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Training in Water Chlorination to Prevent Diarrheal Diseases in Rural Communities of Mexico

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Abstract

This study addresses the crucial role of water chlorination training as a strategy to reduce the incidence of diarrheal diseases in rural communities, specifically in the health jurisdiction of Zacualtipán de Ángeles, Hidalgo, Mexico. The research employed a quasi-experimental design involving 200 households and 50 healthcare workers, divided into intervention and control groups. Participants in the intervention group underwent a structured training program focusing on water chlorination techniques, education on waterborne disease prevention, and monitoring practices. Data collection involved pre- and post-intervention surveys, water quality sampling, and diarrheal disease incidence monitoring. Statistical analysis showed a 40% reduction in diarrheal cases in the intervention group, with a significant improvement in technical knowledge and practical application of chlorination procedures. These findings highlight the effectiveness of community-based and participatory training interventions in enhancing public health outcomes in rural settings. The study also identifies challenges, such as limited resources and high staff turnover, that could hinder long-term sustainability. It concludes with a call for continuous training

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programs and accessible water monitoring systems to ensure consistent water quality. The research contributes to both theoretical discussions on public health education and practical frameworks for implementing low-cost, high-impact interventions in underserved communities.

Keywords: Chlorination; Rural health; Water treatment; Training; Diarrhea; Mexico

INTRODUCTION

Access to safe drinking water remains a persistent public health challenge in rural regions globally, including Mexico. According to the World Health Organization (2020), diarrheal diseases caused by contaminated water are among the leading causes of morbidity and mortality, particularly in children under five. In Mexico's rural sectors, including the jurisdiction of Zacualtipán de Ángeles, Hidalgo, waterborne diseases reflect systemic gaps in water treatment infrastructure and community health education (García-Pérez et al., 2021). Despite the recognized effectiveness of water chlorination in reducing microbial contamination (Hernández-Ramírez & Martínez-Sandoval, 2022), its application is often inconsistent due to limited technical knowledge and lack of structured training for healthcare and community personnel.

Responding to these gaps, this study evaluates the impact of a training program focused on water chlorination for both health personnel and local community members. Prior studies have shown positive outcomes in similar contexts—Hernández-Ramos et al. (2021) reported significant reductions in diarrheal cases following technical education in Peru and Kenya (Mwangi et al., 2021). However, in the Mexican context, particularly in Hidalgo, there is limited empirical data evaluating such interventions.

This research addresses that gap by assessing the effectiveness of an intensive, community-based chlorination training program. The study aims to demonstrate how structured capacity-building initiatives can significantly improve water quality, reduce disease burden, and empower rural populations through knowledge and health-related practices.

METHODS

Research Type

This study employed a quantitative research approach, designed to measure the effectiveness of a community-based training program on water chlorination and its impact on the incidence of diarrheal diseases. The quantitative method was selected due to its suitability for evaluating causal relationships and generating generalizable findings from structured data collection and statistical analysis (Creswell, 2014). As the objective was to evaluate changes in knowledge, practices, and health outcomes before and after the intervention, a quantitative framework allowed for precise measurement and comparison of variables across defined groups.

Research Design

A quasi-experimental design was adopted, involving two groups: an intervention group that received intensive training on water chlorination and a control group that did not. This design was appropriate given the ethical and logistical challenges of full randomization in community-based public health interventions. The use of a quasi-experimental approach enabled the researchers to observe real-world effects of the training while controlling for confounding variables (Moser & Kalton, 2020). Similar designs have been successfully applied in studies evaluating water sanitation and hygiene interventions in low-resource settings (Mwangi et al., 2021; Hernández-Ramos et al., 2021). The training program included theoretical sessions on waterborne disease prevention and practical demonstrations of chlorination techniques.

Population and Sampling Technique

The target population consisted of residents and health workers from the Jurisdiction of Zacualtipán de Ángeles, located in Hidalgo, Mexico—a rural region with high prevalence of waterborne diseases due to poor water quality. The sample was selected using a stratified sampling method, ensuring representation across different community sectors and health service areas. Stratification was based on geographic location, access to water sources, and prior exposure to sanitation programs. A total of 200 households and 50 healthcare workers were selected, equally divided between the intervention and control groups.

Eligibility criteria for participation included being a resident of the jurisdiction for at least one year, being responsible for household water treatment, or being actively involved in health service delivery. Prior studies have shown that stratified sampling enhances representativeness and reduces bias in community-based interventions (Sugiyono, 2019). Additionally, the sample size was calculated to ensure sufficient statistical power ($\alpha = 0.05$; power = 0.80) to detect significant differences in outcomes between groups.

Data Collection Instruments and Procedures

The data collection process was conducted in three phases: pre-intervention, intervention, and post-intervention. The following instruments were used:

Structured questionnaires: Designed to assess baseline and post-intervention knowledge, attitudes, and practices (KAP) regarding water chlorination and diarrheal disease prevention. The questionnaires were validated through a pilot test and reviewed for content validity by public health experts. Reliability was confirmed using Cronbach's alpha (α = 0.87).

Water quality sampling kits: Used to test for microbial contamination and residual chlorine levels. Water samples were collected from household storage containers and analyzed using standard microbiological methods as recommended by the World Health Organization (WHO, 2020).

Health monitoring logs: Used to track the incidence of diarrheal diseases in the target population over a three-month period before and after the intervention. Community health workers recorded self-reported and clinically confirmed cases of diarrhea on a weekly basis.

The training sessions were implemented over a period of three months, comprising weekly four-hour workshops facilitated by public health professionals with experience in rural sanitation. Each session included theoretical content (e.g., transmission of pathogens, chlorine dosage) and practical demonstrations using locally available materials. Participants received printed manuals and visual aids tailored to varying literacy levels. Active participation was encouraged through hands-on exercises and group discussions. Follow-up visits were conducted to support participants and verify the implementation of chlorination practices at home.

Data Analysis Techniques

The quantitative data were analyzed using both descriptive and inferential statistics. Descriptive statistics such as means, standard deviations, and frequency distributions were calculated to summarize sociodemographic characteristics and baseline KAP scores. To evaluate the effect of the training intervention, paired t-tests were used to compare pre- and post-intervention scores within groups, and independent t-tests were employed to assess differences between intervention and control groups. The chi-square test was applied to compare proportions of diarrheal incidence.

Furthermore, a logistic regression model was constructed to determine the relationship between water quality (as measured by residual chlorine levels) and diarrheal outcomes, controlling for potential confounders such as education level, income, and access to sanitation facilities. Statistical significance was set at $p < 0.05$, and all analyses were conducted using SPSS version 26.

In addition, effect sizes were calculated using Cohen's d to determine the magnitude of the intervention's impact. A value of 0.65 indicated a moderate to large effect, suggesting meaningful improvements attributable to the training. These findings provide robust evidence supporting the efficacy of targeted chlorination education programs in resource-limited rural settings.

The entire research process—from instrument development to final data analysis—was conducted between January and June 2024, with full compliance to ethical standards and informed consent obtained from all participants. This rigorous methodological framework ensures the reliability and validity of the findings, offering practical insights for health policy and community-based water management initiatives.

RESULTS

Physicochemical parameters

The evaluation of physicochemical parameters of water before and after chlorination revealed significant changes in critical quality indicators. The water samples obtained from the three sampling points—before chlorination (T1), at the tank outlet (T2), and after distribution (T3)—showed distinct differences in temperature, pH, conductivity, and residual chlorine.

The average temperature ranged from 26.5 °C at T1 to 27.1 °C at T3. This slight increase can be attributed to environmental exposure during distribution. pH values exhibited a modest increase post-chlorination, moving from an average of 6.98 at T1 to 7.21 at T3, aligning with regulatory parameters and suggesting a stabilizing effect of chlorination on the acidity of water.

Electrical conductivity (EC) increased from 496 µS/cm at T1 to 513 µS/cm at T3, indicating the potential contribution of chlorine compounds and environmental inputs through the network. Importantly, residual chlorine concentrations increased significantly after chlorination, reaching 0.78 mg/L at T2 and maintaining 0.73 mg/L at T3, which complies with WHO recommended levels (0.2–0.8 mg/L) and Peruvian national standards (MINSA, 2020).

These results confirm that the chlorination process effectively modifies the physicochemical characteristics of water, ensuring the maintenance of disinfection residuals throughout the system.

Microbial quality

The microbiological evaluation focused on the presence of total coliforms and Escherichia coli as indicators of fecal contamination. The water samples at T1 revealed the presence of both microorganisms, with total coliforms detected in 100% of samples and E. coli in 75%, confirming contamination in untreated water.

Following chlorination, samples from T2 and T3 showed complete absence of E. coli and a 93% reduction in total coliform presence, with only one sample at T2 showing minor total coliform growth (1 CFU/100 mL), likely due to marginal errors in dosing or post-chlorination contamination.

This confirms that chlorination significantly improved the microbiological quality of the water, rendering it safe for human consumption according to WHO guidelines and national regulations.

Community health perception

A survey was conducted with 42 residents to assess their perception of water quality and chlorination. Approximately 85.7% of respondents recognized a difference in water taste or odor post-chlorination. Despite this, 78.5% affirmed that they felt safer drinking the water after treatment, and 90% agreed that chlorination was necessary to avoid diseases.

Interestingly, 19% of respondents reported cases of gastrointestinal illness in the past month, primarily among individuals who admitted to consuming untreated water from alternative sources (e.g., wells, stored rainwater). This suggests a correlation between lack of chlorinated water use and disease incidence.

System reliability and infrastructure

Observational and engineering inspection during the study revealed challenges in infrastructure that may affect chlorination effectiveness. The main issues included:

Inadequate sealing of the distribution tank, which could allow external contamination.

Fluctuations in chlorine dosing due to manual application without automated control.

Absence of residual chlorine monitoring at user endpoints.

These weaknesses suggest the need for improved operational control, maintenance routines, and investment in automation and continuous monitoring technologies to ensure sustained water safety.

Statistical correlation

A Pearson correlation analysis revealed a strong inverse correlation between residual chlorine levels and microbial presence ($r = -0.89$, $p < 0.01$). Likewise, a moderate positive correlation was found between community-reported illness and self-reported consumption of untreated water ($r = 0.68$, $p < 0.05$).

These results statistically support the hypothesis that proper chlorination reduces microbial contamination and consequently, waterborne illness in the population.

DISCUSSION

Significance of Chlorination in Water Quality Assurance

The findings of this study reaffirm the fundamental role of chlorination in ensuring the microbiological safety of drinking water, particularly in semi-rural and peri-urban settings where infrastructure limitations increase the risk of waterborne disease outbreaks. The consistent elimination of Escherichia coli and the drastic reduction of total coliforms post-treatment underscore chlorine's reliability as a primary disinfectant, as recommended by the WHO and endorsed by national health authorities.

The detected residual chlorine levels (0.78 mg/L at T2 and 0.73 mg/L at T3) fall within acceptable thresholds, demonstrating effective dosage and suggesting good preservation of disinfection power throughout the distribution system. These results reflect the successful inactivation of pathogens and offer evidence that even manual chlorination methods, when properly executed, can yield reliable outcomes under local operational conditions.

However, the detection of total coliforms in one sample after chlorination (T2) implies that slight inconsistencies in dosing, potential biofilm development, or post-treatment contamination may occur in the system. This reinforces the need for strict adherence to operational protocols and the inclusion of real-time monitoring as part of a broader water safety plan.

Physicochemical Shifts and their Interpretations

Post-chlorination shifts in physicochemical parameters were within expected ranges and confirm that the disinfection process does not drastically alter the physical properties of water. The modest increase in pH from 6.98 to 7.21 aligns with known chlorine reactions, which often result in slightly more alkaline water due to the formation of hypochlorite ions.

Conductivity increases are often observed due to the presence of added chlorine salts and potential leaching from distribution materials, especially in older systems. The increase from 496 to 513 μS/cm, though marginal, suggests slight mineral enrichment or surface interactions that merit routine inspection of pipe conditions.

These parameters serve not only as indicators of water quality but also as indirect markers of system behavior post-treatment. Their stability throughout the system is encouraging and supports the effectiveness of the chlorination procedure.

Public Health Implications and Disease Reduction

Perhaps the most significant outcome of the study lies in its public health implications. A comparison of microbiological data with community survey results reveals a clear relationship between untreated water consumption and reported gastrointestinal illness.

While only 19% of surveyed residents reported recent episodes of diarrhea, all those affected had consumed unchlorinated water from alternative sources, primarily stored rainwater or well water. This supports the hypothesis that continued reliance on informal sources exposes segments of the population to microbial risks, despite the availability of chlorinated water.

These findings highlight the importance of not only sustaining proper chlorination practices but also increasing community awareness of its benefits. It becomes evident that technological solutions must be complemented by behavioral and educational interventions to achieve full public health protection.

Community Perception and Acceptance

Survey responses indicate that while chlorination is widely accepted (over 90% of participants agree it is necessary), sensory changes in taste and smell are still perceived as drawbacks. These perceptions, although expected, can influence water use behavior and lead to riskier choices—such as avoiding treated water for cooking or drinking.

This phenomenon, known as "organoleptic rejection," is well-documented in the literature and has been observed in other studies conducted in Latin America (Delgado & Espinoza, 2018). It points to the delicate balance between effective dosing and user acceptability. Over-chlorination may secure microbial safety but risks lowering consumption due to taste aversion, particularly in vulnerable populations.

Strategies to mitigate this include dose optimization, clear communication about the reasons for taste and odor changes, and promotion of practices such as aeration before consumption. These community-level tactics may help improve compliance with treated water use and reduce the health burden of preventable gastrointestinal disease.

Infrastructure and Operational Challenges

Although the chlorination process was deemed effective, the evaluation of system infrastructure highlighted several vulnerabilities that may compromise long-term success. Among these are the lack of tank sealing, the absence of dosing automation, and the absence of residual chlorine monitoring at distal points of the network.

Manual chlorination, though viable in small-scale systems, introduces significant variability due to human error, inconsistent reagent concentrations, and lack of real-time feedback. The study's lone post-treatment coliform detection may be explained by such inconsistencies, emphasizing the need for improved dosing mechanisms and training for operational staff.

Moreover, the absence of residual chlorine monitoring at user endpoints poses a risk of undetected chlorine depletion, especially under varying environmental or demand conditions. Integrating low-cost digital sensors and community-led monitoring could help address this gap and maintain protective residuals throughout the network.

Correlation Analysis and Predictive Insight

The strong negative correlation observed between residual chlorine levels and microbial contamination ($r = -0.89$) not only reinforces the validity of chlorination but also suggests that this parameter can serve as a reliable early-warning metric in similar systems. The establishment of threshold-based monitoring protocols could allow for proactive management, especially in areas with intermittent water supply or aging infrastructure.

Likewise, the moderate positive correlation between untreated water use and reported illness ($r = 0.68$) supports the premise that user behavior is a determinant factor in waterborne disease prevalence. This aligns with previous research emphasizing the need for behavior-focused strategies in rural water safety planning (Ramírez et al., 2020).

Alignment with Regional and Global Trends

These findings are consistent with regional water safety challenges documented in Latin American contexts, where decentralized systems and limited infrastructure dominate. The World Bank (2021) reports that over 70 million people in the region rely on small water systems that often lack consistent treatment or monitoring, mirroring the context of this study.

In this light, the present research contributes not only to local decision-making but also to the broader evidence base supporting the implementation of low-cost, locally managed chlorination programs. The outcomes align with global Sustainable Development Goal 6 (Clean Water and Sanitation) by promoting safe water access through appropriate and context-sensitive technologies.

Recommendations for Future Practice

Based on the study's outcomes, several recommendations emerge for improving water safety in similar settings:

Automated or semi-automated chlorination systems should be prioritized to minimize dosing variability.

Routine residual chlorine monitoring at user endpoints should be established, using portable kits or digital sensors.

Public education campaigns focusing on the importance of treated water and addressing taste concerns are essential.

Infrastructure improvements, including tank sealing and pipe maintenance, will prevent post-treatment contamination.

Community engagement should be strengthened to co-design acceptable solutions and encourage safe water practices.

These actions, when integrated into a structured Water Safety Plan (WSP), can transform current practices into resilient, community-driven solutions that ensure continuous access to safe drinking water.

CONCLUSION

Chlorination has been shown to significantly enhance water quality through the effective elimination of E. coli and the reduction of total coliforms, while maintaining acceptable physicochemical parameters. The study reveals strong community support for chlorination, despite some sensory changes associated with its application. This research addresses critical gaps in understanding water treatment efficacy in rural contexts, affirming chlorination as a viable and scalable solution for improving water safety.

The implications of these findings are substantial for both practice and theory. Practically, the study highlights the necessity for infrastructure enhancements, continuous monitoring, and comprehensive public education to ensure sustained drinking water safety. Theoretically, it enriches the existing body of knowledge on effective water treatment methodologies tailored for rural environments.

Future research should prioritize the implementation of automated or semi-automated chlorination systems to minimize dosing variability and enhance reliability. Establishing routine residual chlorine monitoring at user endpoints is essential, utilizing portable kits or digital sensors to bolster safety measures. Public education campaigns are imperative to promote the significance of treated water and to mitigate sensory concerns associated with chlorination. Furthermore, reinforcing infrastructure through improved tank sealing and pipe maintenance is critical to prevent post-treatment contamination. Finally, fostering community engagement in the design of acceptable solutions will facilitate safer water practices.

By integrating these recommendations into a structured Water Safety Plan (WSP), stakeholders can develop resilient, community-driven approaches that ensure continuous access to safe drinking water in similar contexts.

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