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AN EXPLORATORY STUDY OF WATER QUALITY DUE TO WATER LOGGING AND DRAINAGE CONGESTION IN THE BHABODAH AREA

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ABSTRACT

Water logging and drainage congestion are crucial problems in the whole southwest region in Bangladesh over the years. Heavy rains and inadequate drainage of overland run-off increase the rate of percolation and in turn helps in raising water table and may cause water logging problems in Bhabodah and its adjacent area. In this context, the current study aims at delineation of the highly affected domestic level water supply & sanitation situation with their possible solution. Water and wastewater samples had been collected from one of the most severely flood disrupted areas named 'Panchakari' village in both dry and water-logged condition. The shallow tube well water was found to be contaminated with high concentration of Fe 4 mg/L, Mn 3.9 mg/L, Color 396 Pt-Co Unit, and Turbidity 162 NTU. In waterlogged condition, microbial contamination (TC & FC) was also detected in tubewell water. However, Teka River water had high concentration of salinity as Cl^- 858 mg/L, EC 3343 µS/cm and TDS 2061 mg/L. Health risk assessment, using WHO Semi Quantitative Approach, had been determined low to medium level of health hazards in water logged condition of the study area. Nevertheless, wastewater samples exhibit high concentration of BOD 355 mg/L, COD 607 mg/L, TDS 2641 mg/L, TSS 2469 mg/L, Cl^- 1806 mg/L, TC 89 Nos./100 mL and FC 36 Nos./100 mL which pose high risk for the environment. As toilet or septic tank was situated near the tube well (<30m) and remained untreated when disposed into nearby water bodies, sewage pollution had occured. This research recommended some strategical options for the improvement of both water supply and sanitation conditions in the study area. For ensuring safe drinking water, rain water harvesting with storage facility of $150m^3$ could be adopted for a cluster of 50 households. Furthermore, flood resilient tubewells having raised-base-platform would be used to protect the entrance of contaminants during flood time. For the betterment of sanitation situation, mound-built latrine with excavated depth 3.3m circular or 2.6m rectangular pit could be provided for 10 users in waterlogged site. However, other necessary approaches should be implemented by the Government, Non-Governmental Organizations (NGOs) and stakeholders to minimize the existing vulnerable conditions due to waterlogging and drainage congestion in Bhabodah area.

Keywords: *Bhabodah, Water logging, Drainage congestion, Water supply, Sanitation.*

1. INTRODUCTION

Bangladesh is generally considered to be one of the most vulnerable regions in the world to climate change induced sea level rise (Ahmed, 2005). Water logging has been affecting about one million people in Bangladesh during the past two decades leading to large scale damages to crop, employment, livelihoods, and national economy (Rahman, 1995; Ahmed, 1998). It involves deterioration of drainage condition in coastal active tidal rivers of south-west Bangladesh which are main rain water drainage network for coastal polders and low lying beels. The Coastal Embankment Project (CEP) of early 1960s and the commissioning of Farakka Barrage in 1975 had a negative impact upon the geo morphological characteristics of south west part of Bangladesh which accelerated the process of sedimentation in the riverbeds and sluice gates became inoperable (Sarker, 2004; DHV-WARPO, 2000). In the early 70s, the presence of polders restricts the natural tidal flows from upstream and prevents sedimentation on the low-lying lands. As a result, polder areas were suffering from water logging and drainage congestion for quite long periods and that in turn caused large scale environmental, social and economic degradation (IWM, 2010).

Drainage problem of Bhabodah in Jashore district became very severe due to siltation and river encroachment in the main river systems (IWM, 2017). This area is crisscrossed by 7 main rivers and 27 beels. The rate of sedimentation in the Hari-Telegati River from February to April is about 1.2 million tons due to reduced source of flow; these sediments are deposited at river bed. As a result, water drainage capacity decreases gradually for increasing height of river bed with respect to nearby beels. Rain water cannot drain out anywhere naturally by beels and khals and get trapped in beels submerging homesteads, farmlands, roads and educational institutions. It was not possible to conduct TRM at beel Kapalia in 2012. From then, TRM could not be implemented in Bhabodah & its adjacent area. After 2013, rivers are silted up losing its navigability and became waterlogged. About 73,400 hectres of land went under water in 2016-2017. About 70 villages in 5 unions of Abhaynagar Upazila, 100 villages in 16 unions of Manirampur Upazila, 140 villages in 9 unions of Keshabpur Upazila and 69 villages in 5 unions of Jessore Sadar Upazila were severely affected due to drainage congestion. An estimated affected household of 2, 14, 729 nos. and about 8,89,818 populations had been affected during prolonged drainage congestions in 2016 (IWM, 2017). Prolonged water-logging has caused significant displacement presenting humanitarian challenges in safe water supply, sanitation facilities & shelter security. Drinking water is scarce and people use contaminated flood water for washing utensils, clothes, etc. causing various skin and water-borne diseases. Due to lack of sanitation facilities in many areas close to rivers, abundance of Escherichia coli is extremely high and use of river water is cause of gastro-intestinal diseases (IWM, 2017). They cannot use pit latrine because of submerging in flood water and temporary latrines are constructed by the govt. authority. In this context, an in-depth study is imperative to delineate the highly affected domestic level water supply & sanitation situation with their possible solution.

2. METHODOLOGY

The research related field work was conducted at Bhabodah area of Jashore district located in the south-west region of Bangladesh within Khulna division shown in figure 1 & 2. To investigate domestic water supply and sanitation situation, 8 water samples in dry and water logged condition and 3 wastewater samples in waterlogged condition were collected from mostly affected community in Bhabodah, named ‘Panchakari’. Collection, transportation and storage of water samples will be done following laboratory standard methods. And then some improvement options for water and sanitation system were proposed. Various physical, chemical, and biological water quality parameters were tested in ‘Environmental Engineering Laboratory’ at KUET.

For laboratory analyses, standard methods were followed. pH, color, turbidity was determined by electrometric method using pH meter, spectrophotometer and digital turbidimeter, respectively.

Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD) were performed by membrane electrode method and closed reflux titrimetric method.

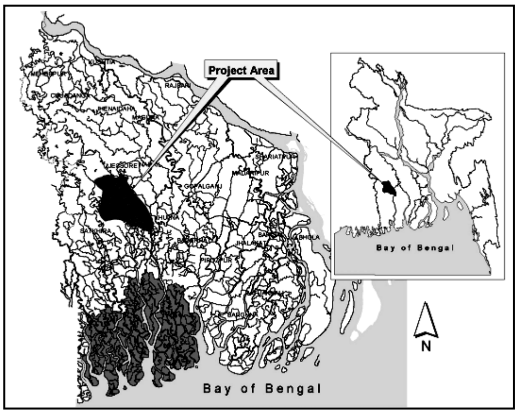

Fig.1: Study area

Fig.2: Selected affected area adjacent to Bhabodah

Biochemical Oxygen (BOD) was carried out using BOD bottles and stored in incubator for 5 days. Total Dissolved Solids (TDS) and Total Suspended Solid (TSS) were determined by gravimetric method. Iron (Fe), Manganese (Mn), Nitrate (NO_3^-), Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-}) were determined by spectrophotometer using ferrover; Sodium powder citrate & sodium periodate; nitrover-5; sulfaver-4 and Potassium per sulphate Powder pillow, respectively. Chloride (Cl^-) and hardness tests were performed by titration method. Silver nitrate ($AgNO_3$) and K_2CrO_4 indicator were used for Cl^-. pH buffer solution, Erichrome Black T dye and EDTA were used for hardness test. Total Coliform (TC) & Faecal Coliform (FC) were determined using X-MG Agar and Membrane Filter with 24 hours incubation. Semi-quantitative risk assessment for water and wastewater were followed by WHO and risk score was calculated using the following methodology:

Table.1: Risk matrix for water

		Consequence or Severity				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Likelihood	Almost Certain (5)	5	10	15	20	25
	Likely (4)	4	8	12	16	20
	Possible (3)	3	6	9	12	15
	Unlikely (2)	2	4	6	8	10
	Rare (1)	1	2	3	4	5
Risk Score		≤5	15-5		>15	
Risk Severity		Low	Medium		High	

Table.2: Risk matrix for sanitation

			SEVERITY (S)				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	4	8	16
LIKELIHOOD (L)	Very unlikely	1	1	2	4	8	16
	Unlikely	2	2	4	8	16	32
	Possible	3	3	6	12	24	48
	Likely	4	4	8	16	32	64
	Almost Certain	5	5	10	20	40	80
Risk Score R= (L)x(S)			<6	7-12		13-32	>32
Risk level			Low Risk	Medium Risk		High Risk	Very High Risk

Risk Score, R = Likelihood (L) x Severity (S) (1)

As an improvement option for water quality, rain water harvesting system is proposed following the mass-curve method.

*Monthly demand (m^3) = (P * q * 30)/1000* (2)

[P=Total estimated population and q=Per capita daily water consumption in lpcd]

*Monthly Yield (m^3/month), Q= (C * I * A)/1000* (3)

[C=Runoff coefficient= 0.7; I=Average monthly rainfall intensity (mm) and A=Catchment area (m^2)]

As an improvement option for sanitation, pit latrine is calculated by using all the equations.

*Effective volume of the pit (m^3), V= 1.33*C*P*N* (4)

[C=Solids accumulation rate=0.06 m^3/person/year for dry pit; P=No. of latrine users and N=Design life in years]
Depth of the pit= V/A [For circular pit, $A = (\pi D^2)/4$; for rectangular

3. RESULTS AND DISCUSSION

3.1 Field Observation

Field investigation was made to know previous and present conditions of the study area. Water rose about 2-2.5 ft above ground during floods in last years. Most of the people of Panchakari village usually take shelter in Panchakari Primary School for about 6 months or more during floods. Tubewells and pit toilets get inundated and become unusable. About 2-3 nos. of temporary latrines and shallow tubewells had been constructed by the Govt. Authority. People use pond water for cooking and shallow tubewells for drinking purpose. In 2018, for river dredging and not for raining so much, water level rose only upto 2.9 mMSL while in previous years a maximum of 4.0 mMSL.

Fig.3: Water logged condition in 2016

Fig.4: Water logged condition in 2018

3.2 Water Quality in Dry and Water-logged Conditions

The results are presented by taking consecutive three months average data for both dry & waterlogged condition & are shown in table 3 & 4.

Table 3: Comparison between test results & Bangladesh water quality standards for water supply in dry season

Sample Para-meter	Unit	STW1	River	Pond	STW2	* DTW1	* STW3	* STW4	* DTW2	Bd. Std.
pH	-	7.01	7.54	7.67	7.3	7.68	7.27	7.39	7.41	6.5-8.5
Color	Pt-Co	396	191	282	196	0	53	37	28	15
Turbidity	NTU	98	46	40	33	2	3	3	4	10
EC	µS/cm	1487	2175	513	689	756	1522	1408	1235	
As	mg/L	0.005	0	0	0.01	0	0	0	0	0.05
TDS	mg/L	1126	1661	307	473	582	1163	1060	943	1000
Cl^-	mg/L	720	858	105	83	203	516	394	448	150-600
Hardness	mg/L as $CaCO_3^{2-}$	257	605	131	346	132	565	306	342	200-500
Fe	mg/L	4	0	0	0.4	0.1	0.5	0.3	0.1	0.3-1
Mn	mg/L	3.9	0	0	1.5	0.1	0.3	0.2	0.1	0.1
NO_3^-	mg/L	1	0.4	0.1	0.4	0.4	0.7	0.5	0.7	10
SO_4^{2-}	mg/L	0	22	16	0	0	0	3	10	400
TC	Nos/100 mL	0	40	84	0	0	0	0	0	0
FC	Nos/100 mL	0	16	38	0	0	0	0	0	0

[Note: STW- Shallow Tube Well, DTW- Deep Tube Well, River- Teka river, *Drinking purpose]

Higher value of color, turbidity and TDS make aesthetic problem for maximum samples. River water showed the highest value of EC both in dry (3342.7µS/cm) and waterlogged condition (2175µS/cm) for saline water intrusion when opening Bhabodah sluice gate. Significant increase in EC in waterlogged condition indicates the entrance of polluting discharges into water. However, DoE std. of EC value is 350µS/cm and Bd. Std. for irrigation and fisheries is 750 & 1000 µS/cm respectively. So pond water can be used for irrigation and fisheries. Again, samples exhibit slight variations from std. limit of Fe, Mn & Cl^-. Higher value of TC/FC may cause adverse health hazards for both human & animals and results in spreading of water-borne diseases among residents of the community if especially pond & river water is used without treatment. No TC/FC was found in ground water samples in dry season and is safe to use. But in waterlogged condition, microbial contamination (TC/FC) was detected for the presence of wastewater and many of the pathogenic organisms from nearby pit toilets which are unsuitable for use. So special attention need to be given to protect water from being contaminated.

Table 4: Comparison between test results and Bangladesh water quality standards for water supply in waterlogged condition

Sample / Para-meter	Unit	STW_1	River	Pond	STW_2	* DTW_1	* STW_3	* STW_4	* DTW_2	Bd. Std.
pH	-	7.28	7.58	7.69	7.32	7.55	7.12	7.37	7.45	6.5-8.5
Color	Pt-Co	370	268	252	153	7	20	22	9	15
Turbidity	NTU	162	144	57	31	3	10	6	5	10
EC	µS/cm	1550	3343	681	901	899	1815	1443	1258	-
As	mg/L	0.005	0	0	0.01	0	0	0	0	0.05
TDS	mg/L	915	1232	382	587	569	932	981	711	1000
Cl^-	mg/L	483	729	114	132	245	484	360	362	150-600
Hardness	mg/L as $CaCO_3^{2-}$	455	781	273	548	621	859	517	719	200-500
Fe	mg/L	3.4	0.1	0	0.9	0.3	0.2	0.3	0.3	0.3-1
Mn	mg/L	2.5	0.2	0.2	0.3	0.3	0.4	0.3	0.4	0.1
NO_3^-	mg/L	4	0.1	0.6	0.1	0.6	1.8	0.6	0.8	10
SO_4^{2-}	mg/L	0	59	1	0	0	2	1	5	400
TC	Nos/100 mL	7	48	70	11	3	5	8	6	0
FC	Nos/100 mL	1	24	39	3	1	3	5	1	0

[Note: STW- Shallow Tube Well, DTW- Deep Tube Well, River- Teka river, *Drinking purpose]

3.3 Semi Quantitative Risk Assessment for water

By using risk assessment matrix in table 1 & equation (1), risk level is analysed for all the samples and is represented as in figure 5 & 6. STW_1 shows highest risk level (Medium) for Fe in both seasons. Again, in fig.6, risk level of all the samples except river & pond water in waterlogged condition rise significantly for the presence of waste water from nearby pit toilet and different garbage. And in both seasons, it is very likely to contaminate river and pond water on regular basis with pathogens that could result in spreading of water-borne diseases among residents of the community. It is also observed that risk level of tube well water samples rise from low to medium. So people should be conscious for using pond & river water, especially for all the drinking water sources during water logged condition.

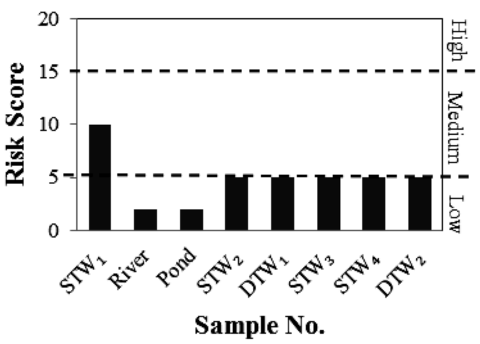

Fig.5: Risk assessment graph for Fe

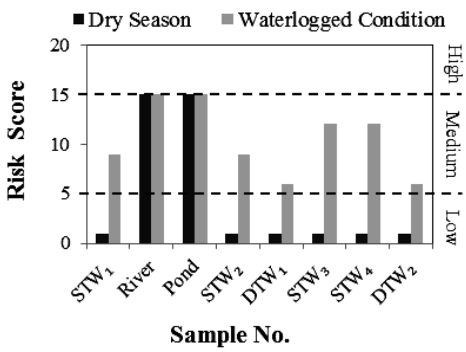

Fig.6: Risk assessment graph for TC/FC

3.4 Exploration of Sanitation Situation

The results are presented by taking consecutive 3 months average data shown in table 5. It can be seen that EC, TDS & TSS values are so high which indicate the presence of organic, inorganic particles and water pollutants. So direct flow of these samples may damage aquatic life and contaminates water bodies. Higher values of BOD & COD indicate water pollution, toxicity of effluents and existence of huge quantity of biologically resistant organic substances that poses high risk for environment. High chloride content (>600mg/L) discharged from S-1 & S-3 into inland water distribution system indicate sewage pollution. High amount of TC/FC containing in the samples contaminates tube well water used for drinking purpose as toilet or septic tank is situated near the tube well (<30m).

Table 5: Comparison among the waste water samples in waterlogged condition

Sample No. / Parameter	Unit	S-1	S-2	S-3	Std. for sewage discharge into inland water
pH	-	7.9	7.67	8.11	5.5-9
Color	Pt-Co	1619	2467	503	
Turbidity	NTU	1534	1802	216	
DO	mg/L	1.1	1.2	1.7	4.5-8*
BOD	mg/L	197	355	133	40*
COD	mg/L	588	607	367	250
EC	μS/cm	1762	1222	4657	
TDS	mg/L	1567	556	2641	1500
TSS	mg/L	2469	1801	347	100
Cl^-	mg/L	671	345	1806	600
Hardness	mg/L as $CaCO_3^{2-}$	932	686	949	
NO_3^-	mg/L	3	9	5	250*
SO_4^{2-}	mg/L	2	3	101	400
PO_4^{3-}	mg/L	4	8	5	35*
TC	Nos./100mL	31	89	48	
FC	Nos./100mL	22	36	27	

[S-1 is collected from waterlogged septic tank water beside Peoples' living & shallow tubewell; S-2 is collected from pond beside pit latrine used for washing and S-3 is from river beside pit latrine used for washing & household purpose; *according to ECR'97 & others are according to BIS 2296: 1982]

3.5 Semi Quantitative Risk Assessment for Waste Water

By using risk assessment matrix (WHO) in table 2, risk level is analysed for all the samples and represented as following graphs.

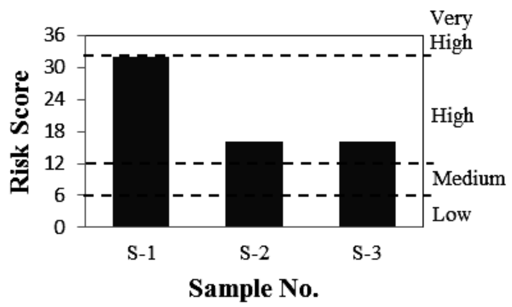

Fig.7: Risk assessment graph for TC, FC, DO, BOD, COD & TSS

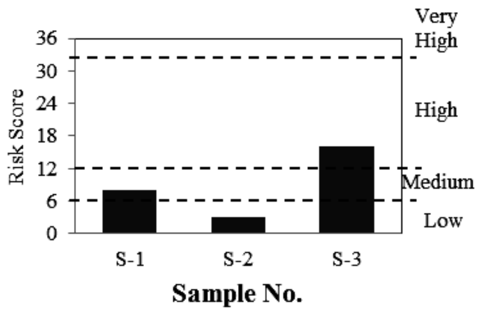

Fig.8: Risk assessment graph for TDS & Cl^-

In fig.7, all the samples lie in the range of high risk. S-1 shows maximum risk score (32). Due to lack of DO and for the presence of excessive amount of TC, FC, BOD, COD & TSS during or after water logged condition, it has possibility to leach waste water from pit to the nearby shallow tube well and contaminate water that can be injurious to health for the users. For excessive amount of TDS & Cl^-, there is possibility to cause sewage pollution in nearby Teka river by S-3 effluents and can be harmful to human health if use without treatment.

3.6 Improving Option of Water quality

3.6.1 Rain Water Harvesting

It is the technique of collection, conveyance & storage of rain water into reservoirs/tanks that consists of elements as roof catchment, gutters, down pipes, first flush devices, filter chamber, storage tank/reservoir & hand pump or other supply system. Schematic diagram of rain water harvesting is shown in fig. 9.

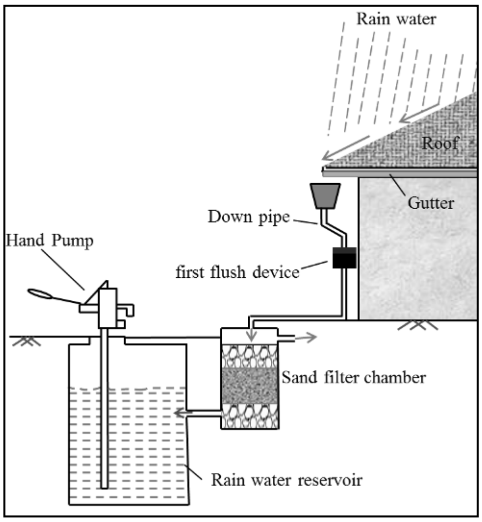

Fig.9: Rain water harvesting

Considering 50 household as a cluster, total study area can be divided into 10 clusters. If per cluster has 250 person and 10 lpcd water is used for drinking & cooking, then monthly demand will be 75 m³ (using equation 2). Assuming total roof area is 2500 m². So by equation 3, monthly yield can be calculated and by using these calculations, graphs can be drawn as following fig. 10 & 11.

From the calculation, water demand & rainwater supply curve are drawn in fig. 10. In fig. 11, cumulative Monthly Supply is 2826.25 m³ & cumulative Monthly demand is 900m³. From the data found in graphs, required storage volume in rain water harvesting system can be calculated in table 6.

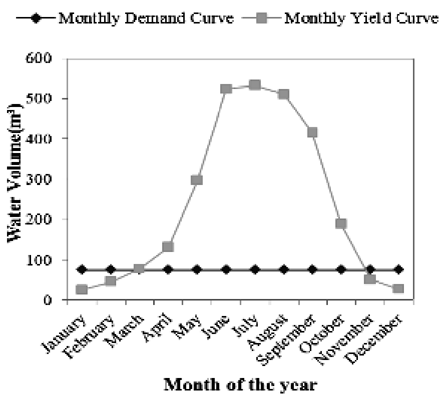

Fig.10: Water demand vs. potential supply curve

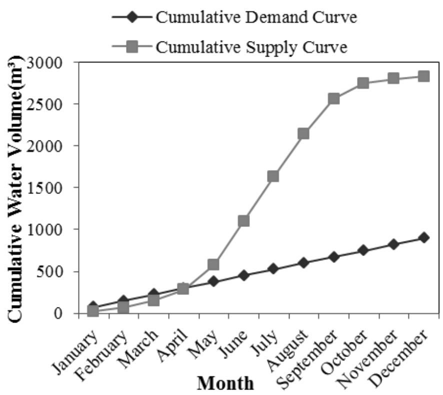

Fig.11: Cumulative demand vs. supply curve

Table 6: Mass Curve Analysis for Required Storage Volume

Month	Monthly Rainfall (mm)	Monthly Supply (m³)	Monthly Demand (m³)	Monthly Stored (m³)	Required Storage Volume (m³)

January	14.8	25.9	75	-49.1	
February	26.1	45.7	75	-29.325	
March	44.6	78.05	75	0	
April	75.4	131.9	75	0	
May	169.9	297.3	75	0	
June	298.7	522.7	75	0	150
July	304.1	532.2	75	0	
August	291.8	510.6	75	0	
September	236.9	414.6	75	0	
October	107.9	188.8	75	0	
November	29	50.8	75	-24.25	
December	15.8	27.6	75	-47.35	

3.6.2 Measures taken for Tubewell

Fig.12: Leakage on tube well

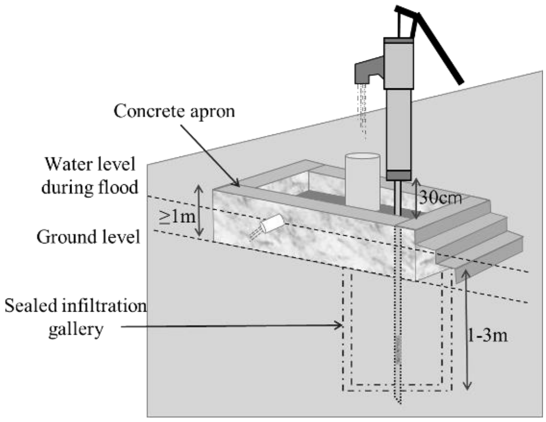

Fig.13: Flood resilience protected well

Fig.12 shows leaks in tubewell from which contaminated water enters into tube well during water logging and make water harmful to the users. So, the leakage should be repaired. A flood resilient protected well can be constructed for preventing flood water contacting with the tube well. In fig 13, schematic diagram of that well is shown. For constructing the well, a concrete apron (≥1m high from ground level) is needed to direct flood water away from the well. A sanitary seal (1-3m) can be provided with clay, grout & concrete to prevent infiltration of contaminants.

3.7 Improving Option of Sanitation System

3.7.1 Mound-built Latrine

In fig.14, the schematic diagram of mound-built latrine is shown. Bottom of the pit should be at least 2 m above ground water table. Minimum horizontal distance should be 30 m between a pit and water source to limit microbial contamination. For 10 nos. of users & 5 years design life, effective volume of the pit 4 m^3 [Using equation 4]. If size of circular pit is 1.25m, depth of the pit will be 3.25m. For rectangular pit of 1.25m, required depth will be 2.56m.

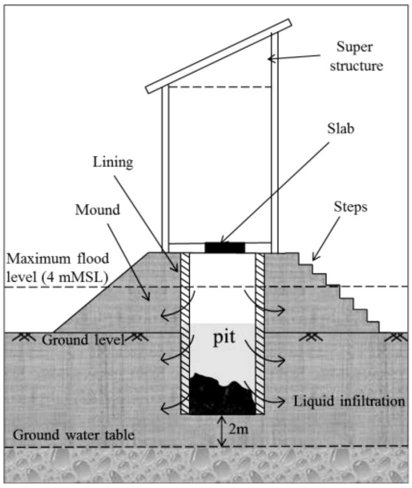

Fig.14: Mound-built latrine

3.7.2 Floating Latrine

Floating latrine is temporary basis used latrine during flood. 6 nos. of plastic drums are used. 3 are used for keeping toilet afloat. 2 are used for installing filtration system having filter material. One is used for installation of pan (3 holes for faecal matter, urine & cleansing water). Collected cleansing water is flown through filter media and finally discharged into water.

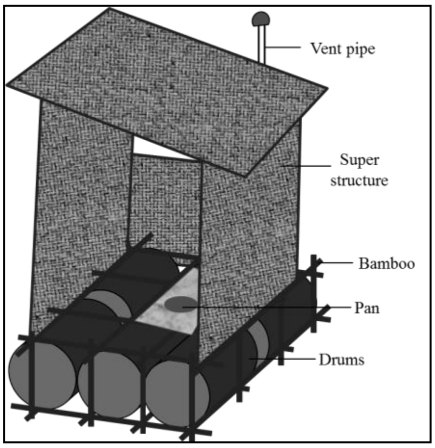

Fig.15: Floating latrine

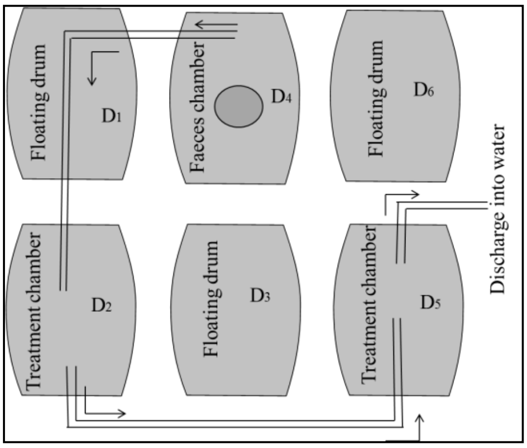

Fig.16: Detailed Schematic diagram of floating latrine

Floating latrine is temporary basis used latrine during flood. 6 nos. of plastic drums are used. 3 are used for keeping toilet afloat. 2 are used for installing filtration system having filter material. One is used for installation of pan (3 holes for faecal matter, urine & cleansing water). Collected cleansing water is flown through filter media and finally discharged into water. Detail schematic diagram of floating latrine is shown in fig.15 & 16.

4. CONCLUSIONS

Water quality and sanitation system of the study area were affected in many ways for waterlogging and drainage congestion. In tubewells, no TC/FC was found in dry season but microbial contamination (TC/FC) was found in waterlogged condition which pose medium level of threat according to WHO sami-quantitative risk approach. Overall, DTW_1 is the most suitable drinking water source in dry season and DTW_2 also seems good except high color concentration (28 Pt-Co). But in waterlogged condition, both DTWs water samples show high concentration of hardness, Mn, TC &

FC beyond the std. limit. STW_2 can be used for washing and domestic purpose although it contains high values of color (196 Pt-Co), turbidity (33.1 NTU) and Mn (1.5 mg/L) in dry season. Whereas other STWs, Teka River and Pond water samples were found to be more polluted and show medium to high risk. For improving the drinking water option in the study area, rain water harvesting system could be adopted with $150m^3$ storage reservoir for every 50 houses cluster. Moreover, the tubewells base-platform could be raised for preventing entrance of contaminants during flood. On the other hand, higher concentration of BOD_5 (355 mg/L), COD (607 mg/L), TDS (2641 mg/L), TSS (2469 mg/L), Cl^- (1806 mg/L), TC (89 Nos./100 mL) and FC (36 Nos./100 mL) of wastewater samples indicate toxicity of effluents and posed high risk to environment and ecosystem. For the betterment of this situation, mound-built latrine is proposed to construct having an excavated depth of 3.3m circular or 2.6m rectangular pit for each 10 users of the area. Moreover, it can be concluded that necessary steps should be taken by the Government and Non-Governmental Organization to minimize the current scenario of vulnerable water and sanitary conditions due to waterlogging and drainage congestion adjacent to Bhabodah area.

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