: poverty, rapid population growth, unplanned urbanization and the impacts of climate change. In Africa, for example, only 24% of the rural population benefits from safe drinking water services, compared to 58% in urban areas [16]. Limited infrastructure leaves households dependent on unprotected sources, exposing them to risks of microbial and chemical contamination [17]. Women and children are particularly affected, with their responsibility for collecting water limiting their access to education and economic opportunities [18].

Furthermore, global statistics show that consumption of untreated water is responsible for nearly 1.8 million deaths annually, 99.8% of which occur in developing countries. Of these deaths, more than 90% are children under five, a particularly vulnerable population [1]. However, access to quality drinking water is a key factor in reducing this infant mortality. It has been proven that improving the quality of domestic water can reduce diarrheal diseases by 15% [19]. Therefore, improving the quality of drinking water can prevent and control waterborne diseases, as safe drinking water is necessary for all normal household uses, including drinking, food preparation and personal hygiene [15].

Faced with these challenges, domestic water treatment appears to be a practical and effective solution for populations without access to safe drinking water. Techniques such as boiling, chlorination, ceramic filtration and solar disinfection (SODIS) are widely used, although they are often limited by economic and cultural constraints. These different methods, when adopted correctly, can considerably improve the quality of domestic water, and considerably reduce the risks of waterborne diseases.in developing countries [20].

A meta-analysis by Clasen et al. (2007) showed that household water treatment can reduce the incidence of diarrheal diseases by 30-40% [21]. Furthermore, studies show that using chlorine solution can reduce diarrheal diseases by 29% [22]. However, the adoption of these practices remains hampered by economic, cultural and educational factors [20, 24].

In sub-Saharan Africa, the situation is particularly critical. The United Nations Development Programme (UNDP) points out that the majority of households rely on unprotected sources, such as rivers and unsecured wells [25]. About 40% of households do not have access to safe drinking water, increasing their vulnerability to waterborne diseases [26]. This reality is exacerbated by inequalities in access to water infrastructure, making household intervention essential. A study by Berihun et al. (2023) found that households in rural Ethiopia that used household water treatment methods, such as boiling and filtration, were able to significantly reduce the risk of waterborne diseases [27].

Similarly, the data of the Ethiopian Demographic and Health Survey (DHS) had revealed that 18% of households treated their water adequately before consumption [28], through simple but effective processes such as boiling, filtration and chlorination, all of which are part of the method, capable of contributing to significantly reducing the incidence of waterborne diseases [29]. However, peri-urban areas, face unique challenges in accessing safe drinking water, where unimproved water sources, such as unprotected wells, poorly maintained rainwater tanks or polluted rivers, are often the only options available to peri-urban populations. This leads to increased risks of waterborne diseases, such as cholera, typhoid and dysentery [9].

Recognizing the crucial importance of drinking water, the United Nations integrated this issue into the Sustainable Development Goals (SDGs), adopted in 2015. Global efforts to improve access to safe drinking water include Sustainable Development Goal 6 (SDG 6), which aims for universal access by 2030.This goal reflects a global awareness of the need to secure access to water to guarantee the health and well-being of populations, an ambition that requires increased investment in infrastructure and community outreach [1]. In addition, the Programmes such as UNICEF's WASH initiative are implementing actions to provide safe drinking water to vulnerable communities. However, challenges related to financing, governance and cross-border cooperation persist, requiring increased investment and coordinated efforts to achieve this goal [30-32].

In the Democratic Republic of Congo (DRC), despite the abundance of water resources, drinking water infrastructure remains insufficient, and the quality of drinking water remains a concern, particularly in rural and peri-urban areas, where populations are often faced with unimproved water sources, while consuming untreated water, thus increasing the risk of water-borne diseases, including About 88% of these diseases are caused by the use of unsafe water, due to insufficient sanitation and hygiene systems [25]. In 2018, the National Institute of Statistics (INS), through the MICS-Palu survey results, revealed that 71% of households used unimproved water sources in peri-urban and rural areas, including 98.3% did not use any of the main methods of treating water at home to make it safer to drink [33].

In Bumba, a territory in the province of Mongala, the situation is also worrying. The results of the MICS-Palu 2018 survey also concluded that 98.9% of households in Mongala Province do not apply any of the methods of water treatment at home [33]. Similarly, a study conducted in 2018by LINANGELO revealed that 86% of households in Bumba do not treat their water before consumption, increasing the risk of contamination by pathogens [34].

This situation sufficiently proves that unfavorable knowledge in the field of drinking water treatment can be at the origin of the possible causes of health risks due to the consumption of untreated water. On the other hand, the water quality problems in the peri-urban environment of Bumba are explained by the lack of coverage by the drinking water distribution network, the non-treatment of drinking water by the majority of its population, the powerlessness of public authorities, the lack of awareness and integration of programs water and health, and also poor hygiene and sanitation practices.

This article is a research protocol aimed at evaluating different practices for treating drinking water at home and identifying the factors associated with these methods in the study environment.

Conceptual framework

The conceptual framework of our study illustrates in detail the process of household drinking water treatment within a community, highlighting critical steps, treatment practices, influencing factors, and public health consequences. The chain begins with the source and collection of water, which relies on various water sources such as rainwater, rivers, traditional wells, and boreholes. These sources are the initial supply points that supply the community. To make this water accessible to the household, a collection system must be put in place, using containers such as jerry cans and drums to facilitate transfer. This collection system must be accompanied by transportation by adult household members, using rudimentary means such as bicycles and wheelbarrows. Transportation is used to bring the collected water to the homes for temporary storage in collection containers, such as buckets with taps and jerry cans with lids, which provide some protection against contamination.

However, for water to be truly safe to drink, it must undergo treatment at home. Several treatment methods are available, including solar disinfection, chlorination, filtration, and boiling. This purification process is crucial to eliminate pathogens and reduce health risks associated with unsafe water. Despite this, many households do not treat water for multiple reasons: ignorance of the risks associated with untreated water, lack of access to necessary products, low education, and poverty are significant barriers to the adoption of these treatment practices. Factors influencing drinking water quality and treatment include abiotic, cognitive, and socio-demographic factors, such as risk perception and knowledge of treatment techniques. These factors shape community behaviors regarding water management. The consequences of poorly treated water are severe for public health: high morbidity and mortality.

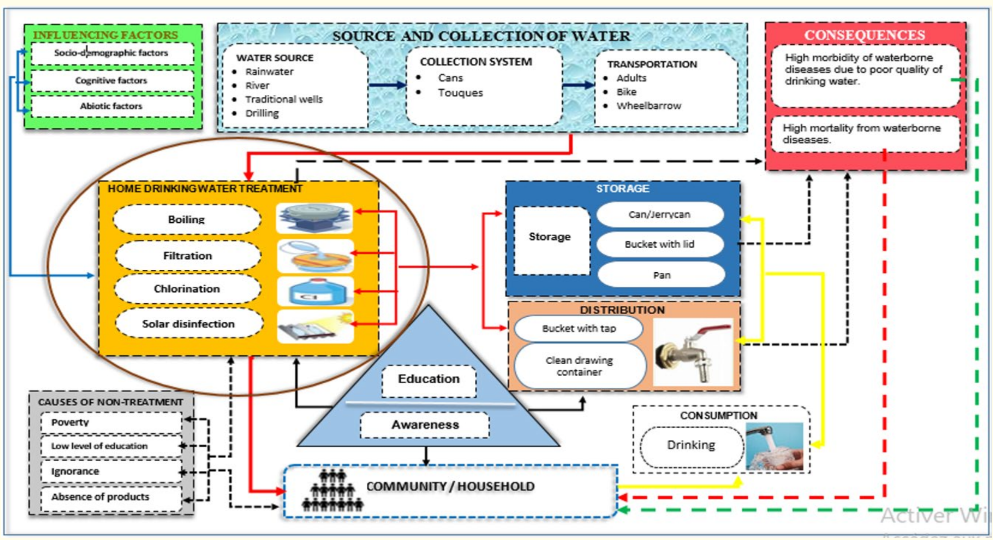

Figure 1: The conceptual framework.

Materials and Methods

Study framework

The city of Bumba will serve as the setting for this study. Bumba is one of three territories and entities located within the administrative limits of the Mongala Province, in the part North of the Democratic Republic of Congo(DRC). It is a communication center, whose majority of the population comes from rural and peri-urban areas, and is dedicated to the exploitation of agriculture for its survival. The hydrography of Bumba is associated with the middle Congo, where the Molua River, the Monama River and the streams: Ndongo, Orap, Lingode, Kano and Mabaya are mainly sources of water supply in the vast majority of the population.

Bumba was selected based on geographical distribution criteria (peri-urban environment and land territory) and source of drinking water supply because the majority of the population gets their water from unimproved sources. The unique challenges justifying the selection of this study setting were that in this environment, the urban part is covered by the water distribution authority "REGIDESO", while the peri-urban environment does not have a drinking water coverage program. These important criteria were taken into account in the selection of households to be surveyed because they can highlight the problem of home treatment of drinking water in the peri-urban environment of Bumba, while having a scientific look at the overall knowledge of households on drinking water, on practices in terms of treatment and management of water at home and also on the factors influencing this practice at home.

In sum, the selection of Bumba reflects a strategic interest in understanding and improving water treatment practices in a peri-urban setting where challenges are exacerbated by lack of infrastructure, socio-economic disparities and lack of regular access to drinking water.

This study will be carried out in households in the avenues of the peri-urban Health Areas of the Bumba Health Zone. This health zone is subdivided into 16 Health Areas (AS), a General Reference Hospital (HGR), 2 Reference Health Centers (CSR) and health posts (PS), where it is located 1,337 km from the capital of the DRC by river and air.

Population under study

It will consist of all heads of households or adults living in households in the avenues of the peri-urban health areas of the Bumba Health Zone.

Inclusion and non-inclusion criteria

Included in this study will be: all heads of households or adults living on the avenues of the selected health areas, present on the day of data collection and available to answer our questionnaire. Any heads of households or adults who do not meet these inclusion criteria will simply be excluded from the study.

Type and period of study

A cross-sectional study with analytical aims will be conducted among 422 households over a period from 1 July to November 30, 2023 in the selected peri-urban health areas of the Bumba health zone (LOKELE MONGALA, MBINZA, BOPOTO, MANGONDO and GOZEN).

Sampling

The sample size will be calculated according to the LUNCH formula below:

$$n = \frac{Z_{1-\alpha/2}^{2} P(1-P)}{d^2}$$

There the proportion of the population treating drinking water at home would be estimated at 50% since it remains unknown in our study environment; with the coefficient Z = 1.96, the degree of error of 0.05 and an anticipated non-response rate of 10%. Our sample size would be 422 households.

These households would be distributed proportionally in the 5 peri-urban Health Areas selected in a simple random manner. In each sampled Health Area, 5 avenues would be selected in a simple random way from the exhaustive list of the different avenues of these Health Area. A total of 25 avenues will be sampled.

Households will be selected at the avenue level by systematic sampling technique after the survey of housing units in each avenue and the calculation of the sampling step. The total number of households surveyed for the 25 avenues was 422. Eligible households were selected by proceeding in the following manner:

- Proportional distribution of 422 households in the 25 sampled avenues;
- Household selection by systematic sampling technique. After counting households in an avenue (N), the sampling interval (k) will be calculated by dividing the numbers of households in an avenue (N) by the size of households to be surveyed in that avenue (n); then, a random number between 1 and k will be drawn, which corresponded to the number of the first household surveyed. The other households will be identified by adding the sampling interval.

Data collection and analysis

Data will be collected using an administered questionnaire and observation guide to describe drinking water treatment and management practices in households.

The assessment of the level of knowledge of household heads on drinking water will focus on understanding of drinking water, treatment techniques, waterborne diseases and contamination factors. The level of knowledge will be classified as "poor" when there were less than six response items given, and "good" when seven or more response items are cited.

The collected data will be encoded on Excel and analyzed on STATA 13 software. All these variables will be taken in their dichotomous form. Qualitative variables will be presented in the form of proportions and quantitative variables in the form of mean ± standard deviation (SD) or median with the variation domains (P75-25) according to the application conditions.

Bivariate analysis of factors associated with household water treatment will be performed with the independent variables. To show the association between these variables and household drinking water treatment, Pearson Chi-Square at the 5% threshold and raw ORs will be calculated. All variables that show a significant association in bivariate will be aligned in a stepwise logistic regression model using a 10% downward approach. Adjusted ORs with CIs at the 95% threshold will be deducted at the 5% significance point (WALD p value).

The results of this study will be published in the form of a scientific article in scientific journals and the restitution of the conclusions and various recommendations will be made during the meetings of the Board of Directors and monitoring of the Bumba health zone, then the micro operational plans for corrective actions will be developed at the level of the health areas.

Ethical considerations

The objectives of the study and the methods of data collection will be clearly explained to participants, in order to enable their voluntary and informed participation.

All interview participants will provide informed consent by agreeing to be interviewed and to provide their opinions on the issues concerning our research. Participation in the study will be voluntary and will not entail any financial benefit.

Authorizations will be obtained from the ethics committee of the University of Kisangani, the dean of the Faculty of Medicine and Pharmacy, the political and administrative authorities of the Province of MONGALA, the health zone of Bumba and the Health Areas.

The anonymity of respondents will be guaranteed throughout the collection and dissemination of results. In the household database, no names will be recorded and even in the data collection guides.

Expected Results

The expected results of this study will be produced based on the following characteristics:

Sociodemographic characteristics of respondents

The description of the socio-demographic characteristics of the respondents (sex, marital status, level of education and profession) will be made using proportions, while the age, the number of persons and children aged 0 to 59 months in households will be described by the mean accompanied by the standard deviation or median accompanied by the interquartile range depending on whether the distribution is symmetrical or not.

Knowledge and attitude of household heads regarding water consumption

Description of the level of knowledge and attitude of respondents on the water consumed (Knowledge about drinking water, about techniques for treating drinking water at home, about waterborne diseases, about factors of contamination of water at home, assessment of the overall level of knowledge about drinking water, perception of investigated on the potability of drinking water drawn, attitude of investigated Faced with the need for home treatment of drinking water, the attitude of investigated on the quality of drinking water consumed, overall perception of investigated on the drinking quality of water drawn and consumed in households)will be evaluated using proportions.

Drinking water supply in households

The description of main source of drinking water supply and people loaded to go and draw water in the household will be analyzed using proportions. While that of the time taken by respondents to fetch drinking water will be done using of the mean accompanied by the standard deviation or median accompanied by the interquartile range depending on whether the distribution is symmetrical or asymmetrical.

Household drinking water treatment practices at home

The description of home treatment of drinking water, techniques used to treat it, reasons for non-treatment, assessment of the level of household practices in home treatment of drinking water will be made using proportions.

Management of drinking water in households

The description of the container used for storing drinking water in the household, household water collection techniques, the shelf life of drinking water, the frequency of cleaning drinking water storage containers and the level of drinking water management will be carried out using the proportions.

Factors associated with home drinking water treatment

The bivariate analysis of the factors associated with home water treatment will be done with the following independent variables: perception of the potability of the drawn drinking water, attitude towards the need for home treatment of drinking water, attitude on the quality of the consumed drinking water, perception of the potable quality of the water drawn and consumed in households, level of knowledge on drinking water and the main source of drinking water supply. All these variables will be dichotomized. The link between home treatment of drinking water and the explanatory variables of interest will be sought using Pearson's Chi-square. The strength of association will be estimated using the raw OR and the p value < 0.05.

To account for potential confounding factors, a 10% downward stepwise logistic regression model will be developed taking into account all explanatory variables significantly associated with home treatment of drinking water ($p < 0.05$). The adjusted ORs derived from the model with the CIs at the 95% threshold will be calculated as well as the p-value of the WALD Chi2 will be presented. These results will be explored in the tables and graphic summaries.

Conclusion

To conclude, this study focuses on the assessment of household water treatment practices in the peri-urban environment of Bumba, an area of critical importance for public health. The expected results will provide a better understanding of the behaviors, knowledge, and barriers that influence household water treatment. This in-depth understanding is essential to tailor public health interventions and programs to be more effective and relevant to the populations concerned.

By identifying the determining factors influencing these behaviors, the results could guide the development of targeted and adapted public policies aimed at strengthening access to safe drinking water for the most vulnerable populations. The adoption of these good practices, combined with awareness campaigns and investments in water management infrastructure, such as the implementation of community training programs, hygiene and sanitation education campaigns, and the improvement of the distribution of essential resources (e.g., chlorine, filters) in peri-urban households, will contribute to significantly reducing waterborne diseases.

By aligning with the Sustainable Development Goals for 2030, this research can also support SDG 6, which aims for universal access to safe drinking water and adequate sanitation by 2030.

Finally, the findings of this work will provide avenues for reflection for an integrated approach to public health, improving the quality of life and resilience of peri-urban communities in the face of challenges of access to drinking water, while providing a solid basis for closer collaboration between local authorities, civil society organizations, and international partners. By focusing on participatory and contextualized approaches, it will be possible to design sustainable solutions that take into account the socio-economic, cultural and environmental realities of the populations of Bumba. This will create a model of integrated water resources management, which could be replicated in other regions with similar challenges, while focusing on reducing inequalities in access to drinking water. This model will thus contribute tangibly to the promotion of public health and collective well-being, preventing thousands of avoidable deaths each year and guaranteeing a fundamental right: access to quality water.

However, a series of explicit recommendations for local interventions and community education are included in this research protocol on these different points:

Strengthening access to water treatment tools

- ✓ *Distribution of water treatment kits*: Provide equipment such as chlorine, and tools for solar disinfection. These kits should be subsidized or distributed free of charge to the most vulnerable households.
- ✓ *Creation of local distribution points*: Establish distribution points for water treatment tools and products in markets, health centers and schools to ensure accessibility and availability for all.

Improving water supply infrastructure

- ✓ *Strengthening improved water sources*: Invest in projects aimed at improving drinking water supply infrastructure such as boreholes, protected wells and water distribution networks.
- ✓ *Community management of infrastructure*: Establish local water management committees to oversee, maintain and improve existing infrastructure, while raising community funds for their sustainability.

Community Education Programs

- ✓ *Awareness and information sessions*: Regularly organize workshops and information sessions in health zones to educate communities on the dangers of consuming untreated water, effective treatment methods, and hygiene measures to adopt.
- ✓ *Participatory approaches*: Encourage active participation of community members in awareness campaigns. The involvement of local leaders, heads of households and women's associations will allow for better adoption of good practices.
- ✓ *Training of local educators*: Train community health workers, teachers and opinion leaders to become educators in water treatment, health and hygiene.

Support for hygiene promotion campaigns

- ✓ *Hand hygiene programs*: Integrate the importance of hand hygiene before handling drinking water into community awareness campaigns.
- ✓ *Promotion of sanitation*: Raise awareness of the links between hygiene, sanitation and drinking water consumption to reduce the

risks of contamination. This includes the construction and maintenance of latrines, the management of domestic waste, and the importance of maintaining water storage containers.

Regular monitoring and evaluation

- ✓ *Periodic surveys*: Conduct regular surveys to measure progress in the adoption of water treatment practices and the evolution of knowledge within households.
- ✓ *Community Feedback*: Establish mechanisms for community members to provide feedback on the effectiveness of interventions and suggest improvements.

Limitations of the Study

From this article protocol, here is an acknowledgement of the limitations of the study on home treatment of drinking water in the peri-urban environment of Bumba, taking into account potential biases and problems of generalization.

Sampling and representativeness

- *Sample limitation*: The study is based on a sample of 422 households in specific peri-urban health areas of Bumba. Although this size is significant for the local context, it may not faithfully represent the entire peri-urban or rural population of the Democratic Republic of Congo (DRC). This limits the generalizability of the results to other regions with different socio-economic or environmental characteristics.
- *Selection bias*: The systematic sampling technique used may introduce bias if certain categories of households are under-represented (e.g. households that are not available during survey visits).

Reporting bias and self-reporting

- *Social desirability bias*: Respondents may tend to report behaviors consistent with investigators' expectations or to exaggerate their level of knowledge and practice of water treatment to avoid any negative judgment.
- *Accuracy of answers*: Data accuracy depends on respondents' recall and comprehension, which can introduce memory errors or biased responses through misinterpretation of questions.

Cultural and socio-economic factors

- *Cultural influence*: Water-related perceptions and practices may be influenced by cultural or traditional factors specific to Bumba, which limits the generalizability of the results to other regions with different cultural contexts.
- *Economic variability*: Household economic capabilities may influence their adoption of water treatment technologies. The study results may not accurately reflect practices in higher or lower income populations.

Cross-sectional nature of the study

- *Temporality*: Since the study is cross-sectional, it only captures a snapshot of household behaviors and perceptions at the time of the survey. Seasonal variations or changes in access to water over time are not taken into account.
- *Absence of causality*: Given the nature of the study, it is difficult to demonstrate causal relationships between factors influencing water treatment practices and observed outcomes. The study provides only associations.

Unmeasured or confounding variables

- *Environmental factors*: The study may not take into account all environmental factors influencing water quality (e.g. contamination by local industries or specific climatic conditions) which may bias the assessment of the effectiveness of home treatment methods.
- *Influence of local infrastructure*: The absence or presence of improved water supply infrastructure in some areas may distort

results in terms of perceived needs for household treatment.

Bias related to data collection methods

- *Spot observation*: Observed or reported water treatment practices may not reflect typical household behavior outside the survey period, which could lead to bias in the data collected.
- *Quality of the tools used*: The accuracy and reliability of the questionnaires and observation guides used to collect data can influence the quality of the responses obtained, particularly if certain questions lack clarity.

These limitations highlight the need for further research to complement knowledge on water treatment in peri-urban contexts, while taking precautions to minimize bias and maximize the representativeness of the results. A longitudinal approach, the inclusion of broader cultural and environmental factors, and additional studies in other regions could strengthen the findings and guide more tailored interventions.

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