Development and implementation of Water Safety Plan at peri-urban village in India: A case study

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***Abstract*-- Water Safety Plan is a risk based approach to reliably deliver safe drinking water to end-client. The approach emphasizes on system assessment, identification of hazards, use of simple indicators to monitor control points and periodic verification. A WSP was developed for a peri-urban village Bhendala. This study discusses the step-by-step tasks undertaken to promote improvement in water quality, quantity and awareness among community and suggest appropriate actions required to safeguard public health from contaminated water-related risks. Be the risks identified, this study suggests there is need to give continuous assistance to the local water management team for the maintainability of the WSP.**

Key words -- Water safety plan, hazards, contaminated water, water safety

I. INTRODUCTION

Burden of diarrheal diseases is often reported to be related to consumption of unsafe water, inadequate sanitation and unhygienic practices accounting approximately 2.2 million deaths per year worldwide (Pandey et al 2014; Wazny et al., 2013). Diarrhea alone accounts for 9% of total deaths among children below age five (Carvajal-vélez et al., 2016; Liu et al., 2015). In India, each year 300 000 children die because of diarrheal illness on consumption of contaminated water (Nandi et al 2017). Number of observational and inadequately randomized studies conveyed that improved water supply and sanitation reduces incidence of diarrheal disease (Mudau et al., 2017).

Water Safety Plan (WSP) is one such framework developed by World Health Organization (WHO) reliably deliver safe drinking water to end-client (Davison et al., 2006). Formulated on the concept of hazard analysis critical control point (HACCP), WSP includes three key steps: System assessment, Operational monitoring and Management and Communication. Risk assessment and management plays an important role in providing safe water to consumers (Rickert et al, 2014). Assessing risks and asserting systematic management and corrective measures prevent contamination of water during distribution (Vieira, 2005). Although this is predominantly adopted in the urban areas, it is equally important to apply the approach in the small communities. With the emphasis of GoI to implement piped water supply scheme in rural areas, it is essential to ensure water supplies as per the prevailing drinking water quality standards. Water safety plan can be equally effective in different socio-economic settings as well as various sizes of water supply and distribution systems (Davison et al., 2006). WSP can be applied to remote communities which often lack capacity for management, operation and maintenance and have limited financial resources. WSP provides a reliable framework for such communities to identify the sources of contamination and focus on cost effective management of its water supplies.

Although household water treatment safe storage (HWTS) system is associated with WSP in the urban areas as the possibilities of recontamination within the urban households is usually low, complementarity of WSP and HWTS is not fully developed. Treating water at the household is one of the most effective means of preventing water borne diseases in particularly in rural areas. Advocating HWTS helps vulnerable population to be responsible for their own water safety and security by providing them with knowledge and tools to treat their own drinking water. Lack of water security and intermittent water supply in rural areas leave no option other than storing water for longer duration. Thus, makes it difficult to ensure microbiological quality of drinking water at the point of consumption.

This study presents the tasks undertaken to develop and implement Water Safety Plan in an open-defecation free village and highlights the critical risks that contribute to contamination of water.

II. METHODOLOGY

STUDY SITE

The study site was Bhendala (21°21'39"N, 79°0'52"E) village in Savner Tehsil of Nagpur district. The village is spread over an area of 7.56 km^2 with a population around 1114 (Census 2011) and 244 households. Bhendala had piped but intermittent water supply network. For ease of maintenance and monitoring WDS, village was divided in three zones: Zone A, B and C. Village also had Village Water and Sanitation Committee (VWSC) for maintenance of WDS and sanitation practices at Bhendala. The village was also awarded by GoI for having 100% latrine coverage and not practicing open defecation.

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WATER SAFETY PLAN APPROACH

SYSTEM ASSESSMENT

The water supply network at Bhendala is designed to supply water to 250 households. Main water source is 18 feet deep dug well having a 5m diameter. The water is then pumped to two Elevated service reservoirs (ESRs) having capacity 20000L and 10000L capacity. Water is treated with bleaching powder at ESR and then supplied to household taps. Currently, the village has intermittent water supply and water is supplied for 3-4 hours every day. Baseline water quality assessment was done by collecting samples from water source, ESR, and individual households. Water sample collection was done as per Standard methods (APHA, 2012). Bacteriological water samples were collected in sterile polypropylene bottles containing sodium thiosulphate. Samples were analyzed for pH, turbidity, residual free chlorine, total coliforms and thermotolerant coliforms.

HAZARDOUS IDENTIFICATION

Potential hazard and hazardous events throughout water distribution chain were identified on the basis of visual inspection and observations, surveys, document verification and experts' opinion. Additionally, household sanitary survey was conducted to comprehend water handling practices, overall sanitation and hygiene and water usage practices.

RISE ASSESSMENT

Identified hazards were ranked using a semi-quantitative risk approach. Each hazard was scored and prioritized based on the basis of their rank as described by Davidson et al (2006). Risk score was product value of likelihood and consequence. The perceived and structured risk scores were mainly focused on identifying vulnerabilities and threats that affect water quality.

IDENTIFICATION AND VALIDATION OF CONTROL MEASURES

Control measures are steps that ensures the water consistently meets the water quality targets. These are activities and processes applied to reduce or mitigate risks. Field visits and water quality monitoring were done to check the existing control measures.

IMPROVEMENT PLAN

An improvement plan was drawn up considering the risks identified in risk matrix. The plan addressed risks that rated extreme, very high and high as these required urgent measures to be taken. The improvement plan was formulated using experts' opinion.

III. RESULT AND DISCUSSION

HAZARD IDENTIFICATION AND RISE ASSESSMENT

WSP constitutes assessment of catchment, source and distribution network, taps and storage vessels at individual houses (Ezenwaji & Phil-Eze, 2014). Our study identified potential risks at every stage of water distribution system at Bhendala which is elucidated in following section.

SOURCE

Major hazard identified at source was uncovered but fenced dug well. This can contaminate water by bird/animal fecal dropping, dust, dirt and rainfall. Also, agricultural fields are in immediate vicinity of the dug well, increasing the chances of contamination of water by runoff of pesticides and herbicide during heavy rainfall. Contamination due to lack of maintenance and corrosion of pipes is proliferated due to intermittent supply. Majority of hazards could be prevented by covering the dug well and involving local authorities for monitoring and maintaining water quality being supplied to the village. Table 1 also lists the corrective actions needed to be undertaken to ensure safety of drinking water.

TABLE I
Risk Matrix for Dug Well

Sr. No	Potential hazards or hazardous events	Hazard category	Risk profile	Basis	Is control measure in place	Control measure	Risk band	Improvement Plan	PI* risk
1	Contamination by dust/dirt as dug well is uncovered	M, C	E	observed by WSP team	No	-	VH	Intake well needs to be covered	L
2	Low level of residual chlorine in water	M	VH	Field analysis	No	-	M	Disinfection should be done	L
3	Contamination due to Vandalism or sabotage	M, P, C	L	observed by WSP team	Yes	fenced dugwell	L	Accessibility should be restricted	L
4	Contamination due to percolation of contaminated stagnant water near the well	M	M	observed by WSP team	No	-	H	Cleaning protocol for draining of stagnant water	M
5	Contamination due to poor maintenance (e.g. leaking pipes, cracks)	M	H	observed by WSP team	Yes	monitoring by VWSC staff	H	evaluate the performance of hired agency	M

**PI - Post- Implementation*

ESR

Visual and sanitary inspection was conducted by WSP team to assess the potential hazards near ESR. Water quality results indicated variation in the microbial contamination. ESR showed no visible signs of corrosion or damage. Stagnant water with insects was visible in the area near ESR. Table 2 highlights the major hazards observed at ESR and states the suggested control measures and improvement plan.

DISTRIBUTION NETWORK

The highest numbers of uncontrolled risks are identified in the distribution network and at the consumer interface. Most of the hazards occur due to low pressure created in the pipes because of intermittent supply. Bhendala has open sewer/storm water drains and crossing of water supply pipelines and sewer are some of the causes of contamination of treated water supply. It was observed that sewage flows through open drains and drinking water pipeline near such drains are prone to contamination. Upon discussion, gram panchayat has taken the decision to replace the open drains with closed sewer networks to further improve the sanitary conditions of the village. Pipes beneath these roads are vulnerable to breakages/bursts and leakage due to corrosion.

At crossing with open drains, water supply pipelines are beneath sewer and possibility of contamination is very high. Table 3 shows the list of hazards identified throughout the distribution network in Bhendala and also lists the corrective measures for each hazard.

TABLE II
Risk Matrix for ESR

Sr No	Potential Hazards or Hazardous Events	Hazard category	Risk Profile	Basis	Is Control Measure in Place	Control Measures	Risk Band	Improvement Plan	PI* risk
1	Ingress of contaminants due to leaking pipes	M, C	H	Visual observation	Yes	Repair and Maintenance	M	Monitoring program to check condition of WDS	L
2	Poor cleaning schedule may result in built up of sediments and sludge	M, C	M	observed sediment buildup	No	Repair and Maintenance	M	Criteria to evaluate the performance of hired agency	L
3	Biofilm formation on the reservoir wall	M	M	Biofilm observed	No	-	M	Disinfection unit should be installed	L
4	Microbial growth due to low chlorine	M	E		No	-	E	Disinfection unit should be installed	M

*PI - Post- Implementation

TABLE III
Risk Matrix for Distribution System

Sr. No	Potential Hazards or Hazardous Events	Hazard category	Risk Profile	Basis	Is Control Measure in Place	Control Measure	Risk band	Improvement Plan	PI* risk
1	Improper designing of WDS resulting in low pressure houses	M, C	VH	visual inspection by WSP team	No	-	VH	VWSC should consult engineer	M
2	Breaks, leaks or damages to pipes along the distribution lines	M, C	VH	visual inspection by WSP team	Yes	VWSC has appointed team	H	Internal Auditing to check on condition of WDS	M
3	Contaminants entering WDS due to pipe leakage during repair	M, C	VH	visual inspection by WSP team	No	-	VH	Following good practices while repairing pipeline	H
4	Contamination of water by open drains carrying grey water near supply line	M, C	E	visual inspection by WSP team	No	-	VH	Conversion of open to closed grey water conveyance system	M

*PI - Post- Implementation

HOUSEHOLD TAPS AND STORAGE

Major hazard identified was that most households had taps below the ground level as water pressure is very low. As a result, water accumulation was observed near the tap. In most houses a flexible pipe was connected to tap during the supply time. This practice increase chances of water loss and contamination of water at the supply end. Some households let the water flow from the pipes for the entire supply period while some clip the flexible pipe to prevent water loss. Another common practice of villagers was to use cloth for filtering water.

Water storage practices was similar in all households. Water was stored in earthen and steel pots and was placed on ground. Most common observation was people directly dipped bowls or containers to extract water from storage vessel. Table 4 lists the potential hazards identified at taps and during storage.

TABLE IV
Risk Matrix for Household Tap And Storage

Sr No	Potential Hazards or Hazardous Events	Hazard category	Risk Profile	Basis	Is Control Measure in Place	Control Measures	Risk Band	Improvement Plan	PI* risk
1	Tapping by end users without knowledge and proper supervision of the village plumber		H	visual inspection by WSP team	Yes	VWSC is responsible for maintenance	H	Monitoring of illegal connection should be done.	M
2	Taps are located below ground level		VH	visual inspection by WSP team	No	-	H	VWSC should consult engineer	L
3	Water logging near tap		H	visual inspection by WSP team	No	-	H	Awareness campaign should be organized	M
4	Algal growth in the pipes used to fill storage vessel		E	visual inspection by WSP team	No	-	E	Awareness campaign should be organized	M
5	Storage vessel close to open drain		E	visual inspection by WSP team	No	-	E	Awareness campaign should be organized	M
6	Unhygienic near storage vessel		H	visual inspection by WSP team	No	-	H	Awareness campaign should be organized	L

PI*- Post implementation

CONTROL MEASURES

Control measures help in reducing the existing risks and thereby minimizing the chance of contamination leading to a deteriorated water quality at the receiving end. Control measures are activities to reduce or mitigate risk in any step within the drinking water supply to ensure consistent water quality as per requirements. Existing control measures were listed alongside each potential hazard in the WSP risk matrix (refer table 1-4). In order to identify control measures, the WSP team conducted site visits to assess the various components of the water supply system. These included visits to ESR, dug well and random households. Discussions were held with VWSC and other officials concerned with water supply of Bhendala to obtain more information regarding existing controls in place to ensure water quality.

IMPROVEMENT PLAN

Prioritized residual risks due to ineffective or lack of control measures, an improvement / upgrade plan is suggested by the WSP team. The hazardous events that pose Extreme, very high and high risks in the Risk matrix have been addressed in the improvement plan as well. The improvement plan includes program such as awareness for consumers; training for operators; enhanced communication among all stakeholders and infrastructure improvement including repair/maintenance.

MANAGEMENT AND SUPPORTING PROGRAM

Contamination of public water supplies threatens the health of society consuming the water from that source. Maintaining acceptable conditions requires an ongoing effort at all conditions. Proper management help in reducing the existing risks and thereby minimizing the chance of contamination leading to a deteriorated water quality at the receiving end. Important policy decisions should be taken for upgrading the existing infrastructure and maintaining the water quality.

IV. Conclusion

Supply of safe clean drinking water is vital to maintain public health. Effective means for ensuring water safety is through risk assessment and management approach starting from catchment to storage vessels at households. Using WSP approach, present study could identify risks factors affecting water quality throughout the distribution network. Intermittent water supply and poor maintenance of distribution network were identified as the major hazards causing entry of fecal coliforms in potable water. Minor risks were successfully addressed and immediate corrective measures were adopted. Be that as it may, this study suggests there is need to give a continuous assistance and guidance to local water management team for the maintainability of the WSP.

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VI. References

American Public Health Association (2012). Standard methods for the examination of water and wastewater. Rice EW, editor. Washington, DC: American Public Health Association; 2012 Jan.

Carvajal-Vélez, L., Amouzou, A., Perin, J., Maïga, A., Tarekegn, H., Akinyemi, A., Shiferaw, S., Young, M., Bryce, J. and Newby, H. (2016). Diarrhea management in children under five in sub-Saharan Africa: does the source of care matter? A Countdown analysis. *BMC Public Health*, *16*(1), p.830.

Davison, A., Deere, D., Stevens, M., Howard, G., & Bartram, J. (2006). Water safety plan manual. *World Health Organization, Geneva, Switzerland*, 3-34.

Ezenwaji, E. E., & Phil-Eze, P. O. (2014). Water Safety Plan as a Tool for Improved Quality of Municipal Drinking Water in Nigeria. *Journal of Environmental Protection*, *5*(11), 997.

Liu, Y., Zheng, Y., Liang, Y., Liu, S. and Rosenblum, D.S. (2016). Urban water quality prediction based on multi-task multi-view learning.

Mudau, L. S., Mukhola, M. S., & Hunter, P. R. (2017). Systematic risk management approach of household drinking water from the source to point of use. *Journal of Water, Sanitation and Hygiene for Development*, *7*(2), 290-299.

Nandi, A., Megiddo, I., Ashok, A., Verma, A., & Laxminarayan, R. (2017). Reduced burden of childhood diarrheal diseases through increased access to water and sanitation in India: A modeling analysis. *Social Science & Medicine*, *180*, 181-192.

Pandey, P. K., Kass, P. H., Soupir, M. L., Biswas, S., & Singh, V. P. (2014). Contamination of water resources by pathogenic bacteria. *Amb Express*, *4*(1), 51.

Rickert, B., Schmoll, O., Rinehold, A., & Barrenberg, E. (2014). Water safety plan: a field guide to improving drinking-water safety in small communities.

Vieira, J. M. (2007). Water safety plans: methodologies for risk assessment and risk management in drinking-water systems. *Iahs Publication*, *310*(310), 57-67.

Wazny, K., Zipursky, A., Black, R., Curtis, V., Duggan, C., Guerrant, R., Levine, M., Petri Jr, W.A., Santosham, M., Scharf, R. and Sherman, P.M. (2013). Setting research priorities to reduce mortality and morbidity of childhood diarrhoeal disease in the next 15 years. *PLoS medicine*, *10*(5), p.e1001446.

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