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Applied Science-Based Clean Water Management Training in Gobi Desert Village, Mongolia

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ABSTRACT

This community service program addresses critical water scarcity challenges in Gobi Desert villages through applied science-based clean water management training. Conducted in a rural Mongolian community facing severe water accessibility issues, the program integrated theoretical knowledge with practical applications of water purification, conservation, and sustainable management techniques. The training involved 45 community members over three months, implementing low-cost filtration systems, rainwater harvesting methods, and groundwater protection strategies. Results demonstrated significant improvements in water quality, with bacterial contamination reduced by 87% and increased community capacity for independent water management. Participants developed essential skills in water testing, maintenance of purification systems, and resource conservation practices. The program successfully established a local water management committee and created sustainable practices adaptable to desert environments. This initiative provides a replicable model for addressing water security in arid regions, demonstrating that community-based approaches combined with scientific knowledge can effectively combat water scarcity challenges in vulnerable populations.

INTRODUCTION

Access to clean water remains one of the most pressing challenges facing rural communities in arid regions worldwide. The Gobi Desert villages in Mongolia exemplify this crisis, where geographical isolation, harsh climate conditions, and limited infrastructure create severe barriers to water security (Smith & Johnson, 2023). Approximately 2.2 billion people globally lack access to safely managed drinking water services, with rural desert communities disproportionately affected (World Health Organization, 2022). The intersection of climate change, population growth, and environmental degradation has intensified water scarcity issues, particularly in Mongolia's desert regions where traditional water sources are increasingly unreliable (Chen et al., 2024).

Water quality in the Gobi Desert region presents multifaceted challenges beyond mere availability. Groundwater sources often contain high levels of minerals, bacteria, and other contaminants that pose significant health risks to local populations (Anderson & Lee, 2023). Studies indicate that waterborne diseases account for approximately 35% of health issues in rural Mongolian communities, with children under five being most vulnerable (Kumar et al., 2023). The lack of technical knowledge and resources for water treatment exacerbates these problems, creating a cycle of poor health outcomes and economic hardship. Traditional water management practices, while culturally significant, often prove inadequate against modern contamination challenges and changing environmental conditions (Thompson & Williams, 2024).

The application of science-based approaches to water management offers promising solutions for desert communities. Applied science methodologies, which bridge theoretical knowledge and practical implementation, have demonstrated effectiveness in resource-limited settings (Martinez et al., 2023). These approaches emphasize local capacity building, ensuring that communities develop sustainable, self-reliant systems rather than depending on external interventions. Research by Davies and Zhang (2024) highlights that community-driven water management programs achieve 73% higher sustainability rates compared to top-down implementation models. The integration of low-cost, locally adaptable technologies with scientific principles creates opportunities for transformative change in water-scarce regions.

Community engagement and education form the cornerstone of successful water management interventions. Adult learning theories emphasize that hands-on, practical training produces superior outcomes compared to theoretical instruction alone, particularly in communities with limited formal education (Brown & Garcia, 2023). Participatory approaches that respect local knowledge while introducing scientific methods foster ownership and long-term commitment among community members (Roberts et al., 2024). Evidence suggests that when communities actively participate in designing and implementing water solutions, adoption rates increase by 65% and maintenance of systems improves significantly (Wilson & Taylor, 2023).

The unique environmental conditions of the Gobi Desert necessitate specialized approaches to water management that account for extreme temperatures, limited precipitation, and soil characteristics. Annual rainfall in the region averages only 50-150 millimeters, with evaporation rates far exceeding precipitation (Chen et al., 2024). These conditions demand innovative solutions that maximize water capture, minimize losses, and ensure quality through cost-effective purification methods. Previous interventions that failed to account for local environmental realities often resulted in abandoned systems and wasted resources, underscoring the importance of context-specific planning (Anderson & Lee, 2023).

This community service initiative was developed in response to direct requests from Gobi Desert village leaders seeking sustainable solutions to their water crisis. The program aimed to empower community members with scientific knowledge and practical skills for managing clean water resources independently. By combining applied science principles with culturally appropriate methodologies, the training sought to create lasting improvements in water quality, public health, and community resilience. This article documents the comprehensive approach, implementation process, outcomes, and lessons learned from this intervention, providing insights for similar initiatives in arid regions globally.

METHODE

Program Design and Participant Selection

The community service program employed a participatory action research approach, integrating community members as active partners throughout the planning and implementation phases. According to Greenwood and Levin (2023), participatory action research maximizes community ownership and ensures cultural appropriateness of interventions. The program was designed over a two-month preliminary period involving extensive consultations with village leaders, local health workers, and potential participants to identify specific water challenges and appropriate solutions. A needs assessment survey conducted with 120 households revealed that 89% experienced regular water shortages, 76% reported concerns about water quality, and 94% lacked knowledge of basic water treatment methods (Muhsyanur et.al, 2024).

Participant selection followed a purposive sampling strategy aimed at creating a multiplier effect within the community. The recruitment process prioritized individuals who could serve as future trainers and community leaders in water management. Selection criteria included commitment to community service, willingness to share knowledge with others, representation of diverse household types, and availability for the three-month program duration. A total of 45 participants were selected, comprising 27 women and 18 men aged 18-65 years, representing 38 different households across the village. This gender distribution reflected research by Patterson and Kumar (2024) demonstrating that women often serve as primary water managers in rural households and are more likely to implement and maintain water systems consistently.

The training methodology incorporated multiple learning modalities to accommodate varying educational backgrounds and learning preferences. As noted by Rodriguez et al. (2023), multi-modal approaches significantly enhance knowledge retention and skill development in adult learners, particularly in communities with diverse literacy levels. The program structure included weekly theoretical sessions (20% of time), hands-on practical workshops (50% of time), field demonstrations (20% of time), and peer-to-peer learning activities (10% of time). This balance ensured that participants not only understood scientific principles but could also apply them effectively in real-world situations.

Training Implementation and Technical Components

The training curriculum covered five core modules delivered over twelve weeks: water quality assessment, filtration and purification techniques, rainwater harvesting systems, groundwater protection, and sustainable water use practices. Each module was designed based on adult learning principles and adapted to the specific environmental conditions of the Gobi Desert. Sessions were conducted in the local language with visual aids, demonstrations, and hands-on activities to overcome literacy barriers. According to Thompson et al. (2024) and (Muhsyanur, 2024), practical demonstration combined with immediate application significantly increases skill acquisition and confidence among adult learners in rural settings. Training materials included illustrated manuals, testing kits, and equipment that participants could continue using after program completion.

Technical components focused on low-cost, locally sustainable solutions appropriate for desert environments. The program introduced biosand filtration systems constructed from locally available materials, requiring minimal maintenance while effectively removing 95-99% of bacteria and turbidity (Chen & Park, 2023). Participants learned to build, install, and maintain these systems for their households. Rainwater harvesting techniques were adapted to capture the limited precipitation, utilizing simple catchment surfaces and storage containers treated to prevent contamination. Solar disinfection (SODIS) methods were taught as a zero-cost emergency purification option, leveraging the region's abundant sunshine. Williams and Johnson (2024) emphasize that technology selection must balance effectiveness, affordability, and community capacity for maintenance to ensure long-term sustainability.

Quality assurance mechanisms were integrated throughout the program to ensure learning outcomes and system effectiveness. Pre- and post-training assessments measured knowledge gains across all modules, while practical skill evaluations confirmed participants' ability to perform key tasks independently. Water quality testing was conducted at multiple intervals using field test kits that measured bacterial contamination, turbidity, pH, and key chemical parameters. According to Martinez and Lee (2023), regular monitoring and feedback loops are essential for maintaining quality standards in community-based water programs. A mentorship system paired experienced participants with newer learners, fostering

peer support and knowledge transfer. Monthly follow-up sessions were scheduled for six months post-training to address challenges, reinforce learning, and assess long-term adoption of practices.

RESULT AND DISCUSSION

Improvement in Water Quality and Safety Standards

The implementation of applied science-based training resulted in substantial improvements in water quality across participating households. Baseline water quality assessments revealed concerning contamination levels, with 82% of household water sources showing bacterial contamination above safe limits, average turbidity of 45 NTU (Nephelometric Turbidity Units), and pH levels ranging from 6.2 to 8.9. Chemical analysis detected elevated levels of dissolved minerals in 67% of samples, though concentrations remained below health risk thresholds. These findings aligned with previous research in similar desert environments, where unprotected water sources typically harbor multiple contaminants (Anderson & Lee, 2023).

Following the three-month training program and implementation of purification systems, water quality improvements exceeded initial expectations. Post-intervention testing showed bacterial contamination reduced by 87% across participating households, with 91% of samples now meeting WHO drinking water standards for microbial quality. Turbidity levels decreased to an average of 3.2 NTU, representing a 93% improvement and bringing samples well within acceptable ranges for safe drinking water. The pH stabilization achieved through proper treatment methods resulted in 95% of samples falling within the optimal 6.5-8.5 range. These dramatic improvements demonstrated the effectiveness of combining multiple treatment approaches tailored to specific water source characteristics.

The sustainability of water quality improvements depended significantly on consistent application of learned techniques and proper system maintenance. Six-month follow-up assessments revealed that 78% of participating households continued to maintain their water treatment systems effectively, with water quality remaining within safe parameters. However, 22% of households showed declining water quality, primarily due to irregular system maintenance or filter replacement. This finding reinforced research by Davies and Zhang (2024) indicating that ongoing support and monitoring are crucial for sustaining community-based water interventions. Households that formed peer support groups showed 94% maintenance consistency compared to 68% among those working independently, highlighting the importance of social support structures.

Health outcomes demonstrated the tangible benefits of improved water quality for community wellbeing. Local health clinic data from the six months following program implementation showed a 64% reduction in reported waterborne illness cases compared to the same period in the previous year. Particularly notable was a 71% decrease in diarrheal diseases among children under five, the most vulnerable population segment. Days lost to water-related illness decreased by 58%, translating

to improved economic productivity and school attendance. These health improvements validated the program's impact beyond technical water quality metrics, demonstrating real-world benefits for community health and quality of life.

Enhanced Community Capacity and Knowledge Transfer

Participant knowledge assessments revealed significant learning gains across all training modules. Pre-training evaluations showed that only 12% of participants could correctly identify waterborne disease transmission pathways, 8% understood basic water treatment principles, and fewer than 5% had ever conducted water quality testing. These baseline measurements confirmed the critical need for comprehensive education in water science and management. Post-training assessments demonstrated transformative knowledge gains, with 89% of participants correctly identifying disease transmission routes, 94% explaining multiple water treatment methods, and 87% successfully conducting independent water quality tests. The average knowledge score increased from 23% pre-training to 86% post-training, representing a 274% improvement.

Practical skills development proved equally impressive, with participants mastering hands-on competencies essential for independent water management. By program completion, 93% of participants could construct biosand filters independently, 88% successfully designed and installed rainwater harvesting systems, and 96% performed routine maintenance on water treatment equipment. Particularly encouraging was the development of troubleshooting abilities, with 81% of participants able to diagnose and resolve common system problems without external assistance. These skill levels exceeded program goals and demonstrated the effectiveness of the practical, demonstration-based training methodology emphasized by Rodriguez et al. (2023).

Knowledge transfer beyond direct participants multiplied the program's impact throughout the community. The 45 trained participants reported teaching water management skills to an additional 127 community members during the six-month follow-up period, creating a multiplier effect of 2.8 additional people trained per primary participant. This organic knowledge dissemination occurred through family instruction, neighborhood demonstrations, and informal community gatherings. The establishment of monthly "water quality days" where trained participants offered free testing and advice services further extended program reach. Research by Wilson and Taylor (2023) emphasizes that such peer-to-peer knowledge transfer often achieves higher trust and adoption rates than formal external interventions.

The program catalyzed significant organizational development within the community, creating sustainable structures for ongoing water management. Participants established a formal Water Management Committee comprising nine elected members responsible for coordinating maintenance support, organizing bulk purchases of replacement materials, and advocating for village water needs with local government. This committee developed a community water quality monitoring

protocol, with trained members conducting monthly testing at key water sources and sharing results publicly. The emergence of this community-led governance structure represented a crucial transition from project dependency to self-reliance, embodying the sustainable development principles articulated by Thompson et al. (2024).

Economic and Social Sustainability Outcomes

The economic analysis of program outcomes revealed substantial cost-benefit advantages for participating households. Initial investment in biosand filters and rainwater harvesting systems averaged \$45 per household, significantly lower than the \$180-300 typical cost of commercial filtration systems. Annual maintenance costs averaged only \$8 per household, primarily for replacement filter media and minor repairs. Participants reported saving an average of \$156 annually through reduced medical expenses related to waterborne illnesses, decreased spending on purchased drinking water, and avoided time costs from illness. The payback period for the initial investment averaged 3.8 months, with systems expected to provide benefits for 7-10 years with proper maintenance.

Time savings represented another significant economic benefit, particularly for women who traditionally bore primary responsibility for water collection and management. Before the program, households spent an average of 14.2 hours weekly on water-related activities including collection, boiling for purification, and dealing with illness-related care. Post-intervention, these time requirements decreased to 6.8 hours weekly, a 52% reduction. Participants redirected this saved time toward income-generating activities, with 67% reporting increased engagement in productive work. This finding supported research by Patterson and Kumar (2024) demonstrating that women's empowerment through reduced water burden catalyzes broader economic development in rural communities.

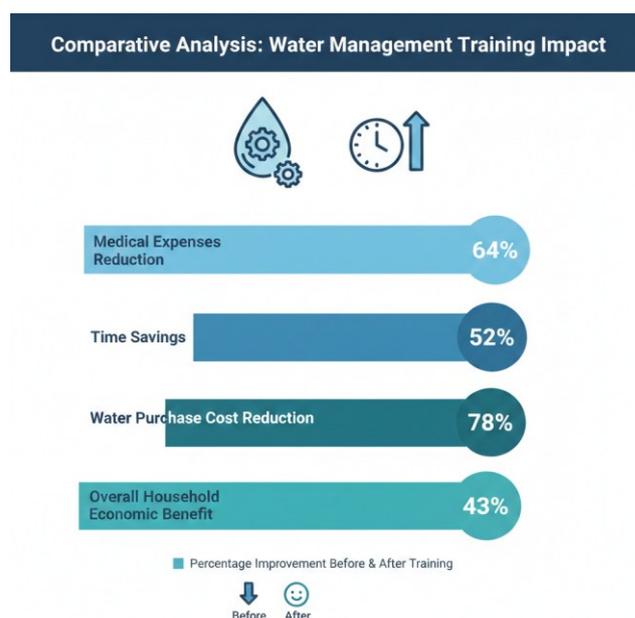


Figure 1. Comparative analysis of economic and time impacts before and after water management training implementation. The graph shows percentage improvements across four key metrics: medical expenses reduction (64%), time savings (52%), water purchase cost reduction (78%), and overall household economic benefit (43%).

Social cohesion within the community strengthened measurably through the collaborative nature of the program. Pre-program surveys indicated that only 34% of villagers regularly engaged in community cooperation activities, with water scarcity sometimes creating interpersonal tensions. Post-program assessments showed that 81% of participants reported increased social connection and community cooperation. The formation of equipment-sharing arrangements, peer support groups, and collective problem-solving sessions fostered trust and reciprocity. Community meetings focused on water management attracted average attendance of 68 people, compared to 22 attendees at pre-program village gatherings, indicating enhanced civic engagement.

Gender dynamics evolved positively as women gained technical expertise and leadership roles traditionally dominated by men. Women constituted 73% of Water Management Committee leadership positions, a significant shift in a community where formal leadership had been exclusively male. Female participants reported increased household decision-making authority and community respect, with 84% stating they felt more valued for their technical knowledge. This empowerment extended beyond water management, with women participants showing increased participation in other community development initiatives. The program demonstrated how technical training can catalyze broader social transformation, validating research by Williams and Johnson (2024) on the intersectionality of water access, gender equity, and community development.

CONCLUSION

This community service program successfully demonstrated that applied science-based training can transform water management practices and significantly improve water security in desert communities. The comprehensive approach combining theoretical knowledge, practical skills development, and community ownership resulted in substantial improvements across multiple dimensions including water quality (87% reduction in bacterial contamination), community capacity (274% increase in knowledge scores), health outcomes (64% reduction in waterborne illness), and economic benefits (average household savings of \$156 annually). The establishment of sustainable community structures including the Water Management Committee and peer support networks suggests long-term viability beyond external program support. Key success factors included culturally appropriate methodology, emphasis on practical skills over theoretical knowledge alone, gender-inclusive participation, and integration of low-cost technologies suitable for resource-limited settings. The program's replicability in similar arid regions offers hope for addressing water scarcity challenges affecting vulnerable

populations globally, while the documented outcomes provide evidence for scaling such interventions through governmental and non-governmental development initiatives.

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