Safer Water for Remote Nepal – Novel Pathways Towards SDG 6.1

Can novel adaptations of water quality monitoring and risk management help remote communities comply with the new water safety standards? Insight into how simple experiments can identify and reduce public health risks in rural water schemes. Arnt Diener[1], Moa A. Kenea[3], Irfan Y. Pratama[3], Madan Bhatta[2], Mohan Bhatta[2], Sara Marks[1]

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Photo 1: Community tap stand in the Nepalese mountains.

Introduction

Recent studies estimate that inadequate drinking water quality causes about 500 000 diarrheal deaths annually [1]. In response, 193 countries have adopted the Sustainable Development Goals (SDGs), and SDG 6 challenges the sector to "achieve universal and equitable access to safe and affordable water for all" by 2030 (Target 6.1). To ensure compliance with the standards for access, quantity and quality, the agreement calls for worldwide monitoring and evaluation (M&E) of water supply schemes even in very remote regions [2]. Credible M&E typically requires complex laboratory setups and technical expertise; thus, there is the need for new methods that are affordable and viable for remote and/or capital-restricted water schemes.

Background and research setup

There are many technical and economic barriers to water supply monitoring in remote mountain villages of Nepal. HELVETAS Swiss Intercooperation's Water Resource Management Program (WARM-P) installed 56 piped supply systems in western Nepal, and these gravity-fed schemes are operated and maintained by the local communities. They provide water intermittently for two-to-six hours per day, and the reservoir tanks buffer seasonal variations in the springs' discharge – similar to many of the region's 5 169 schemes. The piped schemes have significantly improved households' access to water; however, no system-level treatment or quality control has been implemented yet, mainly due to sustainability concerns [3].

SANDEC partnered with HELVETAS to study the technical, social and economic viability of the M&E of their water schemes from October to December 2015. Four WARM-P schemes with 35 water points on the hilly slopes of Dailekh district were selected for the study. The goals were to understand the implications of SDG 6.1 for small rural water schemes and initiate the development of a generic Water Safety Plan (WSP) for such schemes based on national and global guidelines for safe drinking water [4, 5]. The objectives were to: assess the spatial and temporal dynamics of the water quality parameters in the piped water schemes, evaluate the feasibility of various M&E measures, including mobile applications and adapted laboratory setups, and work to understand the effectiveness of scheme adaptations for contamination mitigation and prevention.

We developed and installed an off-grid field laboratory with a low-watt incubation system and a simplified disinfection and cooling approach to replace autoclaving and grid-electricity. We validated the laboratory's suitability for remote areas and trained local staff prior to doing daily water testing for seven five-day cycles. The water quality was tested for: microbial contaminants (*E. coli*, *V. cholerae*, *Enterococcus sp.*, and coliform) using membrane filtration and culture-based enumeration, and physio-chemical parameters (electrical conductivity, pH, turbidity, temperature and free chlorine) with automatic probes and a colorimeter. Comprehensive chemical tests were also done on selective samples at EAWAG's main laboratory. To understand the risk management options, 15 pilot experiments were done, including salt-based contamination tracing and scheme adaptation effectiveness, spring protection and drip chlorination. Treatment interventions were evaluated together with the schemes' committees, and the criteria included: financial and technical viability, community acceptance, and contamination

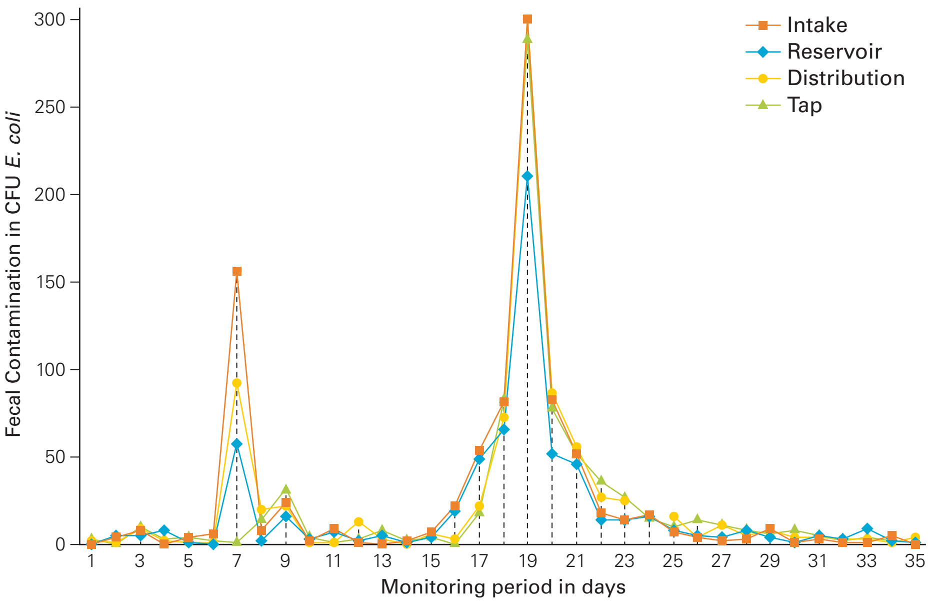

Figure 1: Daily variability of CFU *E. coli* per 100mL along iPWS No IV.

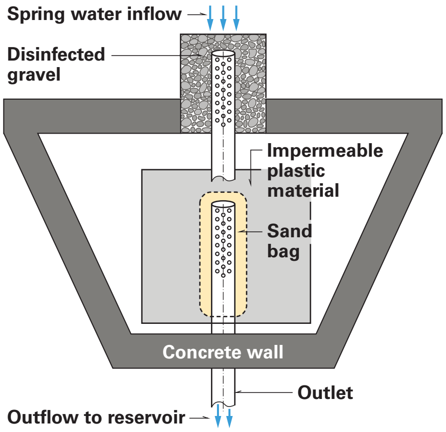

Figure 2: Adapted intake protection for the scheme's spring source.

reduction efficacy under intermittent conditions. In addition, sanitary inspections of 32 water points were done using the mobile phone application *mWater* [4].

Results and lessons learned

Monitoring revealed significant temporal dynamics of microbial contamination in all the systems. At the 35 sampling points, over 85 % of the samples showed *E. coli* concentrations above the national and international standards of 0 CFU/100mL, and daily measurements revealed the temporal sensitivity of water quality compliance. 60 % of all water points met the standards at least one sampling day during the two-month period, but only 4 % were compliant throughout each day during the whole time. The concentration of faecal contaminants showed significant spatial variation among water points, even within schemes. In many cases, the faecal contamination passed from spring intake to the tap. Salt tracer experiments at the intake confirmed contaminant intrusion around the springs. Figure 1 depicts the spatial and temporal dynamics for *E. coli* (CFU/100mL) and identifies the intake as the likely contamination source. In addition, hydro-geologic analyses supported the likelihood of contamination influx in the vicinity of the spring. Assessments of the underlying aquifers of the springs based on physio-chemical and hydro-chemical parameters yielded no evidence of an anthropogenic impact on them.

Sanitary inspections indicated medium to high risk levels for different pathways along the schemes, including pipe leakages, which may explain the occasional increases observed in contamination between the reservoirs and taps. Quantitative correlations between risk scores and actual contamination events were not found to be statistically significant, and statistical analysis was limited by the small sample sizes and limited variation. Qualitatively, the schemes' inspection scores generally aligned with the overall laboratory results. Operational hours and turbidity levels as alternative indicators were not correlated overall with microbial concentrations and cannot, therefore, be regarded as a replacement for microbial assessment or sanitary inspections.

The measured contamination levels and sanitary risk scores were followed by upgraded intake protection pilots and several effective treatment trials at the reservoir and community level. The preventative measures for contamination influx around the intake (Figure 2), i.e. deepening the inlet 1 m and installing a rapid sand filtration element to retain soil infiltration, performed well in terms of efficacy (2-log removal for *E. coli*), financial viability and community acceptance. The combination of UV disinfection and in-line filtration achieved the expected treatment efficacy, but their technical implementation at system level proved problematic despite an adapted setup. The users accepted the use of a continuous chlorinator as an alternative in spite of its adverse odour and taste consequences. This proved technically feasible and effectively deactivated *E. coli* during the monitored period by providing residual chlorine from the reservoir to household storage level.

Conclusion

The project cross-checked results by combining regular water quality monitoring with a comprehensive water scheme assessment and assessed the suitability of both management tools for remote areas. The combined evaluation permitted us to credibly identify the main contamination pathway, which was at the intake rather than pipe level, in contrast to earlier studies on intermittent schemes. At the springs' intake, the observed sanitary inspection scores aligned with the monitored contamination levels and with a hydrogeological assessment.

Our study revealed high daily contamination variability, which discouraged the use of an end-of-the-pipe approach to microbial contamination monitoring. The results also highlighted the benefits of a thorough system assessment and regular audits. The assessment tools (e.g. the salt-tracer experiment) and the modified laboratory proved feasible and were able to facilitate WSP implementation by filling the gap between certified laboratories and field test-kits. Combined with the successfully tested adaptive interventions, the study showed that communities can advance their schemes towards meeting national drinking water quality objectives.

What can we conclude about the implementation of measures to meet SDG target 6.1 regarding access to safe water in remote areas? The lessons apply to small rural water schemes in hilly areas across the globe. Due to the dramatic temporal and spatial dynamics of the study schemes, we found that singular water parameter tests do not offer overall safety for this common water scheme type. National monitoring for SDG 6.1 will profit from integrating thorough risk evaluations for such schemes, e.g. the sanitary inspection score, prior to the successful establishment of basic control measures. These risk evaluations can be used to develop generic WSPs, and the WSPs will add value to the SDG water quality surveillance targets and support national risk management. They will also motivate further research aimed at prioritizing interventions, leading to an increase in the understanding of different scheme types, and of locational and seasonal influences on water quality risks.

[1] Wolf, J., Prüss-Ustün, A., Cumming, O., Bartram, J., Bonjour, S., Cairncross, S., Clasen, T., Colford, J.M. Jr., Curtis, V., De France, J., Fewtrell, L., Freeman, M.C., Gordon, B., Hunter, P.R., Jeandron, A., Johnston, R.B., Mäusezahl, D., Mathers, C., Neira, M., Higgins, J.P. (2014): Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income countries: systematic review and meta-regression. Journal of Tropical Medicine and International Health *19 (8)*, 928–942.

[2] United Nations General Assembly (2015): Transforming our world: the 2030 Agenda for Sustainable Development. New York.

[3] HELVETAS (2013): The Effectiveness and Outcomes of Approaches to Functionality of Drinking Water and Sanitation Schemes. Water and Infrastructure Series 2013/1.

[4] World Health Organization (2011): Guidelines for drinking-water quality, 4th ed.

[5] Government of Nepal (2010): Nepal Drinking Water Quality Surveillance Guideline.

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