Climate Resilient WSP Document with Hazards Analysis Report

Development and implementation of climate resilient water safety plan in vulnerable rural communities: WHO-WSP Project

PRACTICAL ACTION
Technology challenging poverty

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Executive Summary

The project areas have 3 different geographical locations including flood, coastal and drought which are always susceptible to climatic effects. Planning for safe water supply in the long term is set in the context of external uncertainties arises from the climatic and environmental effects. Considering this broader issues of climate change, **Region specific c**limate resilient **WSP** guidance has been developed with a view to create more sense among rural community, users, caretakers, mechanics, development practitioners, water supply staff and others regarding hazard types, their sources, risks rating, control measures, monitoring system and plan of improvement. WSP guideline is based on climatic and environmental hazard analysis and their impacts of water points. The information has been collected through conducted literature review, KAP baseline survey, water quality test, sanitary inspection, consultation with relevant stakeholders and observations on existing water points at union and upazilla level.

The geophysical characteristic of the project locations (Faridpur, Pirojpur, Barguna and Naogaon) locations include flood, coastal and drought that are susceptible to climatic effects. There are 10 types of water sources in these areas including SHTW (Deep set HTW), DHTW, community water supply using deep aquifer, RWHS, PSF, RW, AIRP; HH based arsenic removal filter, direct pond and river. Out of these water options, SHTW is common in all 3 regions. Impacts on the water sources due to the climate change include increased/decreased precipitation, sea level rise, tidal surges, drought proneness, changed normal maximum/ minimum temperature, changed wind speed and direction, water quality reduction by microbial, chemical and physical contamination are found common in all areas except riverine flood in flood prone areas, depletion of water table in drought and saline intrusion in coastal areas. **Associated impacts on health** include arsenicosis patient found dominating in flood prone areas, and diarrhea patients especially children and female found more in coastal and drought prone areas which is due to lack of capacity, behavior change and alternative safe water sources. **The report also explains the hazards vs risk** rating from low to very high on the basis of likelihood, severity and potential effects on human health by the biological, chemical and physical hazards found in water sources and HH storage.

Region specific control measures against risk for each type of technologies have been prepared along with monitoring and improvement plan. Also some alternative solutions have been proposed that will guide people to undertake decision before the installation of water facilities. For example, reverse osmosis or PSF are suggested as suitable water option for coastal areas, arsenic and iron removal filter for flood prone areas and deep set hand tube well or rain water harvesting system in drought prone areas.

Supporting programmes including development/re-printing of communication and awareness raising materials, facilitation of training and social mobilization events for WSP has been done with a view to ensure community, mass people, caretakers, technician, mason, project staff, organization staff and related public and private staff for understanding WSP and influence of their actors. The materials include sticker, leaflet, bill board, sign board, WSP pocket booklet, WSP calendar, WSP training manual etc. A management plan has also been developed considering corrective measures and contingency plan relating to physical (Turbidity), chemical (Arsenic) and microbial hazards potentially affecting water points

1. Introduction

This report describes the process of hazard analysis, risk prioritization, control measures, improvement plan and operational monitoring, supporting programme and management plan for each geographical location. The focus of attention has been given on the impacts of climate change and environment and seasonal variations like flood, cyclone and drought on water sources. As per WHO guidelines for drinking water quality in 2004, recommended that Water Safety Plans (WSPs) should be introduced in all water supplies as a key component of water safety management. With general WSP, the requirement of climate resilient WSP came forward and with the support from WHO and related stakeholders has been developed and implementing to increase the water security and safety by engaging community, DPHE, LGIs, department of health and education, NGOs, private sector and local entrepreneurs.

The analysis has been done based on the findings of water options exits in 6 (4 coastal, 1 flood and 1 drought prone union) unions of 4 upazillas under 4 districts. The information's have been collected through consultation, workshop, site visit, interview, sanitary inspection, water quality test, desk work and literature review with main focus on bacteriological, chemical and physical hazards influenced by environmental and climatic parameters.

From the analysis it is revealed that in flood prone areas main hazardous event is flood that causes microbial and chemical (arsenic and iron), in drought prone areas depletion of water table (Over abstraction of water for irrigation) and microbial and in coastal areas excessive saline intrusion in ground water and microbial contamination.

The operational monitoring of control measures and improvement plan has been developed digitally and information collection by applying mobile Aps by engaging relevant stakeholders like DPHE, Department of education, health, NGOs, entrepreneurs. This experience provides the sector with an understanding as to how to do the hazardous analysis, develop and implement climate resilient WSPs including its replication at scale and the modifications that may be required for scaling up.

This will also support and guide practitioners, academia, implementers, researchers, private entrepreneurs and policy makers in understanding the importance of climate resilient WSPs and the process steps required to implement WSPs in different geographical locations. They will also understand and interpret the advantages and challenges including the areas of improvement. The technology vs climate specific hazard analysis, control measure, improvement plan and operational monitoring has also been done in details and reported as Annex (1-3).

2. Objectives

- ✓ To identify and analyse all potential biological, chemical and physical hazards associated with each steps of the water supply system (Source to consumption) in different geographical location that affect the safety of drinking water.
- ✓ To assess risk and its prioritization, possible control measures
- ✓ To develop an improvement plan for increasing water security and safety hazard monitoring framework

3. Methodology

Hazardous analysis, risk analysis and control measures consisted of site visit, desk analysis and literature review. Visual inspection and observations of aspects such as the area surrounding abstraction points revealed hazards. Hazard identification also included assessment of historic information and events.

4. Area Wise Climate Resilient WSP Guidelines with Hazard Analysis

The project has been dealt with 3 different geographical locations and 10 types of water options are being used by the users, their hazards, risks and impacts due to the environmental and climatic hazards. According to KAP baseline survey, there are 813 water options (DTW 24; SHTW 357 including Deep set HTW 71; Ring well 48; RWHS 24; Onsite Water Supply 7; PSF 57, AIRP –20, HH based arsenic removal filter -18 & Pond/River 258) are used by the 810 sampled HH. Sanitary inspection of the said sources was done and water qualities of the 10% of the sources were tested by using field test kits.

4.1.1. Coastal Area

Annual maximum temperature increased is 0.5ºC and highest increment of minimum temperature is 0.3ºC. The trend of maximum temperature increasing and minimum temperature decreasing which is 0.113/decade and -0.046/decade respectively. The significant rates of increment per hundred years 3.7°C. The significant trends of minimum temperature per hundred years are decreasing which is 3.8°C. Significant negative deviations of rainfall are found -38% in Barisal region. Which consequences reduced freshwater flows combined with increased sea levels have led to the results being anticipated like increased salinization of surface and ground waters, increased inundation of coastal freshwater wetlands and lowlands, and reduced quality of water supply.

Salinization was predicted to increase in coastal belts for two reasons. Firstly, rising sea levels was expected to lead to upcoming of sea water in coastal aquifers, threatening the use of those aquifers for drinking water supplies. Secondly, drought reduces the flow of water to river mouths allowing seawater to intrude further inland. For these situations, desalination is considered to cope with future seawater intrusion events, exacerbated by climate change **(Ref. KAP baseline survey report).**

Increased saline concentration leads to increase treatment costs for salt removal that make the water source abandoned for using drinking and cooking purposes. Also tidal surge overwhelm saline

water, faecal sludge and waste water containment system that influence the saline and pathogenic contamination of the susceptible water sources.

Due to the lack of accessibility and availability of safe water sources, people somewhere are using water direct from pond and river for their drinking purposes. Out of that, very few people are using water after alum coagulation as treatment in their HH storage.

In coastal area, there are 5 types of water sources are being used by the people which are given in the below table 4.1.

Table 4.1: Type of water sources

Sl. No.	Source of Water	Broad Category
1	SHTW	Ground water
2	PSF	Surface water
3	Pond	
4	River	
5	RWHS	Rain water

In the coastal area, due to the climate change impact on the existing water sources, a risk assessment and control measures have been done on the basis of the source and type of hazards that are given in the below table 4.2. The above sources of water facilities have been diveded into three broad categories include ground water, surface water and rain water.

Table 4.2: Assessment of Risk by using semi-quantitative approach and Control Measures

Water source	Hazardous event (Source of Hazards)	Hazard Type	Likelihood	Severity	Score	Risk Rating (Before consideration of Control)	Control Measures
Ground water	Sea level rise, tidal surges and less rainfall reduces the flow of water, so sea water intrude underground	Chloride	2	5	10	High	• Mixing with the sources of low chloride content. • Alternative water source i.e. RO, MAR, ultrafiltration, desalinization
Surface water (Pond and river)	Cyclone, high tide	Chloride and microbial	1	5	5	Low	• Protection of pond • Introduce PSF • Introduce individual water purification/disinfection for both pond and river water
Rain water	Cyclone with tidal surges	Physical and microbial	1	5	5	Low	• Protection of water reservoir during cyclone

On the basis of the above control measures, a drinking water quality improvement/upgrade plan and short-term and long –term operational monitoring plan has been developd and explained in the below table.

Table 4.3: Drinking water quality improvement/upgrade plan and operational monitoring plan

Source of water	Hazards	Control measure	Improvement/upgrade plan	Accountabilities	Operational monitoring plan
Ground water	Salinity/ Chloride	• Mixing with the sources of low chloride content i.e. rain water, pond water • Alternative water source i.e. RO, MAR, ultrafiltration, desalinization	• Increase recharging into the aquifer for the dilution of salinity up to drinking water quality standard • Install treatment plant or alternative water option like RO, desalination plant, ultrafiltration	• DPHE • LGIS • Community	• Chloride test by using field kit @ monthly
Surface water (Pond and river)	Chloride and Microbial	• Protection of pond • Introduce PSF • Introduce individual water purification/disinfecti on for both pond and river water	• Renovate/construct pond embankment • Install PSF • Develop water purification/disinfecti on system for both pond and river water treatment	• DPHE • LGIS • Community	• Chloride test by using field kit @ half yearly • Sanitary inspection @ weekly • Residual chlorine @ daily
Rain water	Physical and microbial	• Protection of water reservoir during cyclone	• Tie up reservoir with the strong support • Seal all openings/entrances of the reservoir	• Community/ owner	• Sanitary inspection @ daily • E.coli test @ half yearly

4.1.2. Flood Prone Area

Annual maximum temperature increased is 0.5ºC and highest increment of minimum temperature is 0.3ºC. The trend of maximum temperature increasing and minimum temperature decreasing which is 0.138/decade and 0.259/decade respectively. The significant rates of increment per hundred years are 3.6°C. The significant trends of minimum temperatures per hundred years are increasing 2.6°C. Significant negative deviations of rainfall are found -14% at Faridpur **(Ref. KAP baseline survey report).**

The effects of climate change on water quality in flood prone area; one of the greatest challenges for water supply is flood and precipitation that impacted on water sources through inundation and overwhelming waste water and faecal containment systems. There is evidence from records that climate change is already increasing the frequency of extreme wet days and addressing the resultant water quality impacts under these conditions have not been undertaken, it is likely that increased pollutant loads would be found.

Issues associated with flooding will become more significant with the anticipated result including increased inflows to and pressure on water storage infrastructure, more intense storms, increased sediment and nutrient concentrations, disrupting drinking water supplies and sanitation systems and

cutting off towns. Increased temperature is leading to proliferation of bio-hazards (Algae, Pathogens) and more intense precipitation events are often associated with reduced short-term water quality.

During flood the situation become worse in many folds due to the inundation of toilet and faecal materials are released from the containment, as most of the toilets were built below the flood level. Health's impacts are prevailing due to these hazards are diarrhoea, dysentery, skin diseases.

In flood prone area, there are 5 types of water sources are being used by the people which are given in the below table -04. Dominating options are Shallow tube well which is mostly arsenic contaminated. Few DHTW were found but difficult to install due to the presence of bed rock **(Source: DPHE).**

Due to the lack of accessibility and availability of safe water or alternative water sources, people **(Including documented and undocumented arsenicosis patient)** of someplace are still using arsenic contaminated tube well water for their drinking and cooking purposes.

Table 4.4: Type of water sources

Sl. No.	Source of Water
01	SHTW
02	DHTW
03	AIRP
04	RW
05	HH based AS filter

In the flood prone area, due to the climate change impact on the existing water sources, a risk assessment and control measures have been done on the basis of the source and type of hazards that are given in the below table 4.5. The above sources of water facilities have been diveded into one broad category which is ground water.

Table 4.5: Assessment of Risk by using semi-quantitative approach and Control Measures

Water source	Hazardous event (Source of Hazards)	Hazard Type	Likelihood	Severity	Score	Risk Rating (Before consideration of Control)	Control Measures
Ground water	Flood, precipitation and inundation	Physical, microbial and chemical	2	5	15	High	• Flood proof tube well and latrine. • New Tube well in an arsenic free aquifer. • Alternative water source i.e. Arsenic removal filter, AIRP

On the basis of the above control measures, a drinking water quality improvement/upgrade plan and short-term and long –term operational monitoring plan has been developd and explained in the below table.

Table 4.6: Drinking water quality improvement/upgrade plan and operational monitoring plan

Source of water	Hazards	Control measure	Improvement/upgrade plan	Accountabil-ities	Operational monitoring plan
Ground water	Physical, microbial and chemical	• Flood proof tube well and latrine. • New Tube well in an arsenic free aquifer. • Alternative water source i.e. Arsenic removal filter, AIRP	• Renovate/install flood proof tube well and latrine • Install new tube well in arsenic free aquifer • Install or renovate alternative water source i.e. Arsenic removal filter, AIRP	• DPHE • LGIS • Community	• E.coli test @ Annually • Physical (Turbidity) test @ half yearly • Chemical (As, Fe,) test @ half yearly • Sanitary inspection @ weekly • Observation @daily

4.1.3. Drought Prone Area

The amounts of rainfall decreased and highest increment of minimum temperature is 0.3ºC. The trend of maximum temperature increasing and minimum temperature decreasing which is 0.068/decade and -0.008/decade respectively. The significant trends of minimum temperatures per hundred years are decreasing 2.3°C. Significant negative deviations of rainfall are found -14% **(Ref. KAP baseline survey report).**

These changes in temperature and rainfall are predicted to continue and will result in the increased occurrence of drought with the anticipated results including reduced inflows to water storage, reduced recharge rate of ground water, increased risk of algal blooms, reduced stream flows in major catchments.

Low flows and reduced water levels tend to increase the concentration of pollutants and nutrients and cause longer term poorer water quality. Pollutant concentrations increase when conditions are drier and water quality was negatively influenced by summer droughts. Increased water temperatures in the water supply system may lead to increased microbiological activity and increased health risks to consumers.

Drought impacted on water sources through ground water depletion, less precipitation and lowering water table in peak dry period which often leads to inactive most of the SHTW and needs ponding during abstraction of water. This also increased dependence on potentially less safe alternative water sources and limit people to use of safe water for doing hygienic practice especially after the use of toilet and before feeding their children. As a result, health's impacts are prevailing including diarrhoea, dysentery.

In drought prone area, there are 3 types of water sources are being used by the people which are given in the below table 4.7. Dominating options are Deep Set HTW.

Table 4.7: Type of water sources

Sl. No.	Types of option
01	Deep Set HTW
02	DHTW
03	RW

In the drought prone area, due to the climate change impact on the existing water sources, a risk assessment and control measures have been done on the basis of the source and type of hazards that are given in the below table 4.8. The above sources of water facilities have been divided into one broad category which is ground water.

Table 4.8: Assessment of Risk by using semi-quantitative approach and Control Measures

Water source	Hazardous event (Source of Hazards)	Hazard Type	Likelihood	Severity	Score	Risk Rating (Before consideration of Control)	Control Measures
Ground water	Drought, lowering water table/water table depletion	Physical and microbial	2	5	10	High	• Introducing Deep set HTW. • Reducing over abstraction of water and increasing recharge • Alternative water source i.e. RWHS, Ring Well

On the basis of the above control measures, a drinking water quality improvement/upgrade plan and short-term and long –term operational monitoring plan has been developd and explained in the below table 4.9

Table 4.9: Drinking water quality improvement/upgrade plan and operational monitoring plan

Source of water	Hazards	Control measure	Improvement/ upgrade plan	Accountabilities	Operational monitoring plan
Ground water	Physical and microbial	• Introducing Deep set pump. • Reducing over abstraction of water and increasing recharge • Alternative water source i.e. RWHS, Ring well	• Renovate/install Deep set HTW • Install or renovate alternative water source i.e. RWHS, Ring Well • Conduct social mobilization activities	• DPHE • LGIS • Community	• E.coli test @ Annually • Physical (Turbidity) test @ half yearly • Sanitary inspection @ weekly • Observation of water use in multipurpose including irrigation and its management @ weekly

5. Supporting Programmes

Supporting programmes provide a valuable opportunity to build institutional and individual capacity of users, caretakers, water supply mechanics, water suppliers and other stakeholders to manage risks associated with water scarcity and reliability (in addition to water quality risks) that influence by the climate change effects including flood, drought and saline intrusion. These programmes are used to bring together stakeholders from different disciplines to support to managing water resources, for more resilient water supplies. Training, community mobilization, orientation, inception, communication materials development, liaison and networking has been done under this programme and gradually mentioned in the below sub sections:

5.1.1. List and Type of communication and awareness materials

The project was introduced below communication and awareness raising materials mostly in pictorial forms which are easy to understand by the rural community people regarding the type of hazards and its impact on water quality and public health and how to cope and make climate resilient water safety plan (WSP). The materials were customized by fitting with the local context and under process of reprinting for the targeted beneficiaries and stakeholders.

The target beneficiary communities were organized and shared the matrix of both climatic and environmental hazards in pictorial forms including seasons, intensity, impacts.

List and type of materials:

- WSP HH checkboard for the beneficiaries to monitor water safety measures undertake from source to consumption regularly
- Pocket book (Water option wise) for the users to understand hazards with their water sources and what need to do for improvement
- Leaflet for the mass people to get information about the WSP
- Bill board and signboard for wider dissemination of the WSP related information
- WSP manual on operation and maintenance for the caretakers to improve their skill and guide them as and when need
- WSP manual for the project staff for their training and improve understanding
- Sticker for displaying water quality test result for the water users to understand the status and undertake corrective measures against any hazards found in the sticker
- Reflective sticker on arsenic, 5 steps from source to consumption, 5 major issues
- Video documentary (60 second) for Local Cable TV network
- Community radio (60 second) only use audio part from developed Video documentary for cable TV network

5.1.2. Description of community mobilization interventions

Awareness campaign

The project organized awareness campaign for WSP to mobilize community people to take necessary measures against hazardous condition from point water sources to water consumption at hh level during disaster and normal period. A Significant number of people around 1,329,451 (Table 5.1) attended in these activities including day observance, courtyard meetings, folk songs, bill board, cable TV network, consultation, group discussion and drama which covered gender, age, occupation, institution, location, and economic class. The campaign programmes have been facilitated by trained field mobilizer with coaching and mentoring support of zonal staff of the project. They delivered the sessions addressing water quality issues, steps of water safety plan (source to consumption), effects of climate/disaster and mitigation measures, responsibilities of community people and the different institutions.

Table 5.1: Beneficiaries were reached by awareness campaign

Sl	Activities	Quantitative Progress			Beneficiaries		
		Target	Achievements	Remaining Target	Total Beneficiaries	Male	Female
1	Observe World water day (Rally, miking)	6	6	0	105000	47244	57756
2	Courtyard meeting	241	149	92	2163	511	1652
3	School session	102	63	36	3396	1527	1869
4	Religious institution based discussion	58	40	11	2086	1569	517
5	Cable TV network for WSP message dissemination	17	5	12	20000	8999	11001
6	Pot and folk song, Jaari Gaan	6	1	5	300	150	150
				Total	**132945**	**60000**	**72945**

World water day

The community people observed world water day on March 22, 2017 in the 6 unions with participation of Union Parishad Chairman, Member, Female Members, DPHE representative, Health Assistant, Family Planning Assistant, and Family Welfare Worker working at Union level, Students, and community people. The communities organized rally, miking, and discussions on the issue of waste water and water safety plan. More than 105,000 people attended these sessions where 1100 were female.

Courtyard Meeting

Community people with different age group of female attended the courtyard meetings. Union facilitators conducted the sessions and discussed on the issues of water safety plan including safety of water source, collection, transportation, preservation, and use. They also discussed on climate resilient WSP issues, and the responsibilities of household members. During reporting period more than 2,163 people enhanced their knowledge on WSP.

Mobility Map

A mobility map/diagram has been developed by the community about multidimensional path of getting services (from where, whom, cost etc.) for mitigating their problems (i.e. individual, HHs, Community, Village, Union, Upazila & District level as well).

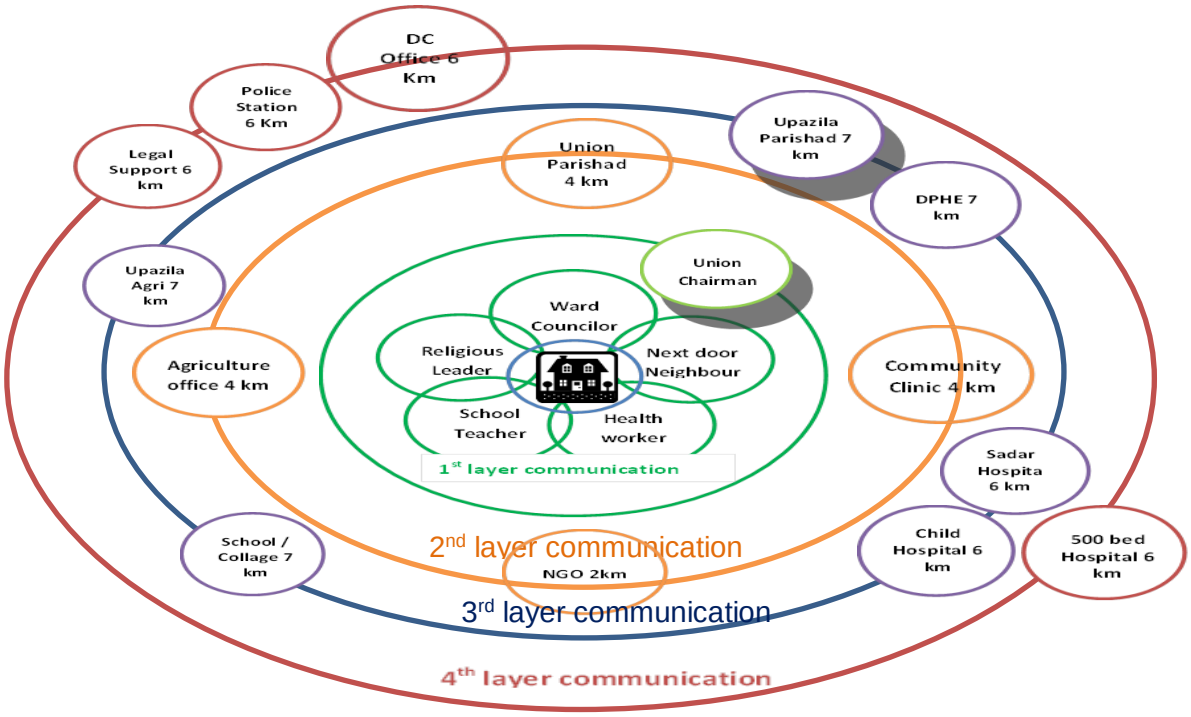


Figure C: Relationship & Networking (Mobility) Map of Aliabad Union Community

School Session

More than 3300 school students attended the sessions on Water Safety Plan including handwashing practices, contamination sources of water from source to consumption, health effects and taking corrective measures.

Religious institution based discussion

Union facilitators conducted 40 sessions on WSP where 2080 students of Madrasha attended to improve understanding and knowledge. They have a plan to replicate this among their mates, neighbours and families.

Pot, folk song, and drama

A local cultural event like Pot, folk song and drama on the WSP issues was organized in the community where around 300 people both male, female and children were attended and gathered information and messages that increased their responsibility and commitment.

Cable TV Network

The project is broadcasting video documentary on WSP messages through local cable network at four areas in reaching out to people of four Upazilla's as a recreation mechanism as well as purposive achievement of the project. To date around 20,000 people was reached by this event and they are able to tell about the safe water, hazards and hazardous event and take actions against the hazards.

Households visit

The project was local leaders who have strong acceptability to communities and voluntary mentality and oriented them as change agent to visit neighbours and counselling on the importance of water safety and making their water points safe and resilient. They have done this successfully.

Bill board and sign board

The project is under process to build 4 bill boards in four Upazilas and 6 sign boards for 6 unions put key message with photos and place it close to public places (terminal, highway road side, hat bazar, tourist spot) which is most convenient to attract mass people to see and learn.

Mass gathering

In addition to this, Practical Action was organized six mass gatherings sessions at respective Unions for awareness resining. These events were very effective in communicating hygiene messages and changing their attitudes.

5.1.3. Training

Orientation and training has been given to the project staff, water point operators, tube well mechanics, DPHE field staff, users, union health staff on climate resilient WSP to improve their understanding and skill. Now they are scaling up this learning to their regular practice, operation and maintenance and neighbours.

5.1.4. Engagement of stakeholders

Stakeholders including DPHE, department of health, education, LGIs, WatSan committee, private sectors, and local entrepreneurs are engaged with this climate resilient WSP programme to mainstream this within their current ongoing programme for dissemination, leveraging resources, monitoring and follow up and linking with private sectors and local entrepreneurs for future support.

The above social mobilization, capacity building and networking activities on climate resilient WSP from water source to the HH storage have created some visible and tangible changes of behavioural practice, ownership and planning of the community and other stakeholders. Few examples of changes are given below through some pictorial presentation.

At Water Source

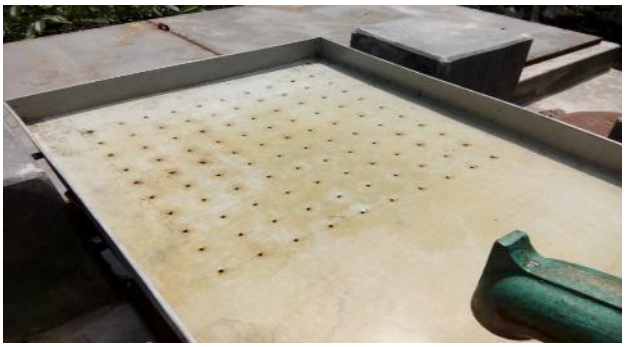
The user of the SHTW renovate the platform after getting information and motivation on WSP from the project

Before

After

The users of the below Arsenic Iron Removal Plant (AIRP) became aware about the importance of WSP and they are improving their practice of operation and maintenance and hygienic practice of its use.

Before



After

The below users of the Ring well became aware about the hygienic use of their water options i.e. surrounding cleanliness, waste, waste water

Before

After

At HH storage

Before

At HH storage no cover was used by the user

After

Now users are gradually improving their hygiene practice

Water Transportation

The water user became motivated about the importance of WSP through orientation, courtyard session and folk song, now she is practicing hygienic issue from collection to consumption.

Before

After

6. Management Plan/ Procedures

Some abnormalities were detected in the water distribution system (Source to HH storage) through conducting regular monitoring, observation and follow up and responded through corrective action to ensure the continuity of safe water being supplied, therefore, timely response is an important consideration. For some control measures, such as disinfection against E.coli, chlorination with proper dosing, reducing chloride content and arsenic and reducing turbidity and the monitoring may need to be on-line and may require instantaneous corrective action in response to a deviation.

The corrective actions and contingency plan for physical (Turbidity), chemical (Arsenic) and microbial hazards due to occurring climatic hazardous events including flood, drought and sea level rise/cyclone that potentially affecting water points are illustrated for selected control measures in Table 6.1

Table 6.1: Corrective measures and contingency plan relating to physical (Turbidity), chemical (Arsenic) and microbial hazards potentially affecting water points

Control measures	Critical limit	Monitoring	Corrective Action	Contingency plan
Maintain sanitary integrity of the services and safety from flood and tidal surges from microbial and physical (Turbidity) contamination	All vents, openings and inspection covers maintained according to the critical limits	Sanitary inspection, turbidity and chlorine residual testing by users, caretakers or water quality control staff	All vents, opening and inspection covers immediately repaired on sign of damage and all operators/ caretakers/users trained to ensure the renovation works	Facilities for emergency response like chlorination, repair and maintenance make available at site where the chance of contamination
Maintain protection from cyclone, tidal surges and sea level rise for saline contamination	Chloride content within limit and good quality water, no community complain	Chloride content testing by users, caretakers or water quality control staff	All openings repaired and filter media immediately changed or renovated by the owners/operators or water control staff	Facilities for emergency response like filter materials, repair and maintenance make available at site where the chance of contamination
Maintain regular performance of arsenic and iron filter	Arsenic concentration within limit (50 ppb), no complain from the community	Arsenic and iron content testing by users, caretakers or water quality control staff	Filter media immediately changed or renovated by the owners/operators or water control staff	Facilities for emergency response like filter materials, repair and maintenance make available at site where the chance of contamination

Annex -1: Technology wise hazard analysis in Flood prone Area

Along with the climatic hazard in flood prone area, there are some environmental hazards that impacted on the water sources and HH storage as well. The technology wise hazard matrix, their risk analysis, control measures, operational and monitoring plan are given in the below sub annexes (Annex1.1 to 1.3)

Annex -1.1: Water option wise Hazard Matrix

Sl #	Source of Water	Option wise hazards								
		As+ (ppb)	Fe	E. Coli (#/100ml)	Mn mg/L	NO_3 mg/L	Turbidity NTU	pH	Chlorine mg/L	Chloride mg/L
	Options									
1	SHTW	√	√		√			√		
2	Ring Well		√	√		√		√		
3	DHTW	√	√					√		
4	AIRP	√	√					√		
5	HH based filter									
	At storage									
1	Water at HH storage			√		√	√			

Annex -1.2: Assessment of Risk by using semi-quantitative approach measures

Water source	Hazardous event (Source of Hazards	Hazard Type	Likelihood	Severity	Score	Risk Rating (Before consideration of Control)	Basis
SHTW	Natural process in underground water-oxidation/reduction theory	Arsenic	2	5	10	High	Potential disease of arsenicosis
	Natural process in underground water	Iron	2	4	8	Medium	Potential disease like dysentery and aesthetic problem
	Natural process by increasing temperature, dissolved minerals and wastes	pH	4	2	10	High	Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation
	Manganese occurs naturally in many surface water and groundwater sources	Mn	2	4	8	Medium	At concentrations exceeding 0.1 mg/l, the manganese ion imparts an undesirable taste to beverages and stains

							plumbing fixtures and laundry.
DHTW	Like SHTW	Arsenic	2	5	10	High	
		Iron	2	4	8	Medium	
		pH	4	2	10	High	
Ring Well	Like SHTW	Iron	2	4	8	Medium	
	Inundation, no/faulty platform, side leaching, lack of safe separation distance from latrine	E.coli	2	5	10	High	
	Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks.	NO_3	2	4	8	Medium	Potential effects called Methaemoglobinaemia, causes cyanosis
	Like SHTW	pH	4	2	10	High	
AIRP	Lack of functionality of treatment process	Arsenic	2	5	10	High	
	Lack of functionality of treatment process	Iron	2	4	8	Medium	
	Like SHTW	pH	3	2	6	Medium	
HH storage	Water point, collection, transport without cover, Storage in a dirty and wet place without cover and clean pot	E.coli	5	5	25	Very high	
	Contaminated water point	Turbidity	2	4	8	Medium	
	Contaminated water point	NO_3	2	4	8	Medium	

Annex -1.3: Control measures, operational monitoring and improvement plan

Sl#	Hazardous event (Source of Hazards)	Existing Control Measures	Suggested Control Measures	Operational monitoring plan	Improvement plan
1	Natural process in underground water for Arsenic contamination-oxidation/reduction theory	No specific control measures	• Use alternative water sources including Rain Water Harvesting (RWHS), reverse osmosis (RO) treatment • Abstract water from less contaminated source • Use multiple sources to dilute pollutant	• Water quality test @ six month interval from source and distribution point of treatment plant by using field test kit • Monitor cleaning of the treatment plant and management of residuals @ 15 days interval but it depends on quality of raw water	• Install/renovate alternative water sources like RWHS, AIRP, HH arsenic removal filter, RO • Introduce less contaminated source • Make people aware to use multiple water sources
2	Natural process in underground water for Iron contamination	No available control measures	• Alternative water source like RWHS, treatment plant including AIRP, HH based water filter, RO	• Conduct regular inspection and observation by using indigenous practice i.e. Guava leafs are used to identify the presence of iron • Water quality test @ six month interval from source and distribution point of treatment plant by using field test kit • Monitor the pumping of water into the plant before collection daily • Monitor cleaning of the treatment plant and residuals management	Install/renovate alternative water sources like RWHS, AIRP, HH removal filters, RO
3	Natural process by increasing temperature, dissolved minerals and wastes for pH contamination	No available control measures	• Introduce enhance treatment i.e. RO • Select cooler place as site for the water point installation • Dilution of water with low pH water	• Monitor the operation and maintenance (O&M) of the treatment plant on monthly • Sanitary inspection on weekly • Water quality test of treatment plant on weekly by using pH meter	• Renovate treatment materials with its proper O&M • pH adjustment by reducing temperature i.e. install water point at cooler place • Install RO

4	Manganese occurs naturally in many surface water and groundwater sources	No available control measures	• Use alternative water source like RWHS, HH based water filter, RO • Abstract source water from depths that minimize concentration of pollutants • Optimize existing treatment to remove arsenic	• Monitor O&M of the treatment plant on monthly basis • Water quality test at inlet and water distribution point of treatment plant on quarterly basis by using field test kit	Install/renovate alternative water source like RWHS, treatment plant including RO, HH based filter, AIRP
5	Inundation causing wastewater containment, treatment and management systems to become less effective and greater transport of manure from grazing animals that influences/contributes to E.coli contamination	• Temporary defenses around sensitive locations i.e. raised water options considering highest flood level • Contingency plans for closure i.e. alternative water source, chlorination, purification, boiling • Increase setback distance from water point to storage of faecal matter		• Enhanced monitoring during and after a flood • Sanitary inspection daily • Water quality test during the event weekly but post event six monthly	• Renovate water option above the flood level • Ensure availability of alternative water source, water purifying tablet, bleating powder and boiled water
6	No/faulty platform, side leaching contribute to deteriorate the water quality especially the microbial contamination (E.coli)	• Improve water points with proper renovation • Minimize the dumping of waste near to the water point • Improve filtration process of treatment plant		• Sanitary inspection daily • Water quality test on monthly basis • Monitor O&M of filter media and treatment process on monthly	• Install/Renovate water options • Install lining or wrapping with coarse sand outside of the ring well • Make people aware to minimize the dumping of waste
7	Lack of safe separation distance from latrine contribute to deteriorate the water quality especially the microbial (E.coli) contamination	• Ensure the safe separation distance from water point to toilet (More than 10m)		• Sanitary inspection weekly • Water quality test @ six monthly	• Install/ Renovate latrine more than 10m from water point • sealing pit with lining

8	Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks.	No available protection	• Use alternative water options like RWHS, filter media, RO treatment plant • Abstract water from deeper or better confined aquifer	• Sanitary inspection weekly • Water quality test @ six monthly by using field test kit	• Install/ Renovate alternative water option like RWHS, HH based filter, RO. • Install / renovate deep aquifer with casing
9	Lack of functionality of treatment process for Arsenic contamination in case of AIRP	• Optimize existing treatment to remove arsenic i.e. Aeration, filtration • Introduce enhance treatment i.e. reverse osmosis		• Proper O&M of filter materials • Water quality test @ six monthly by using field test kit	• Install/ Renovate alternative water option like RWHS, RO • Replace or proper maintenance of filter materials and its working principles
10	Lack of functionality of treatment process for Iron contamination in case of AIRP	• Optimize existing treatment to remove arsenic i.e. Aeration, filtration • Introduce enhance treatment i.e. reverse osmosis		• Proper O&M of filter materials @ 15 days interval but varying with raw water quality • Water quality test @ six monthly by using field test kit	• Install/ Renovate alternative water option like RWHS, HH based filter, RO • Replace or proper maintenance of filter materials and working principles of AIRP
11	E.coli contamination at HH storage due to unhygienic practice at all steps of water value chain including water point, collection, transport without cover, storage in a dirty and wet place without cover and clean pot	• Ensure hygienic practice at all steps from source to consumption i.e. washing water pot, use cover during transportation and storage, keep pot at dry, elevated and clean place • Minimize the dumping of waste near to the water point		• Sanitary inspection weekly • Proper monitoring of hygienic practice at all 5 steps • Water quality test @ six monthly by using field test kit	• Renovate water pot • Renovate the place where store water at HH level • Make people aware to use cover and clean water pot prior water collection

12	Contaminated water point due to intense precipitation causing greater erosion of lands and loads from urban storm water that influences / contributes to turbidity at HH storage	• Collect water from safe source or use alum coagulation/ water purification tablet like aqua sure tablet • Collect water from source into cleaned water pot		• Sanitary inspection weekly • Proper monitoring of hygienic practice in water pot and source water daily • Water quality test @ six monthly by using field test kit	• Make users aware to clean water pot daily prior collection • Make available alum coagulant or water purification tablet • Install / renovate alternative water source or filter media like RWHS, HH based filter, RO

Annex -2: Technology wise hazard analysis in drought prone Area

Along with the climatic hazard in drought prone area, there are some environmental hazards that impacted on the water sources and HH storage as well. The technology wise hazard matrix, their risk analysis, control measures, operational and monitoring plan are given in the below sub annexes (Annex2.1 to 2.3)

Annex -2.1: Water option wise Hazard Matrix

Sl	Water Source	Option wise hazards								
		As+ (ppb)	Fe	E. Coli (#/100ml)	Mn mg/L	NO_3 mg/L	Turbidity NTU	pH	Chlorine mg/L	Chloride mg/L
1	Deep Set HTW			√			√	√		
2	Ring Well			√			√	√		
3	Point Water Supply (DHTW)							√		
	At storage									
1	Water at HH storage			√						

Annex -2.2: Assessment of Risk by using semi-quantitative approach measures

Water source	Hazardous event (Source of Hazards	Hazard Type	Likelihood	Severity	Score	Risk Rating (Before consideration of Control)	Basis
Deep Set HTW	Reduced inflows to water storage, reduced recharge rate of ground water, increased risk of algal blooms	E.coli	2	5	10	High	Potential Illness from bacteria
	Entering fine sand	Turbidity	2	4	8	Medium	High turbidity obstruct the disinfection process that leads to microbial contamination and potential impacts on health. Create aesthetic problem.
	Natural process by increasing temperature, dissolved minerals and wastes	pH	3	2	6	Medium	Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation

DHTW	Like Deep Set HTW	pH	3	2	6	Medium	
Ring Well	Faulty platform, side leaching, lack of safe separation distance from latrine	E.coli	4	5	20	Very high	
	Entering fine sand through side leaching	Turbidity	5	3	15	High	
	Like Deep Set HTW	pH	4	2	10	High	
HH storage	Water point, collection, transport without cover, Storage in a dirty and wet place without cover and clean pot	E.coli	5	5	25	Very high	

Annex -2.3: Control measures, operational monitoring and improvement plan

Sl#	Hazardous event (Source of Hazards)	Existing Control Measures	Suggested Control Measures	Operational monitoring plan	Improvement plan
1	Reduced inflows to water storage, reduced recharge rate of ground water, increased risk of algal blooms due to drought by natural process that influence or contribute to E.coli contamination	No specific control measures	• Use alternative water options like RWHS, filter media	• Sanitary inspection monthly • Water quality test @ six monthly	• Install alternative water sources like RWHS, filter media
2	Faulty platform, side leaching contribute to deteriorate the water quality especially the microbial contamination (E.coli)	• Install/renovate platform of water point • Introduce lining or wrapping with course sand outside the water point specially for ring well • Minimize the dumping of waste near to the water point • Improve filtration process of treatment plant / filter media		• Sanitary inspection daily • Water quality test @ monthly • Monitor the operation and maintenance of filter media and treatment process on monthly basis	• Install/Renovate water options • Install lining or wrapping with coarse sand outside of the ring well • Replace or maintenance of filter materials of treatment plant / filter media • Make people aware to minimize the dumping of waste
3	Lack of safe separation distance from latrine contribute to deteriorate the water quality especially the microbial (E.coli) contamination	• Ensure the safe separation distance from water point to toilet (More than 10m)		• Sanitary inspection weekly • Water quality test on six monthly basis	• Install/ Renovate latrine more than 10m from water point • sealing pit with lining

4	Entering fine sand through side leaching into the water point that influence and contribute to turbidity contamination	• Use lining or wrapping of course sand round the water point especially for ring well • Use filter with deep set pump • O&M of filter materials • Use alum coagulation	• Use alternative water source like rain water harvesting system, reverse osmosis	• Sanitary inspection weekly • Water quality test @ six monthly • O&M of filter materials @ 15 days but depends on raw water quality	• Renovate Ring well/deep set pump • Clean / remove filter materials • Introduce alum coagulant
5	Natural process by increasing temperature, dissolved minerals and wastes for pH contamination	No available control measures	• Introduce enhance treatment i.e.RO • Select cooler place as site for the water point installation • Dilution of water with low pH water	• Monitor O&M of the treatment plant @ monthly • Sanitary inspection weekly • Water quality test @ weekly basis by using pH meter	• Renovate treatment materials with its proper operation and maintenance • pH adjustment by reducing temperature meaning install water point at cooler place or dilution by using low pH water
6	E.coli contamination at HH storage due to unhygienic practice at all steps of water value chain including water point, collection, transport without cover, storage in a dirty and wet place without cover and clean pot	• Ensure hygienic practice at all steps from source to consumption i.e. washing water pot, use cover during transportation and storage, keep pot at dry, elevated and clean place • Minimize the dumping of waste near to the water point • Ensure the safe separation distance from water point to toilet (More than 10m)		• Sanitary inspection weekly • Proper monitoring of hygienic practice at all 5 steps • Water quality test @ six monthly by using field test kit	• Renovate water pot • Renovate the place where store water at HH level • Make people aware to use cover and clean water pot prior water collection

Annex -3: Technology wise WSP in Coastal Area

Along with the climatic hazard in coastal area, there are some environmental hazards that impacted on the water sources and HH storage as well. The technology wise hazard matrix, their risk analysis, control measures, operational and monitoring plan are given in the below sub annexes (Annex3.1 to 3.3)

Annex -3.1: Water option wise Hazard Matrix

Sl	Water Source	Option wise hazards								
		As+ (ppb)	Fe	E. Coli (#/100ml)	Mn mg/L	NO_3 mg/L	Turbidity NTU	pH	Residual Chlorine mg/L	Chloride mg/L
1	SHTW	√	√	√				√		√
2	Pond			√			√	√		
3	PSF							√		
4	RWHS							√		
5	River						√	√		
	At storage									
1	Water at HH storage			√			√			

Annex -3.2: Risk analysis and control measures

Water source	Hazardous event (Source of Hazards	Hazard Type	Likelihood	Severity	Score	Risk Rating (Before consideration of Control)	Basis
SHTW	Tidal surge, no/faulty platform, lack of safe separation distance from latrine	E.coli	3	5	15	Very high	Potential Illness from bacteria
	Natural process in underground water-oxidation/reduction theory	Arsenic	2	5	10	High	Potential disease of arsenicosis
	Natural Process, manmade, lack of underground recharge vs abstraction, sea level rise, intrusion of seawater into fresh ground water aquifers	Chloride	2	4	8	Medium	Potential corrosion of metals into the distribution system, taste problem

	Natural process in underground water	Iron	2	4	8	Medium	Potential disease like dysentery and aesthetic problem
	Natural process by increasing temperature, dissolved minerals and wastes	pH	2	2	4	Low	Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation
RWHS	Natural process by increasing temperature and wastes	pH	3	2	6	Medium	
PSF	Like RWHS	pH	3	2	6	Medium	
Pond	Not protected, fish culture, bathing, waste disposal	E.coli	5	5	25	Very high	
	Not protected, waste disposal, bank erosion.	Turbidity	5	3	15	High	
	Like RWHS	pH	4	2	8	Medium	
River	No control, different sources	Turbidity	5	5	25	Very high	
	Temperature, dust, waste	pH	5	3	15	High	
HH storage	Water point, collection, transport without cover, Storage in a dirty and wet place without cover and clean pot	E.coli	5	5	25	Very high	
	Unsafe water point i.e. pond, river	Turbidity	5	3	15	High	

Annex -3.3: Control measures, operational monitoring and improvement plan

Sl#	Hazardous event (Source of Hazards)	Existing Control Measures	Suggested Control Measures	Operational monitoring plan	Improvement plan
1	sea level rise, cyclone and tidal surges Increased Salinity / Chloride content in underground water by Natural Process	No specific control measures	• Use alternative water source like RWHS, RO, Pond Sand Filter (PSF) • Dilution with low saline water	• Sanitary inspection monthly • Proper monitoring of operation and maintenance of treatment plant or filter media @ 15 days but depends on raw water quality • Water quality test @ six monthly by using field test kit	• Install/renovate alternative water sources like RWHS, PSF, RO treatment plant
2	Natural process in underground water for Arsenic contamination-oxidation/reduction theory	No specific control measures	• Use alternative water sources including RWHS, RO treatment • Abstract water from less contaminated source • Use multiple sources to dilute pollutant	• Water quality test @ six month interval from source and distribution point of treatment plant by using field test kit • Monitor cleaning of the treatment plant and management of residuals @ 15 days interval but it depends on the raw water quality	• Install/renovate alternative water sources like RWHS, AIRP, HH arsenic removal filter, RO treatment • Introduce less contaminated source • Make people aware to use multiple water sources
3	Natural process in underground water for Iron contamination	No available control measures	• Alternative water source like RQHS, treatment plant including AIRP, HH based water filter, RO	• Conduct regular inspection and observation by using indigenous practice i.e. Guava leafs are used to identify the presence of iron • Water quality test @ six month interval from source and distribution point of treatment plant by using field test kit • Monitor regularly the pumping of water into the plant before collection • Monitor regular cleaning of the treatment plant	Install/renovate alternative water sources like RWHS, treatment of ground water by AIRP, HH removal filters, RO

4	Natural process by increasing temperature, dissolved minerals and wastes for pH contamination	No available control measures	• Introduce enhance treatment i.e. RO • Select cooler place as site for the water point installation • Dilution of water with low pH water	• Monitor O&M of the treatment plant on monthly basis • Sanitary inspection @ weekly • Water quality test of treatment plant @ weekly by using pH meter	• Renovate treatment materials with its proper O&M • pH adjustment by reducing temperature meaning install water point at cooler place • Install RO
5	Cyclone and tidal surge causing wastewater containment, treatment and management systems to become less effective and greater transport of manure from grazing animals that influences/contributes to E.coli contamination	• Temporary defenses around sensitive locations i.e. raised water options considering highest flood level • Contingency plans for closure i.e. alternative water source, chlorination, purification, boiling • Increase setback distance from water point to storage of faecal matter		• Enhanced monitoring during and after cyclone and tidal surges • Sanitary inspection daily • Water quality test during the event weekly but post event six monthly	• Renovate water option above the peak level of cyclone and tidal surges • Install /Renovate alternative water source including RO, filter, water purifying tablet, bleaching powder and boiled water
6	No/faulty platform contributes to deteriorate the water quality especially the microbial contamination (E.coli)	• Improve the platform of water point • Minimize the dumping of waste near to the water point • Improve filtration process of treatment plant		• Sanitary inspection daily • Water quality test @ monthly • Monitor O&M of filter media and treatment plant @ monthly	• Install/Renovate water options • Replace or maintenance of filter materials of treatment plant • Make people aware to minimize the dumping of waste
7	Lack of safe separation distance from latrine contribute to deteriorate the water quality especially the microbial (E.coli) contamination	• Ensure the safe separation distance from water point to toilet (More than 10m)		• Sanitary inspection weekly • Water quality test @ six monthly	• Install/ Renovate latrine more than 10m from water point • sealing pit with lining
8	Not protected pond meaning fish culture, bathing, waste disposal, drainage connection with farming land, improper embankment contributes to E.coli contamination	• Ensure the protection of pond	• Use filter media like PSF • Use Alum coagulant, chlorination, water purifying tablet like aqua sure	• Proper O&M of filter materials • Water quality test on monthly basis by field test kit	• Install/ Renovate pond for protection • Install filter media like PSF • Make people aware to use Alum coagulant, chlorination, water purifying tablet with proper dosing

9	E.coli contamination at HH storage due to unhygienic practice at all steps of water value chain including water point, collection, transport without cover, storage in a dirty and wet place without cover and clean pot	• Ensure hygienic practice at all steps from source to consumption i.e. washing water pot, use cover during transportation and storage, keep pot at dry, elevated and clean place • Minimize the dumping of waste near to the water point • Ensure the safe separation distance from water point to toilet (More than 10m)		• Sanitary inspection weekly • Proper monitoring of hygienic practice at all 5 steps • Water quality test @ six monthly by using field test kit	• Renovate water pot • Renovate the place where store water at HH level • Make people aware to use cover and clean water pot prior water collection
10	Not protected pond influences / contributes to turbidity	• Ensure the protection of pond	• Use filter media like PSF and RO treatment • Use Alum coagulant, chlorination, water purifying tablet	• Sanitary inspection weekly • Water quality test @ monthly by using field test kit	• Make available alum coagulant or water purification tablet • Install / renovate alternative water source or filter media like PSF, RO treatment
11	River contributes to turbidity	No specific control measures as flowing water body	• Use RO treatment • Use Alum coagulant, chlorination, water purifying tablet	• Sanitary inspection daily • Treated water quality test on monthly basis by using field test kit	• Make available alum coagulant or water purification tablet like aqua sure tablet • Install / renovate alternative water source or filter media like PSF, osmosis treatment
12	Unsafe water point i.e. pond, river contributes to turbidity at HH level	• Use Alum coagulant, chlorination, water purifying tablet like aqua sure	• Use alternative water source like RWHS,RO, PSF	• Proper monitoring of hygienic practice in water pot and source water daily • Sanitary inspection daily • Treated water quality test @ monthly by using field test kit	• Make available of Alum, bleaching powder and water purifying tablet • Install / renovate alternative water source like RWHS,RO, PSF