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# Development and Implementation of Water Safety Plan in Kondawatuwana Water Supply Scheme

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**Abstract:** A Water Safety Plan (WSP) for Kondawatuwana Water Supply Scheme (KWWSS) was developed by National Water Supply and Drainage Board (NWSDB). Possible hazards were identified through field visits. The risks were assessed using a semi-quantity approach. The existing control measures and the verification of control systems were used to assess the residual risks and form a prioritized standard risk matrix. Based on this, an improvement plan was drawn up to suggest corrective actions and a time frame for implementation. The findings of this study are being used to modify or repair components of the water supply system and upgrade management procedures. Water Safety Index is introduced as a bench marking management tool in order to monitor the progress of implementation of WSP. This paper highlights the lesson learned during the development and implementation of the WSP and the key challenges faced.

**Keywords:** Drinking Improvement Plan, Risk Assessment, Water Quality Monitoring, Water Safety Index, Water Safety Plan

## 1. Introduction

According to the World Health Organization (WHO) Guidelines for Drinking-Water Quality, water safety plans (WSPs) is the most effective means of ensuring the safety of a drinking water supply (WHO, 2004). This concept draws from the traditional multiple-barrier risk management techniques and the Hazard Analysis and Critical Control Point (HACCP) approach, which is applied in the food manufacturing industry. The HACCP-concept has been successfully implemented and refined in several water supply systems to improve drinking water quality and security. Several cases studies from industrialized and from developing countries document increased compliances with drinking water quality regulations and reduced cost of operation as result of implementing HACCP. The WSP has been developed based on these experiences.

Developing a WSP involves undertaking risk assessment and identifying hazards at each step of drinking water supply from catchment to consumer (WHO 2004). Over the last decade, WSPs have gained acceptance as an important framework for achieving water quality and health-based targets. WSP can be developed for any type of water supply system, piped- or community-based. Public water utilities in Australia, UK, Latin America and the Caribbean (Bartram et.al, 2009), Bangladesh (Mahmud et.al, 2007), Belgium, Switzerland and the Netherlands have successfully developed and implemented WSPs for their water supply system.

The experiences with WSPs for small, community-managed water supplies are limited and being developed. This has been because of the difficulty in implementing water quality management in situations with limited technical expertise which are often remote. The use of model or guided WSPs may also help to significantly reduce the costs and complexity of implementing WSPs within utility supplies in developing countries (Howard et al. 2005). Godfrey and Howard (2004) documented the WSP approach with certain alteration to overcome the challenges likely to be faced in developing countries, which is limited to small systems.

A case study of implementing a WSP for a large piped-water supply in a developing country is presented in this paper. NWSDB is more concerned in implementing WSP in Kondawatuwana water supply scheme, due to following site specific reasons:

1. Raw water have been contaminating by waste water, solid waste disposal, sewerage disposal, manure disposal and agriculture chemical in the catchment area;
2. The algae concentration is higher in the raw water and can be controlled by limiting

nutrition from point and Non-point pollution sources;
3. The treatment is less effective in removing Iron (Fe) and Manganese (Mn) in terms of aesthetic quality;
4. The water contains silica micro particles and the treatment plant is not equipped for removing silica;
5. The water is consumed by more than 325,000 people from this area and considerably high rates of water loss experienced.

## 2. Methodology

### 2.1 Study Area

KWWSS is an organized urban piped water supply system established under the Eastern Coastal Towns of Ampara District (ECTAD) project and implemented by NWSDB in year 2000. NWSDB is responsible for operating intake, water treatment plant, storage tanks and distribution systems.

Water was extracted from intake in the irrigation tank, and the treatment plant is located closed to the source. The treatment processes includes lime and alum feeding, pre-chlorination, Dissolved Air Floatation (DAF), rapid sand filters with air and water backwashing system, post chlorination and neutralization system. The Water treatment plant is designed to produce 72,000m3/day of drinking water complying with the SLS standards. The water is distributed to Ampara town, adjacent towns, the coastal towns of Ampara district and two towns in Batticaloa district as shown in Figure 1. It is expected to serve 436, 400 numbers of people in the design horizon of year 2030. The current water production is only about 60% of its designed capacity.

### 2.2 Development Plan

The approach for developing the WSP was based on the guidance of WHO expert and the water safety plans manual (Bartram et.al, 2009). The approach was modified to deal with the specific problems found in this drinking water supply system such as higher water loss, limited data availability, unplanned development, and lack of consumer awareness. These issues are common to several developing countries and the information presented in this paper could be useful to practitioners facing similar challenges.

### 2.3 Formation of the WSP team

The WSP team consisted of staff from NWSDB and stakeholders. The strategy in developing, and implementing the WSP was carried out through working together as teams for catchment and treatment, distribution and consumer. The support of local authorities and stakeholders were required for collection of information related to the catchments. Presentations were arranged to NWSDB staff and the stakeholders to understand the important of the WSP and the benefits of implementing in Kondawatuwana water supply scheme.

### 2.4 System Assessment

Figure 1 shows the schematic of the KWWSS including the source, treatment plant and coverage areas. This scheme has 9 intermediate sumps with pump houses and 16 elevated towers, connected with 20 water transmission mains and two direct pumping systems to distribution system using variable speed drive. The water is supplied through 1,500 km of pipeline to about 90,000 metered connections.

Water samples were tested and analyzed from source, component of each unit process, storage locations, and tap of selected consumers for physical, chemical and bacteriological parameters according to standard methods. Water quality data records for the previous 3 years were also analyzed.

A household sanitary survey was conducted in the catchment in 200 household in three Grama Sevaka Niladhari Divisions (Himuthurawa, Paragahakale, and Abayapura). The survey study was designed especially to identify the causes of pollutant in the catchment area.

### 2.5 Hazard Identification

Hazard identification was done for the catchment area, raw water source, water treatment plant, storage locations, distribution networks and selected household storages. Hazards within the catchment area and in the cascade arrangements of reservoirs were identified by the household sanitary surveys, visit by the WSP team, land use pattern and satellite images. Hazards within the water treatment plant were identified with the help of treatment plant operators and NWSDB officers.

Within the storage and distribution system, the hazards were identified by reviewing the condition of structures and pipes based on the maintenance schedule and experience of operation and maintenance staff. Few selected household storages were inspected to identify the hazards.

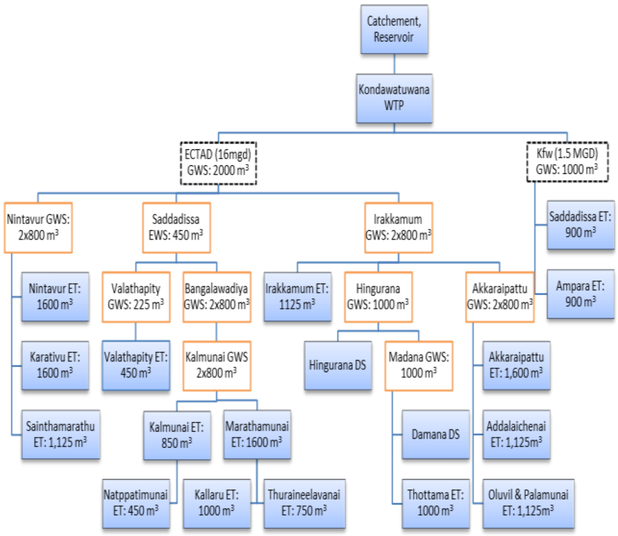



Figure 1: Basic elements for describing the water supply system

The transmission lines were mapped including the locations of flow meters in order to improve the calculation of actual water loss in the system. The likelihood and consequence for each hazard was identified for risk assessment.

### 2.6 Risk Assessment

The risks were assessed using a semi-quantity approach (Deere et.al. 2001). The likelihood and consequence of each hazard was identified based on the field visit, expert opinion, available data, previous studies, and experience of Operation and Maintenance (O&M) staff. Each hazard was scored according to the likelihood of occurrence and consequence in terms of health-based targets and compliance with regulations. Residual risk score was generated based on individual scores and existing validated control measures.

### 2.7 Identification and validation of control measures

Control measures are steps taken to ensure that the quality of water supplied consistently meets targets. Site visits were conducted to identify existing control measures and to assess the effectiveness of the control measures. The validation of the control measures was done by reviewing the maintenance and monitoring records and field inspection.

The residual risk score was calculated based on the findings from the validation of the control measures. In the final risk assessment matrix, risks were categorized in terms of their potential impact on the performance of the water supply system and its capacity to deliver safe drinking water to consumers. Workshop discussions were held for WSP teams and O&M staffs including treatment plant operators to finalize risk assessment matrix and prioritization of residual risk.

### 2.8 Improvement plan

An improvement plan was drawn up to address the all uncontrolled and prioritized residual risks. The plan included risks that scored very high (score >15) and high (score 10-15) on the risks band. The less significant risks (medium and low risk) were not specifically addressed in the plan as these would be eliminated once the control measures for more significant risk are implemented or risk with less priority.

## 3. Results and Discussions

Hazard identification and risk assessment for each component within the water supply system is presented in the following sections.

### 3.1 Catchment and Raw Water Source

Table 1 shows the list of potential hazard from the catchment to consumer. These hazards include existing as well as potential hazard based on future growth and development of the areas in and around the raw water source. The hazards exist due to the prevailing anthropogenic activities around the vicinity of the raw water source. Rainfall runoff is contaminated due to these activities, resulting in the potential contamination of the source water.

Other anthropogenic sources include discharge of wastewater from human habitations including animal farm and horticulture in domestic level and discharge of drainage water containing agrochemicals from paddy fields. This is a result of inadequate urban development planning in allocating settlement areas and catchment for drinking water source.

The challenge in controlling contamination of raw water sources is enhanced due to social and cultural aspects prevalent in the region. Enforcing control measures or corrective actions to restrict the use of water bodies for such activities is a challenge. Implementing any such measure without involving the local community in the complete decision process would be ineffective.

### 3.2 Water Treatment Plant

Selected hazards identified in the water treatment plants by the WSP team and the operators are described in Table 1. The WSP team reviewed the procedures in the treatment plant and it was found to be operating as per standard operating procedure (SOP) and some risks were identified. However, the online monitoring system was not operational. This increases the risk of not identifying changes in the quality of water being supplied to the community.

The maintenance of water treatment plants poses a key challenge. This was observed, due to lack of local agent readily available in purchasing the spares for maintenance. This also leads to lack of proper monitoring of the water quality being supplied. The efficiency of the water treatment plant was calculated based on the available monitoring parameters. Figure 2 depicts the boxplot with quartile spread of treatment efficiencies for each parameter.

Checking of the risks of protozoan & Disinfection-by-Products (DBPs), replacing the defective online monitoring systems, checking the water treatment efficiency of unit processes, following standard operation procedure for normal operation, preparing emergency plan for incidents and emergency situations, maintaining proper asset management systems including maintaining minimum spares for M&E equipment and laboratory items are suggested improvements.

### 3.3 Distribution network

The low number of uncontrolled risks was identified in the distribution network as shown in Table 1. Prior records have shown deterioration in water quality in the distribution network with sudden exposure of colored water due to disturbance of iron and manganese settled in the pipelines.

There is no extreme risk identified in the distribution network because of non-availability of sewer lines in the vicinity of the drinking water pipeline which may leads to cross connections. However, preparedness for corrective maintenance works, monitoring and maintaining positive pressure throughout the distribution network; written hygienic procedures for repairing burst mains and laying new mains, including disinfection before return to service; avoiding disturbance of deposits by avoiding sudden increases in flow and flow reversals and a programme to routine flushing and maintenance; are to be followed to maintain the quality of supply in distribution system.

Regular internal and external inspection of service reservoirs/water towers to make sure there are no structural defects and that access hatches, vents and other openings are either locked or covered to prevent ingress are proposed to ensure re-contamination in storage.

### 3.4 Households

Findings of the household sanitary survey and the hazards are shown in Table 1. The most common risk of recontamination comes from the water handling and storage practices of the users themselves. Even if the tap water supplied is free from contamination, it may get recontaminated in few places as a result of people dipping their hands into the stored water, lack of hygiene in the household and the storage container being accessible to children.

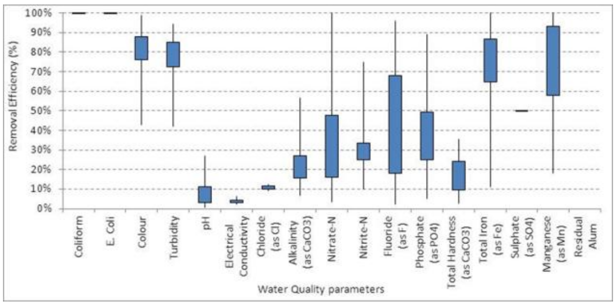


Figure 2: The efficiency of the water treatment plant

Hazards within the households completely depend on the users, awareness within the community regarding these hazards and willingness to adopt safe sanitary practices. NWSDB has established a call center (a tall free number of 1939) that operates 24 hours to address customers' complaints. This is important to receive feedbacks from consumers to further improve the water supply services and to provide assurance to the customers that NWSDB strives to provide good quality water that meets the local potable water standards. NWSDB also is introducing consumer guide manuals and trained plumbers for establishing best practices in internal plumping

### 3.5 Water quality monitoring

Water quality monitoring was done at all levels of the supply including raw water sources, water treatment plants, distribution network and households. No microbial contamination was observed in any part of the water treatment plant transmissions and consumer’s tap. Recontamination was observed within the distribution network. Further, residual chlorine was more than the required 0.2 mg/l in 100%of the samples collected from household taps.

### 3.6 Control measures

No control measures were present within the catchment which is not a protected zone. This is under forest cover, certain anthropogenic activities were found to exist. Water samples were analyzed to validate controls at WTP. Studying water quality records, visual inspection and the experience of the operator also helped in validation. Visual inspection showed that several unit operations were found to be working effectively. Even though it removes Fe, Mn below guideline value they are settled in pipelines.

Certain control measures were found in the distribution network. Booster chlorination is done at WTP, intermediate sumps and few elevated tanks and residual chlorine levels are checked at consumer premises. It is in the range of 0.1–0.3 mg/l which confirmed that chlorination was being done effectively.

### 3.7 Improvement plan

The improvement plan includes corrective actions such as capital works such as repair/ rehabilitation and maintenance, community awareness programs for consumers, training programs for operators enhanced communication among various stakeholders etc. The implementation of the improvement plan is in progress and the post-implementation risk scores from the potential risks to be calculated after implementation of corrective actions.

In the case of catchment, WTP and distribution network, a significant reduction in risk has been assumed as there are construction and repair works. However, in households, corrective actions involve behavior change. Therefore, marginal risk reduction is expected as consumer response cannot be accurately predicted. Implementation of corrective actions within a timeline is the responsibility of WTP operators.

Table 1: Risk Matrix from Catchment to Consumer

| ID-No | Hazardous event | Associated hazards (and issues to consider) | Hazard type | Risk | | | Risk rating | Controls | Possible validation | Risk | | | Risk rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | C | S | | | | L | C | S | |
| A.1 | Seasonal variations | Changes in source water quality (e.g. Algae) | C | 4 | 5 | 20 | **Very High** | Sonication at intake, Selective withdrawal from multi-level intake Powdered activated carbon dosing at the treatment plant, | Historical algae monitoring data (catchment and after treatment) Historical data on algal blooms | 3 | 5 | 15 | **High** |
| A.2 | Geology | Iron, Manganese etc. into water. | M | 3 | 4 | 12 | **High** | Selective withdrawal from multi-level intake not operated | Historical water quality monitoring results and Dredging records | 3 | 4 | 12 | **High** |
| A.3 | Agriculture | Agricultural waste, Slurry and dung spreading, | C,M | 3 | 4 | 12 | **High** | Codes of practice on agricultural | Historical water quality monitoring | 3 | 4 | 12 | **High** |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Disposal of dead animals | | | | | | chemical use and slurry spreading, Public awareness to agrochemicals when needed only | results | | | | |
| A.4 | Forestry | Pesticides, PAHs - polyaromatic hydrocarbons (fires), | P,M | 3 | 4 | 12 | **High** | Awareness to Forest & Wild life Department | Historical sanitary inspection records | 3 | 4 | 12 | **High** |
| A.5 | Farming | Cattle defecation in the catchment (a source of potential pathogen like Cryptosporidium) | M | 3 | 4 | 12 | **High** | Preventing livestock grazing, Moving farm operations away from sensitive locations | Historical microbial source water quality data, sanitary survey results for buffer distances, Historical catchment inspection results | 3 | 4 | 12 | **High** |
| A.6 | Army Camp & Houses | Effluents, contaminants polluting source water | P,C,M | 4 | 5 | 15 | **Very High** | Awareness Program, Introduce toilet for dwellers in catchment, Reduce soil erosion & runoff, Buffer zone vegetation. | Collaboration with Environmental Authority to obtain historical reports on effluent discharge | 3 | 5 | 15 | **High** |
| B.1 | Operation failure of stop logs | Entering of High turbidity and sediments | P,C | 3 | 4 | 12 | **High** | Repairing of online monitoring of Turbidity in Raw water line | Equipment maintenance and replacement records | 3 | 4 | 12 | **High** |
| B.2 | Instrumentation failure | Loss of control | M | 3 | 4 | 12 | **High** | Continuous monitoring with alarms | Equipment maintenance and replacement records | 2 | 4 | 12 | **High** |
| D.1 | Cross connections / unhygienic practices | Contamination | P,M | 2 | 5 | 10 | **High** | Property inspections, Public awareness, Approved quality of materials in customer plumping | Historical water quality monitoring results Historical incident records | 2 | 4 | 8 | **High** |

**3.8 Management programs**

SOPs are a critical focus during the implementation of a WSP and to be developed. This requires documenting procedures to be followed during normal operating conditions and in specific 'incident' situations. An incident is a situation where water being supplied for drinking purposes might become unsafe (WHO 2004).

Investigation should be undertaken involving all staff to discuss the current performance, assess inadequacy of current procedures and address any issues or concerns during documentation of procedure. An annual review protocol has also been prepared, which includes testing water quality at each step of the water supply system and comparing this to critical limits based on the drinking water guidelines.

### 3.9 Supporting programs

A key finding of this study is the importance of supporting programs. It was found that the water supply utility alone cannot ensure the provision of safe drinking water and protection against water-borne diseases. As shown in "Households", improper storage and handling also cause recontamination. Therefore, it becomes necessary to create awareness about point-of-use water treatment. Tools such as locality meetings and informative posters and use of mass media have to be deployed to promote safe water practices and hygiene.

Local dispensaries and primary health centers should report cases of water-borne diseases to the local government hospitals. Training and awareness workshops have been carried out to enhance the skills of WSP team members and public health inspectors and to increase their capacity to employee training to disseminate the concept of WSP, monitoring employee performance through indicators such as response time, % customer complaint solved and supply restoration time after cleaning or repair.

### 3.10 Challenges faced during implementation

One of the challenges faced during this study is related to the feasibility of catchment protection within the water supply. Since agricultural drainage is directed to the reservoir, it might not be feasible to change and implement policies regarding land use and catchment protection. It is also not possible to delineate a timeline for each corrective action. Therefore, instead of substantially restricting activity within the catchment, stakeholders should be sensitized about the need to restrict on activities causing the drinking water source polluted.

In the context of water supplying in developing country, there are some limitation in the allocation of funds for rehabilitation activities, although there is full commitment of the operator and top level management of NWSDB. The coordination of framework for the WSP and the communication between various stakeholders are required a motivation mechanism.

Public health surveillance is of great importance in order to meet health-based targets. Sufficient data regarding water-borne diseases were not available at primary health care centers. More efficient record keeping is needed to identify incidents of disease and quantify the effects of WSP.

## 4 Conclusion and Recommendation

### 4.1 Conclusion

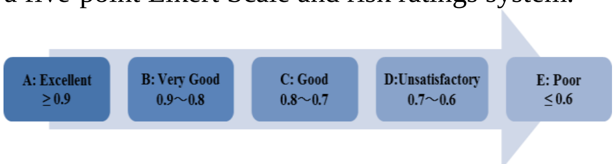
This study describes the process of developing and implementing a WSP for one of the large-piped water supply in Sri Lanka. To introduce the concept of WSP, it was essential to have a key resource person with prior experience in developing WSPs. This experience came from WHO and NWSDB who have formed a group of experts to guide future WSP development in Sri Lanka and steps have been taken to identify and train water supply officials from selected regions.

The findings of the WSP study are being used to prioritize the interventions planned as a part of the activities of operation and maintenance staff. The principles of WSP have been used to make day-to-day operations more efficient and employees more accountable. It has resulted in better communication and incident reporting.

This study revealed certain vulnerabilities in the water supply system, especially within the catchment areas and the support from stakeholders are highly valuable. Further, it was found that there is a lack of consumer awareness regarding point-of-use water treatment and limited availability of health data, which is not conducive to achieving health-based targets. Supporting programs are, therefore, critical to address these issues.

### 4.2 Recommendation

The primary operational characteristic of the WSP is the provision of a water safety index (WSI) which identifies drinking-water safety levels using a five-point Likert Scale and risk ratings system.




The closer a value in the WSI is to 1, the higher its safety grade. The WSI is considered to be a very useful indicator with its advantage of quick understanding of the drinking-water safety level of a water plant and an objective and structured system to identify its weak points or vulnerabilities.

Equations to calculate WSI is as follows:

WSI = (safety rating ratio) - (risk rating ratio)

$$\text{Safety rating ratio} = \frac{\text{total no. of low rating item}}{N}$$

N = total number of assessed WSP check-list items)
Risk rating ratio = (medium ratio) + (high ratio) + (very high ratio)

$$\text{Medium ratio} = \frac{\text{total no. of medium rating item}}{3N}$$

$$\text{High ratio} = \frac{\text{total no. of high rating item}}{2N}$$

$$\text{Very high ratio} = \frac{\text{total no. of very high rating item}}{N}$$

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**References**

[1]. Bartram J. , Corrales L., Davison A., Deere D., Drury D., Gordon B., Howard G., Rinehold A and Stevens M. (2009). Water Safety Plan Manual: step-by-step risk management for drinking water suppliers. World Health Organization (WHO) - International Water Association, Geneva.

[2]. Godfrey, S., & Howard, G. (2004). Water safety plans for piped urban water supplies in developing countries. Loughborough: WEDC.

[3]. Howard, G., Godfrey, S., Tibatemwa, S., & Niwagba, C. (2005), Water safety plans for piped urban supplies in developing countries: a case study from Kampala, Uganda. Urban Water Journal, 2(3), 161–170.

[4]. Mahmud, S. G., Shamsuddin, A. J., Ahmed, A. F., Davison, A., Deere, D., & Howard, G. (2007). Development and implementation of water safety plans for small water supplies in Bangladesh: benefits and lessons learned. Journal of Water and Health, 5(4), 585–597.

[5]. Report of consultancy services for experts and special technical assistance for eastern province water supply development project by Nihon Suido consultant co. ltd.

[6]. Report of the performance, against the design parameters, of the unit processes of the Kondawatuwana water treatment plant by K. Vinothan, NWSDB.

[7]. Sri Lanka Standards Institute, Specification for portable water: SLS 614:2013, physical and chemical requirement.

[8]. Sri Lanka Standards Institute (1985), Sri Lanka Standards (SLS) 722: Tolerance Limits for Inland Surface Waters used as Raw Water for Public Water Supply. Colombo, Sri Lanka: http://www.slsi.lk/.

[9]. Urban water safety planning capacity training Handbook.

[10]. World Health Organization (WHO) (2011). User Manual: Water Safety Plan Quality Assurance Tool. Geneva: World Health Organization (WHO).

[11]. WHO. (2004). guidelines for drinking-water quality (3rd ed.), Geneva: World Health Organization.