DEVELOPING WATER SAFETY PLANS FOR BANGALAWADY WATER TREATMENT PLANT, SAMMANTHURAI, AMPARA

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ABSTRACT

Changes in land use pattern, improper techniques in water treatment process, and changes in the rate of application of agrochemicals and fertilizers have significant impacts on the treated and raw water quality. Therefore, qualitative and quantitative assessments of water quality are required from catchment to consumer to develop sustainable water management procedures, and this can be implemented by "Water Safety Plans" as its primary objective is to ensure drinking water quality from catchment to consumer through a comprehensive risk assessment and risk management procedure. The Bangalawady water treatment plant located in Sammanthurai, at about 13 km away from Ampara town was selected for this study to develop "Water Safety Plan" since it produces 10000 m^3/day of potable water and treated water is distributed to 1800 households who are living nearby areas, namely Sammanthurai, Kalmunai, Sori Kalmunai and Veeramunai. Intake of this treatment plant is located at Weeragoda, 9 km away from treatment plant. This plant is responsible for operating intake, water treatment plant, storage tanks and distribution systems. The treatment processes consist of screening, pre-chlorination, aeration, coagulation and flocculation, sedimentation, filtration with air and water backwashing system and post chlorination. Possible hazardous events were identified from catchment to consumer by questionnaire surveys, field visits and laboratory tests. A risk matrix was developed to identify the severity of residual risks by assigning rating based on likelihood and severity of hazardous events and existing control measures. Based on the ratings, an improvement plan was drawn up to suggest corrective actions to minimize the residual risks by modifying or repairing components of the water supply system.

Keywords: drinking water quality, hazardous events, risk matrix, residual risk, water safety plan

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INTRODUCTION

"Access to safe drinking water is a basic need for human development, health and well-being and because of this it is an internationally accepted human right" (WHO, 2011). Only 2% of water sources available in the world are consumable for drinking and still more than one billion people have lack of access to safe water supplies, a substantial majority of these people are living in Asian countries (Saini et al., 2014). In Sri Lanka, 88% of water-borne diseases were caused due to unsafe water supplies and inadequate sanitation. Moreover, more than 15 districts out of 25 districts have inadequate potable water for consumption (NWSDB, 2010).

According to the report published by National Water Supply and Drainage Board in 2010, pipe-borne water coverage in Sri Lanka is around 34%, and rest of the population depend on local sources, namely wells, hand pump tube wells, small scale rural water supply schemes, rain water harvesting and surface water bodies such as irrigation tanks, canals, streams and springs for drinking and other general needs (NWSDB, 2010). The primary objective of water supply systems is to provide safe drinking water and those systems are influenced by number of factors such as quality of source water, effectiveness of treatment and integrity of the distribution system (Vieira, 2011). Managing water resources and supplying safe drinking water has become a key challenge in the contemporary generation due to highly likelihood of contamination on raw water and treatment processes (Vieira, 2005).

The rural water supply schemes have been provided to the communities in Sri Lanka hence water is easily accessible to consumers at the most of locations. However, ensuring the quality of water is really challengeable, since there are possibilities of contamination on treated water, as well. Therefore, the main objective of this study is develop Water Safety Plans (WSPs) to adapt for Bangalawady water treatment plant, located at Sammanthurai to ensure contamination free on treated water by comprehensive risk assessment and risk management procedure.

The diagrammatic overview of key steps involved in developing WSPs is depicted in Figure 1. Among the five key steps stated in Figure 1, much more attention need to be given to identify and establish qualified and dedicated teams who have substantial knowledge and experience on water abstraction, all water treatment unit processes, distribution network systems and identification of multiple hazards from catchment to the point of consumption (Bava, 2015).

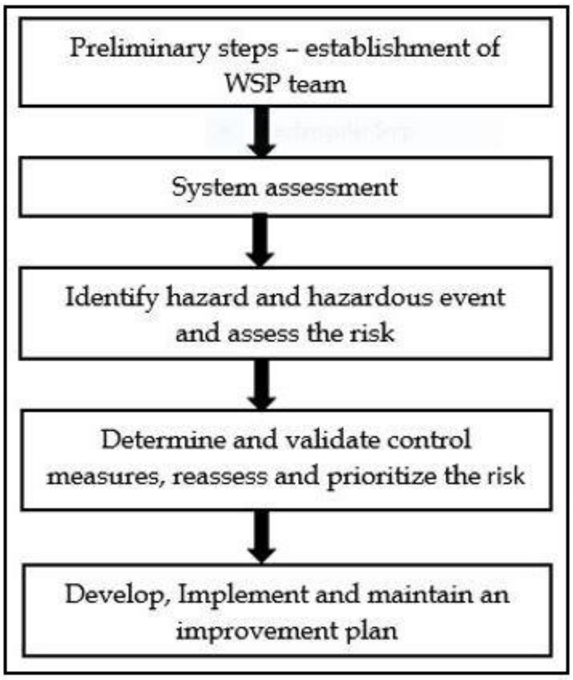

Figure 1. Key steps in the development of the water safety plans (WHO, 2011)

MATERIALS AND METHODS

Study Area

The Bangalawady water treatment plant located at Sammanthurai, at about 13 km away from Ampara town was selected for the study since it is one of the main water treatment plant located in the south eastern part of Sri Lanka which produces 10,000 m^3/day of potable water and treated water is distributed to 1,800 households who are residing adjacent areas, namely Sammanthurai, Kalmunai, Sori Kalmunai and Veeramunai (NWSDB, 2010). Intake of this treatment plant is located at Weeragoda, 9 km away from treatment plant as depicted in Figure 2. This plant is responsible for operating intake, water treatment plant, storage tanks and distribution systems.

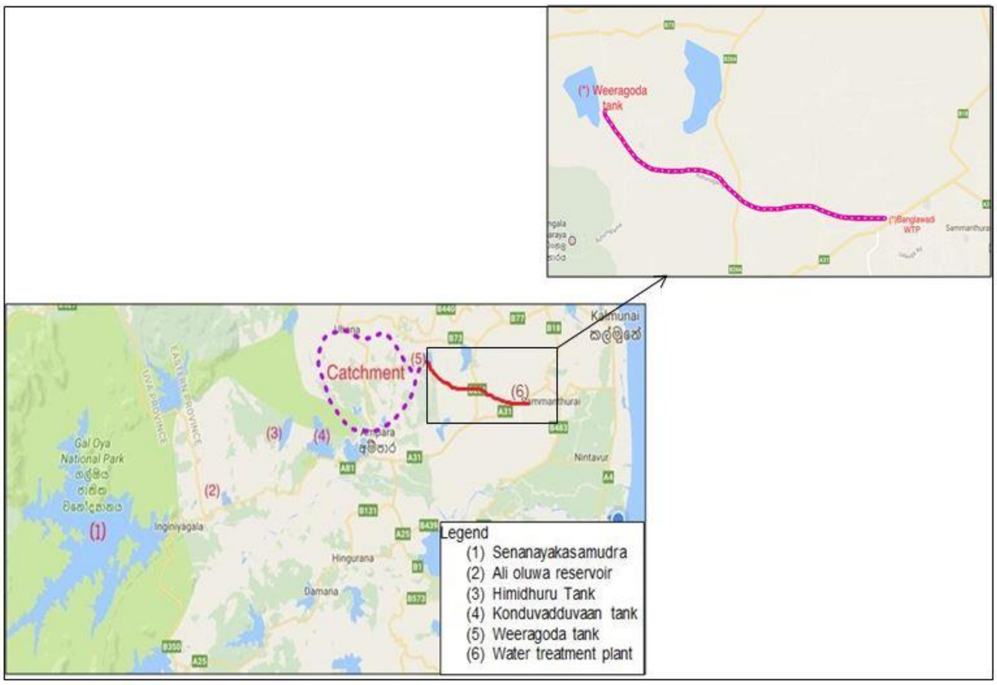

Figure 2. Location of Catchment of intake and water treatment plant

Development Plan

The specific WSP plan for Bangalawady water treatment plant was developed based on the guidelines stipulated by experts of World Health Organization (WHO) and the manual of water safety plan (Bartram et al., 2009). This was a modified approach to deal with the specific conditions found in this drinking water supply system. Higher contamination at intake area, limited testing facility, unplanned development, and lack of consumer awareness are some of the key issues pertaining to Bangalawady water treatment plant and the information presented in this paper could be useful to developers facing similar challenges, since these issues are common to several other water treatment plants as well.

System Assessment

Weeragoda tank, which is the main intake of this treatment plant receives water from Senanayaka samudraya through ‘Ali Oluwa’ reservoir, Himidurawa tank and Kondavattavana tank. Thereafter, water is conveyed to treatment plant from Weeragoda tank by lined canals. The Bangalawady treatment plant performs different unit processes namely, screening, aeration, pre-chlorination, coagulation and flocculation, sedimentation, filtration with air and water backwashing system and post- chlorination to purify the water conveyed from intake. Eventually, the treated water is transmitted to overhead tanks and subsequently distributed to households. Schematic diagram of whole network processes of water treatment from intake to distribution network are depicted in Figure 2.

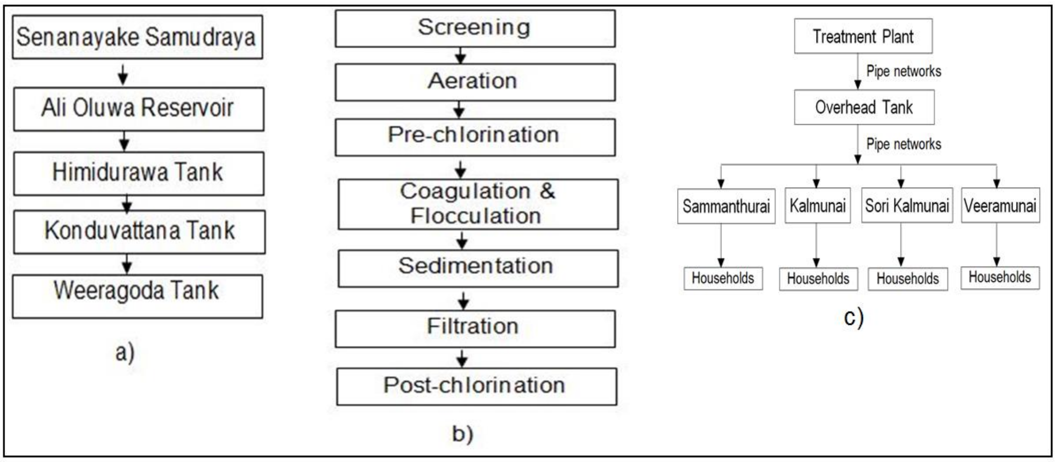

Figure 2. Overall processes from intake to consumers. a) Water conveyance to Intake; b) Treatment unit processes; c) Distribution network

Test results of water quality parameters, namely Turbidity, Colour, pH, Chloride, Sulphate, Nitrate and iron were obtained from Bangalawady treatment plant for 2 year periods (01st January 2017 - 31st December 2018) to identify the hazards associated with treatment process and assess the seasonal variation of water quality parameters received from intake.

Hazard Identification

All types of hazards, namely micro biological, physical and chemical associated with each step in the water supply scheme from catchment to the point of consumption were identified by distinct techniques: Hazards within the catchment area were identified by field visits, land use patterns and household sanitary surveys; Hazards within treatment plant were identified by means of performing water quality testing, visual inspection and with the assistance of staff attached to the treatment plant; Hazards associated with distribution network were identified by field visits and questionnaire survey which was carried out to around 200 randomly selected households who are residing in Sammanthurai, Kalmunai, Sori Kalmunai and Veeramunai.

Hazard Assessment

The risks associated with each hazard and hazardous event were analysed by identifying the likelihood of occurrence (e.g., rare, likely, almost) and evaluating the severity of consequence if the hazard occurred (e.g., insignificant, minor compliance impact, catastrophic public health impact) (Deere et al., 2005). Each hazard was scored using a semi-quantitative approach proposed by Deere et al. (2001) and subsequently residual risk was calculated by multiplying both scores of likelihood and severity as shown in Table 3.

Validation of Controls Measures

The effectiveness of existing control measures, which can be activities or processes were validated by reviewing the monitoring records, field inspections and manufacturer's specification. Moreover, technical data from scientific literatures and WHO guidelines were also used in the validation processes. In the final risk matrix as shown in Table 1 and Table 2, risks were categorized as low, medium, high and very high in terms of their potential impacts on water supply system to deliver safe drinking water to consumers.

Improvement Plan

Existing risk mitigating measures and developed risk matrix were used to develop the improvement plans. Improvement plans which consist of different time frame of control measures, namely short, medium and long-term were proposed for each significant uncontrolled risk where the existing control measures were ineffective. These improvement plans were mainly identified for hazardous events, which have "very high" and "high" risk rating; nevertheless, those plans can also eliminate the other less significant (medium and low) risks. Residual risk of each hazardous event was recalculated, taking the new proposed control measures into account.

RESULTS AND DISCUSSION

Potential sources of hazards, hazard type and newly proposed measures together with risk rate, which was calculated in terms of likelihood and severity using semi-quantitative risk matrix approach proposed by Deere et al. (2001) for water treatment plant, and intake and distribution networks are presented in Table 1 and Table 2 respectively .

Table 7. Risk matrix with risk rate and improvement plan (Water Treatment Plant)

No	Hazardous event/ Source of hazard	Associated hazards and issues to consider	Hazard type	Risk			Risk rating with considering existing controls	Proposed Controls	Possible validation	Risk			Risk rating with considering proposed controls
				L	C	S				L	C	S	
1	No proper gas leakage identification method in chlorine cylinder storage room	Chlorine gas leakage is harmful to surrounding inhabitant, failure of treatment plan	Chemical & Physical	5	5	25	**Very high**	Purchasing and replacing the equipment (ammonium torch)	Regular equipment maintenance and replacement records	1	5	5	Low
2	Damaged depth gauge - used to measure the water depth in storage tank	Loss of control	Physical	2	4	8	Medium	Purchasing and replacing the equipment	Regular equipment maintenance and replacement records	1	4	4	Low
3	Seasonal variation	Huge change in source water	Chemical & micro-	4	5	20	Very high	Construction of pre settlement tanks with high	Maintain historical rainfall data,	2	5	10	Medium

		quality	biological					retention time for the intake of source water.	continuous monitoring of intake				
4	Water treatment process units are open to air	Contamination by wildlife, paddy stews and cottons fall in to the treatment process units	Physical & Chemical	3	5	15	High	Fencing, locking premises.	Regular site inspection, Adopting rapid repairing procedures	1	5	5	Low
5	Damaged timber barrier in the coagulation tank	Inadequate treatment and (/or mixing) untreated water (with treated water)	Physical	2	5	5	Medium	Reconstruction of coagulant tank with appropriate material	Equipment maintenance and replacement records	1	5	5	Low
6	Manual machine handling and no warning system	Loss of treatment work, communication failure and loss of control	Physical	4	4	16	High	Proper machine handling, continuous monitoring with alarms.	Purchasing policy and procedures, trained staff and continuous monitoring with alarm	2	4	8	Medium

Table 2. Risk matrix with risk rate and improvement plan (Intake and Distribution networks)

No	Hazardous event/ Source of hazard	Associated hazards and issues to consider	Hazard type	Risk			Risk rating with considering existing controls	Proposed Controls	Possible validation	Risk			Risk rating with considering proposed controls
				L	C	S				L	C	S	
1	Inadequate screen size and blocked in existing screen	Inadequate particle removals	Physical & Micro-biological	3	5	15	High	Reduce the screen size (use appropriate screen size)	Equipment maintenance and replacement records	1	5	5	Low
2	Human assess – disposing dead animals, domestic solid waste and washing vehicles	Potential loss in the quality of source water due to contamination	Chemical & Micro-biological	4	5	20	Very high	Restricted access to catchment and fencing	Regular catchment inspection, public education	2	5	10	Medium

3	Direct septic tank and toilet discharge by settlers residing nearby the catchment area	Fecal contamination in the source water	Chemical & Micro-biological	4	5	20	Very high	Awareness program among public, Introduce toilet systems for dwellers in catchment,	Collaboration with Environmental Authority and make awareness program among public	2	5	10	Medium
4	No back up during power cut	Interrupted treatment / loss of disinfection	Physical.	4	4	16	High	Stand-by generators	Equipment maintenance and replacement records	1	4	4	Low
5	Famers make unauthorized connection in water transmission pipe lines. (Distribution Network)	Contamination by backflow	Physical.	2	4	8	Medium	Protecting pipe lines	Regular site inspection	1	4	4	Low

Table 3. Semi-quantitative risk matrix (Deere et at., 2001)

	Severity or consequences					
Likelihood		Insignificant or not	Minor complian	Moderated	Major regulator	catastrophic public health
	Rare (R:1)	1	2	3	4	5
	Unlikely (R:2)	2	4	6	8	10
	Moderate (R:3)	3	6	9	12	15
	Likely (R:4)	4	8	12	16	20
	Almost certain (R:5)	5	10	15	20	25

Risk score	< 6	6 – 10	11 – 15	>15
Risk rate	Low	Medium	High	Very high

Assigning ratings of Likelihood and Severity to each identified hazards were carefully decided with the help of technical staffs of treatment plant and intake by considering water quality test data, existing control measures, field inspection and questionnaire surveys. Eventually, risk matrix was calculated by multiplying both ratings.

CONCLUSION AND RECOMMENDATION

Conclusions

The hazards identified (Table 2) in the catchment and intake are primarily caused by prevailing anthropogenic activities in the vicinity of raw water source such as discharge of grey and black water from households, discharge of solid waste from animal farm and horticulture, and agrochemicals from paddy fields. Therefore, rainfall runoff is contaminated, leading to potential contamination of source water. Preventive measures of those aforesaid anthropogenic activities can be implemented by educating people who are residing in the proximity of raw water source thereby reducing contamination and protecting water quality of raw water.

The hazards identified (Table 1) in the water treatment plant are mainly caused by improper maintenance and handling of instruments, delaying on repairing and replacing instruments when they are out of order. Moreover, there is no backup plan during power cut which causes complete interruption of water supply.

A very few numbers of hazards were identified in distribution network compared to intake and treatment plant. Consumers' behavior plays a vital role on contamination in the distribution network and their improper handling and storage can also lead to recontamination of water. For instance, even though the potable water supplied is free from contamination, it may get contaminated as a result of people dipping their hands into the stored water, lack of hygiene in the household and the storage containers being accessible to children.

Recommendations

The WSP study is carried out only considering catchment of Weeragoda tank, which is the intake of Bangalawady treatment plant. However, Weeragoda tank receives water from Senanayaka samudraya through Ali Oluwa reservoir, Himidurawa tank and Kondavattavana tank. Therefore, it is better to carry out a study to aforementioned water bodies also which would reduce the hazards accumulating to Weeragoda tank. Moreover, hazards in the distribution line were identified by questionnaire survey which was carried out to only 10% of total households. Therefore, expanding questionnaire surveys to more number of households would give a much better results.

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