Water Safety Plan for a Groundwater System in the Village of Natiyagama

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Abstract: The WHO introduce Water Safety Plans (WSPs) with the aim of consistently providing safe, acceptable and adequate drinking water. This comprehensive guideline deliver critical action plans necessitated from the catchment to the consumer by use of risk assessment and risk management strategies. The guideline provides the framework of the approach yet development and implementation of a flexible WSP is solely based on the adaptation to meet the required water quality standards. An adaptation of a WSP for a groundwater system is discussed with reference to a water supply unit in the village of Natiyagama. The 11 modules under the 3 key components were examined with respect to the existing management procedure carried out at the Natiyagama community water supply. A new plan was developed with the refinement of the current management approach. This plan included the identification of hazards and hazardous events using a matrix risk assessment and introduction of a WSP review plan. The existence of a renowned hydraulic civilization in Sri Lanka can be attributed to the advanced and well thought out water management of the times and the way forward in managing the country's water resource is through the adaptation of WSPs for our water supply systems.

Keywords: Water Safety Plans, Water management, Adaptation of WSPs, Natiyagama

1. Introduction

Water Safety plans (WSPs) are developed and implemented in water supply systems to provide safe and acceptable drinking water consistently from the catchment to the consumer. The WHO introduced the concept of WSPs as a technical approach providing guidelines for the adaptation of management procedures that consider all aspects and attributes of the system. The key features of a WSP are the comprehensive identification and elimination of risks appropriately. In order to achieve this objective, the WSP framework is divided into 3 major components that are consistently guided by health-based targets. They further subdivide into 11 modules for an easy action plan. Considering drinking water supply for small communities, WHO has further simplified the process into 6 tasks as shown figure 1. (WHO, 2014). However, the major components include system assessment, operational monitoring, and management and communication (Davison et al., 2006).

The WSP strategy is developed methodically using the 11 modules as key steps. However, the success of the implementation depends on the flexibility and dynamic nature of the overall plan. It is ever evolving to accommodate the changes taking place in the system and to achieve the required water quality standards and

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WSP MODULES (WHO, 2009)	WSP TASKS (WHO,2012)
PREPARATION	
1 Assemble the WSP team	1 Engage the community and assemble a WSP team
SYSTEM ASSESSMENT	
2 Describe the water supply system 3 Identify the hazards and hazardous events and assess the risks 4 Determine and validate control measures, reassess and prioritize risks 5 Develop, implement and maintain an improvement plan	2 Describe the community water supply 3 Identify and assess hazards, hazardous events, risks and existing control measures 4 Develop and implement an incremental improvement plan
MONITORING	
6 Define monitoring of control measures 7 Verify the effectiveness of the WSP	5 Monitor control measures and verify the effectiveness of the WSP
MANAGEMENT AND COMMUNICATION	
8 Prepare management procedures 9 Develop supporting programmes	6 Document, review and improve all aspects of WSP implementation
FEEDBACK AND IMPROVEMENT	
10 Plan and carry out periodic WSP review 11 Review the WSP following an incident	

(Adapted from WHO, 2019)

Figure 1. WSP process

objectives (Davison et al., 2006).

A team of experts are recruited to formulate a thorough plan to identify all hazards and hazardous events occurring from the point of source, treatment facility, distribution lines up to the end user. These hazards are assessed for their level of risk and the significant risks are mitigated with use of control measures. These control measures require performance checks through monitoring and several procedures are put forward to verify the effectiveness of the WSP by assessing the product and end user experience for the required standards and objectives. Every action step is documented to maintain transparency and to rationalize the outcomes. Periodic evaluation of hazards, risks and controls are necessary to implement improvements to the plan and to establish management procedures for normal and incidental circumstances (WHO Gorchev HG, 2004).

WSPs are usually implemented on large-scale water suppliers that use surface waters as source water. Especially in Sri Lanka since the year of 2014 numerous large scale pipe borne water systems that have surface waters as abstraction points have been successfully implemented as evidenced by Kandana and Konduwatawana supply systems (NWSDB, 2011, 2018). However, WSP implemented for groundwater systems in Sri Lanka are minimal compared to surface waters. Groundwater is used in small communities but show much more complexity than the former system. Unlike surface water bodies, the groundwater is invisible, and its flow underground is slow. Compared to surface water, groundwater is less vulnerable to pollution. If polluted, the groundwater remediation is costly, even unaffordable to the developed countries. Therefore, groundwater protection is of utmost importance (Bartram et al., 2009). Additionally, people in the dry zone of Sri Lanka are heavily reliant on groundwater of the area due to the water scarcity and pollution (Hettiarachchi, 2008). The poor management of groundwater causing depletion of aquifers, leaching of fertilizer and presence of excess fluoride levels are highlighted problems of the area (Hettiarachchi, 2008). The deteriorating health of the native people due the above problems and their resolutions are widely discussed. Therefore, WSP for groundwater systems in general and especially for areas of the dry zone are crucial to mitigate the above predicament.

The Natiyagama agricultural village in the dry zone of Sri Lanka suffers from excess TDS levels causing unpalatability and drinking water problems in the area. In order to mitigate the problem a water desalination treatment plant was installed at the village school to provide drinking water to the people of the village (Wu et al., 2022). This paper discusses a water safety plan proposed to the community water supply system at Natiyagama. Salient features of the WSP approach consistent with the community projects included are outlined.

2. WSP Team

The experienced multidisciplinary team has competence of the complete water supply system. This team has the authority to make decisions and a capacity to help manage risks. Apart from the implementation and stakeholder teams consisting of the school principal, members of the community and representatives of the Ministry of Education and the public health inspector of the Mihinthale MOH area, an advisory team of various experts was involved in the development of the community treatment plant. Experts on water chemistry, hydrogeology, membrane systems, geophysics, statistics from the prestigious institutes of the Chinese Academy of Science, National Institute of Fundamental Studies, University of Peradeniya, National Water Supply and Drainage Board and the Joint Research and Demonstration Centre were actively involved and still serve as the advisory committee to the water supplying facility.

3. System Description and Risk Assessment

Every water supply system is unique when compared. Therefore, the characteristics and the features unique to these systems should be identified to properly gain perspective in implementing a well thought-out WSP. Subsequently, the system description is used to identify any significant risks posed to the system. These risks are duly addressed through implementation of different control measures.

3.1 System evaluation

Before and even after the installation of the water purification plant many data were collected and documented for the better understanding of the system. Geological, geographical, structural and contour maps were utilized. The land use, population density, soil and rainfall data were assessed in finding suitable locations for the treatment plant. Extensive research was also done in determining the evolution of contaminants in water through time and water quality index (WQI) was defined and used. Apart from that, aquifer model formulations, field and hydrogeochemical surveys, groundwater recharge hydrology, available treatment methods for groundwater and documentation of important indigenous knowledge and practices should be continually collected for better definition of the system.

3.2 Hazards and hazardous events, risk prioritization and control measures

The hazards are dealt with usually as they materialize and are apparent through information collected of the system. A main objective of a WSP is the systematic identification of hazards and hazardous events that are further evaluated for their level of risk. Control measures are then placed according to the significance of the risks. Risk matrix approach is a major tool used to assess the risk factors of the hazards identified through system evaluation. Table 1 below is a list formulated for village treatment plant in Natiyagama which should further be improved on with expert intervention.

Table 1 – Risk matrix and control measures for the water supply system of Natiyagama

Hazard	Type	Frequency (1-5)	Severity (1-5)	Rating (1-25)	Existing/proposed Control measures
The addition of plastic trash, bio-wastes and household chemical bottles to abandoned wells or fields create micro-plastics, organic chemicals contamination	Microbial and Chemical	3	5	15 (high)	Proper closing of abandoned wells and cordoning sensitive areas
Micro-plastics and other fine debris may block fine aquifer flowlines creating dry wells	Physical	2	3	6 (moderate)	Fencing the sensitive areas around the well
Prolonged dry conditions result in increased evapotranspiration of agricultural wells resulting in water salinity and dried wells	Chemical and Physical	3	3	9 (moderate)	Increase of green cover to promote water percolation

Excessive pumping in large diameter wells (agricultural wells) results in water salinity and dry wells.	Chemical and Physical	1	3	3 (low)	Limit to pumping test recommendations
Source groundwater is chemically contaminated due to pesticide use	Chemical	3	4	12 (moderate)	Conducting awareness programs for organic farming
Source groundwater is biologically contaminated by human and animal wastes	Microbial and Chemical	4	4	16 (high)	Introducing a standard WASH management system
Source water can be contaminated due to birds dropping	Microbial	1	3	3 (low)	Cover with a lid
Source water becomes dry upon pumping that result shortage of supplied water	Physical	3	5	15 (high)	Limit to pumping test recommendations
Water quality deterioration of treated water due to membrane fouling	Chemical	3	3	9 (moderate)	Rainwater flushing before and after use of the plant

4 System Upgrades

The Improvement/ upgrade plans are developed if the significant risks are not mitigated by the control measures put forward. System changes, technology updates, and efficiency improvements after review process are also done through upgrade plans.

Suggestions for improvement are as follows; developing an assessment chart for the water plant functioning, developing isotope work to determine the extent of nitrate plume within aquifer, and extending a Memorandum of understanding with the Ministry of Education and the Research group. Further, Isotope work to validate groundwater-surface water mixing (if any), restoring tube wells not in use, developing community training programs and replacing sand and activated carbon filters by UF technology. These upgrades can further strengthen the WSP in achieving its objectives.

5 Operational Monitoring and Verification

Monitoring performance of the WSP ensures that water quality standards and health-based objectives are consistently met.

5.1 Monitoring of controls

Controls are placed in mitigating the significant risks identified and proper functioning of these control measures should be ensured. Control measures should be rapid, simple and routine.

Chemical analysis to monitor pH, TDS and turbidity are performed monthly. Water pressure values are regularly checked to ensure optimal performance of the membrane treatment system.

Further controls and methods of monitoring should be defined with further refinement of the plan at the hand of the experts.

5.2 Verification

Verification of WSP is carried out to maintain effectiveness of the plan consistently. This is done through monitoring performance of control measures to meet the defined standards, through auditing of the entire WSP process and through monitoring customer satisfaction.

For verification purposes, it was proposed to check the treated water quality by NIFS as internal auditing and the NWSDB as an external audit. Further, monthly survey of school teachers are done for reception of treated water.

6 Supporting WSP Management and Procedures

Standard operating procedures (SOP) should be prepared for normal and incidental conditions. This is continually updated concerning the upgrade plans and emergency and incidental situations.

Water plant operations are automated. However, a trained operator from the school is available. SOP is available with a poster showing quick SOP steps. Additionally, emergency contacts are given of the Rajarata University of Sri Lanka as well as the NIFS.

Supporting programs are encouraged to develop skills and knowledge of the WSP team as well as the related stakeholders, to strengthen relationships with all and to improve attitudes regarding the entire process.

Laboratory quality controlling, operator training, calibration and maintenance and consumer education are some of the supporting programs that can be implemented at the Natiyagama village treatment plant.

7. Feedback Reviews

Data collected from the monitoring process, new processes and experiences faced are reviewed periodically by the WSP team to identify the weaknesses and inadequacies and rectify them accordingly.

Recording of WSP team changes, new activity in the aquifer, introduction of new treatment systems, operator training changes and SOP updates are some of the feedback at the treatment facility. These changes should further be documented and reviewed during implementation of upgraded WSP.

Finally, the WSP team meets following an incident, emergency or unforeseen event to analyze the incidents and revise the WSP accordingly. Here, the cause of incident needs to be determined and the gap in WSP for incident needs to be recognized with appropriate revision to prevent the incident taking place in the future.

8. Conclusion

WSP should be an integral component in any water supply system. WSPs are successfully implemented in large-scale systems in Sri Lanka. WSP for small community water supply systems especially considering The North Central Province facing several health challenges due to the drinking water problems are brought to attention. The Natiyagama water treatment plant is one such system installed to provide safe drinking water to the community. Expertise in modelling, data analysis, hydrogeology, process design are mostly welcome in implementation of WSP in groundwater water supply systems. Demarcation of groundwater catchment is crucial to ensure proper implementation of WSP as residents do not identify the negative impacts from poor water management, as source is invisible. The water safety plan was proposed with the vision of promoting WSP in such systems as well as to ensure consistent performance in the treatment facility.

References

Bartram, J., Corrales, L., Davison, A., Deere, D., Drury, D., Gordon, B., Howard, G., Rinehold, A., & Stevens, M. (2009). Water Safety Plan Manual: Step-by-step risk management for drinking-water suppliers. In *WHO Library Cataloguing-in-Publication Data* (Vol. 28, Issue 2). WHO. https://doi.org/10.1055/s-0038-1635552

Davison, A., Deere, D., Stevens, M., Howard, G., & Bartram, J. (2006). Water safety plan manual. *International Water Association*, *1*(May), 108.

Hettiarachchi, I. (2008). A Review on Ground Water Management Issues in the Dry Zone of Sri Lanka. *BALWOIS 2008- Ohrid, Republic of Macedonia 27-31 May 2008*, *May*, 1–7.

NWSDB. (2011). *Kondawatuwana Water Supply Scheme Water Safety Plan* (Issue January).

NWSDB. (2018). *Water Safety Plan Kandana*.

WHO. (2014). Water safety plan : a field guide to improving drinking-water safety in small communities. In *World Health Organisation*.

WHO Gorchev HG, O. G. (2004). *Guidelines for Drinking-water Quality, 3rd Edition*. *1*, 564.

Wu, Z., Senanayake, N., Dayaratna, S., Bandara, D., Pathmanadan, R., Ritigala, T., Weragoda, S. K., Jayarathna, L., Jayasundara, A. C. A., Wei, Y., Chen, X., & Weerasooriya, R. (2022). Sustainable pressure-driven membrane facility controlled by a smartphone application for groundwater desalination in the dry zone of Sri Lanka. *Ceylon Journal of Science*, *51*(1), 51. https://doi.org/10.4038/cjs.v51i1.7979