Engineers Without Borders- Sweden

Pre-Study of the current drinking Water and Sanitation Situation in Goaldihi Village

Carin H [a], *Hanna C* [b], *Mloelya P* [c], *Moa L* [d], *Olof S* [e], *Subhajyoti M* [f], *Valisoa R* [g], *Victor* [h]

AbstractPre-study of the current drinking water and sanitation situation in Goaldihi Village'

Bangladesh is a developing economy with a large population of more than 167 million. Being a Low & Medium Income-group Country (LMIC), the infrastructure of safe drinking water and sanitation (WASH) is in its nascent stage. This research paper identifies the deficiencies of current infrastructure leading to the problem of drinking water contamination and explores possible economic solutions as to the suitability of the land and customs. The paper also acknowledges the threat of rising sea levels due to global warming and has incorporated the forecasted rise in its design. The paper has duly considered the agrarian nature of the society and recognizes the need to involve the citizens for effective results and to support them socio-economically. The project recommends City Wide Inclusive Sanitation (CWIS) to support drinking water treatment initiatives.

Keywords: LMIC; WASH; infrastructure; global warming; drinking water; contamination; socio-economic; CWIS

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1. Introduction

The Project entails understanding the ground scenario of available water infrastructure at a rural village in Bangladesh, disseminating data from available survey reports, logically narrowing it down to a few solutions, and finally proposing a techno-commercially feasible solution to address the water contamination problem.

1.1. *Risks identified*

Drinking water is one of the basic necessities for livelihood. Deviation from standards proposed by WHO and other regulatory bodies has far-reaching consequences that may be seen immediately in case of cholera caused by coliform bacteria or prolonged illness due to contamination of drinking water by carcinogenic fertilizers.

- High level of fecal contamination evident from the presence of e-coli in water samples collected from shallow tube wells which are primary drinking water sources.
- Transfer of knowledge regarding personal hygiene into practice needs to be promoted by raising awareness. This can also prevent recontamination of water while handling.
- Animal waste runoffs aiding contamination of water sources is likely as the terrain is flat and part of riverine flood plains.
- Impact of pesticides and fertilizers on groundwater quality needs to be ascertained in the long run.
- Proximity of tube wells next to pit latrines assists water contamination.
- Surveyed data showed a very high-water table of 2.5 meters. This is disadvantageous as the minimum vertical distance between the bottom of latrine pits and the water table should be at least 2 meters.

1.2. *Method*

The project team mapped the current water infrastructure conditions and evaluated possible solutions in the context of demographics, terrain & socio-economic conditions of rural Bangladesh. Upon brainstorming of ground survey reports and actual photographs of examined location the project team identified thirty-one probable aspects influencing drinking water quality. The literature review was done targeting these specific 31 factors to identify the problem, its cause, effect, and solution.

It is duly acknowledged that drinking water contamination is the result of improper sanitation and hence to deal with the root of the problem, interventions are required both at the point of drinking as well as sanitation.

Notable solutions explored are tabulated below.

Table 1. Solutions explored

Sanitation solutions	Drinking water solutions
1 Composting toilets	1 Chlorine tablets
2 Elevated pit latrines	2 Raised tubewells
3 Fecal sludge management (biogas)	3 Ceramic Filtration
	4 Solar pumps for deep tubewells

1.3. *Results and discussion*

Multiple references suggested that chlorine tablets mixed with water are a sure-fire way to kill the pathogens prevalent in water. Several commercial products like halotab, zeoline etc. are quite common. It comes with the downside of producing carcinogenic tri-halo compounds and hence was excluded for further consideration.

Solar pumps are effective in harnessing renewable energy to extract groundwater as deep as 300 meters. Water from such depth is naturally free from surface or subsurface contamination as they are disconnected from shallow composting soil by impermeable rocky strata. Having such solar pumps in the individual households is not feasible and having a zonal pump distributing piped potable water via an overhead tank is a possible solution. Since this would mean associated costs of piping infrastructure, the payback period will be very long and hence was not perused further

1.1.1. *Composting Toilets*

The composting toilet is a cost-effective solution not only to prevent open defecation but also to avoid leaching from latrines that contaminate drinking water sources and spread diseases. By diverting urine and feces at the source, dry composting of feces is made possible, producing a hygienized product that can be reused in the fields as fertilizer. The cost of a single compost toilet is about BDT 55,605 per unit, including elevation ensuring operation during monsoons. Alterations to the design by adding a ramp to enable access can be made but require the additional cost of BDT 141,000 support as building costs will increase. Dimensions of the composting chambers that are to contain the fecal matter are based on the number of users (n), composting time (tc), and the volumetric flow rate of the fecal matter per person (Qf). Assuming that every person produces about 4.2 liters of fecal matter and 42 liters of urine monthly the minimum volume of the digestion chambers can be calculated via equation 1 [1].

$$Vc = n \times tc \times Qf \tag{1}$$

If assumed a family of five would use the toilet with a 12-month composting time, the calculation implementing equation 1 as presented in equation 2 shows that the volume of each compost chamber needs to be at least 0.252 m3. When cross-referenced with the instructions from the Protos [2] manual shows that a width of 1.6x0.67 meters suits the design which means that the chamber height needs to be at least 0.24. As an example, equation 3 shows that a jerry can (20 L) would need to be emptied every third day for urine removal.

$$Vc=5\ \text{[PE]}\times 12\ \text{[months]}\times 0.0042\ \text{[m\^{}3/month, Person Equivalent (PE)]} = 0.25 \tag{2}$$

$$t=(0.02\ \text{[m\^{}3]})/(5\ \text{[PE]}\times 0.042\ \text{[m\^{}3/month, PE]})\approx 0.095\ \text{month} \tag{3}$$

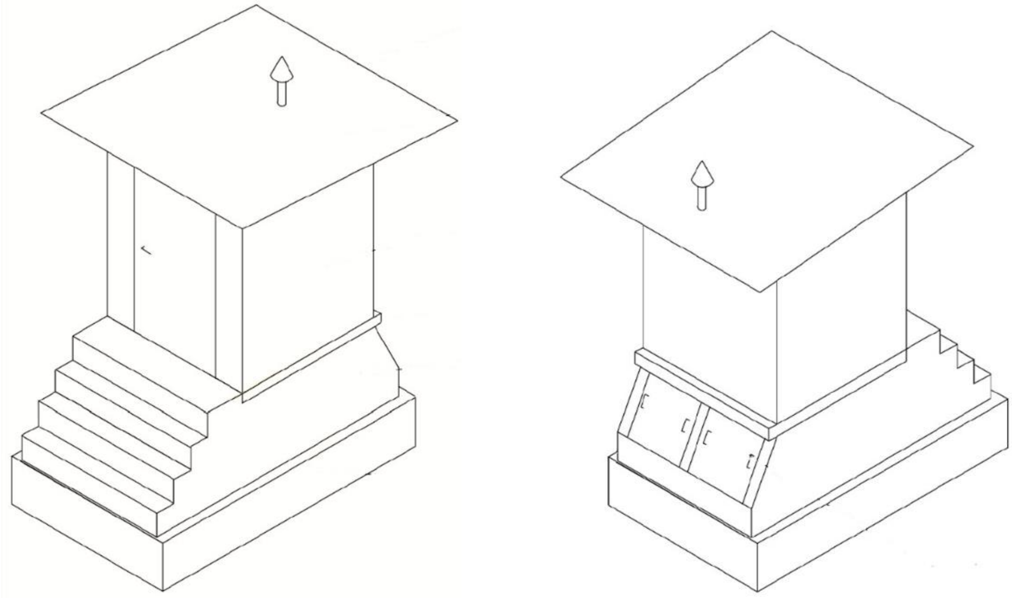

Fig. 1. Schematic drawing of composting toilet (front & back views)

The elevation for the composting toilet is recommended for anyone implementing these in areas prone to flooding. The benefits of not contaminating local drinking water outweigh the additional cost. The ramp is harder to defend economically as the expenses increase by almost a factor of five. Having even one individual using open defecation is a risk for a whole community, hence providing access-friendly solutions could increase the quality of life for a large part of the population as approximately nine percent of the Bangladesh population are considered to be physically challenged [3].

1.1.2. *Elevated pit latrines*

Earthen raised pit latrines are latrines that are elevated above ground level and are suitable for the areas where flooding is recurrent. In these latrines, most of the pit area is above ground, while a small portion of it is underground. The bottom of the pit should be at least 2 meters distance from the water table [4]. The above-ground section of the pit is meant to be non-lined with porous capacities, while the underground level is lined to avoid groundwater contamination [5]. A permeable soil mound is placed surrounding the external pit perimeter to filter the liquid coming from the porous lining of the pit (fig. 2). This mound must be thick enough and well compacted to ensure infiltration conditions [6].

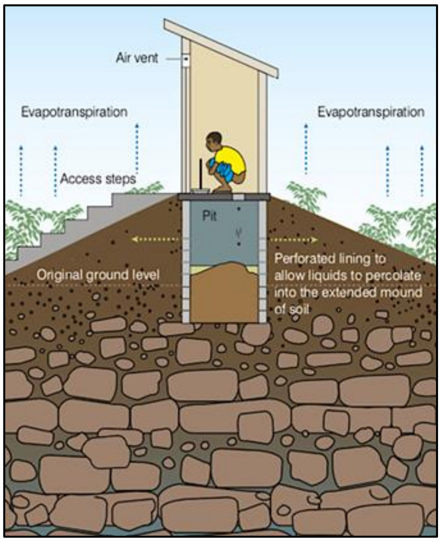

Figure 2: A raised latrine with a pit mainly above the ground [5]

For the design dimensioning of the earth-raised pit latrine, the *"Latrine Design Construction Manual"* [7] was used. This manual presented two tables that worked together to obtain the sizing of pit latrines (tables 2, 3). Table 2 shows sludge accumulation rates according to pit conditions, while table 3 shows dimensions according to table 2's conditions and projected pit life span. Toilet customs in Bangladesh mean a small amount of water to clean themselves goes into the pit latrine. Thus, option B in table 3 was chosen.

Table 2: Sludge accumulation rates [7]

Pit Conditions	**Sludge Accumulation Rate**	
	Degradable anal cleansing materials (e.g. paper, leaves) and water	**Non-degradable anal cleansing materials (e.g. stones, plastic)**
Water in Pit (e.g. pour-flush latrine)	A	B
Dry in the pit (e.g. no or small amount of water in the pit)	B	C

Although the average household in Bangladesh is 4.5, the pit latrine was designed for six users (table 3). This is because pit design tables were set in pairs, and the next lower value would be four users, being less than the average 4.5 users required. To avoid the short lifespan of the pit latrine and extend the period of desludging, a 5-year lifetime was chosen. Also, a rectangular layout was selected to limit the elevation of pit access which can avoid higher capital costs and be physically challenging for some people. Hence, the pit dimensions selected were 1.0 meters in length x 1.5 meters in width x 1.7 meters in depth (table 3).

Table 3: Pit design for 6 users [7]

Pit Dimensions	**Pit Depth (D)(metres)**											
	2 Year Lifetime			**5 Year Lifetime**			**10 Year Lifetime**			**15 Year Lifetime**		
Square or Rectangular Pit Length (L)x Width (W) (metres)	A	B	C	A	B	C	A	B	C	A	B	C
1.0 x 1.0 (square)	1.2	1.6	2.1	1.7	2.3	3.2	2.9	4.1	4.9	4.1	5.9	8.6
1.0 x 1.5	1	1.2	1.6	1.3	1.7	2.3	2.1	2.9	4.1	2.9	4.1	5.9
Circular Pit Diameter (d) (metres)	A	B	C	A	B	C	A	B	C	A	B	C
1.0	1.4	1.9	2.6	2	2.8	3.9	3.6	5.1	7.4	5.1	7.4	10.8
1.5	0.9	1.1	1.4	1.2	1.5	2	1.9	2.5	3.6	2.5	3.6	5.1

In addition to the current flood levels of 90 cm [8], the future flood levels in the region are forecasted to increase by 26.14% in the upcoming 20 years [9]. Since the average water table depth was about 2.5 meters in the surveyed locality, a total pit depth of 1.7 m was split into 1.5 m above ground and 0.5 m below ground to ensure a minimum vertical distance of 2m from pit bottom to water table.

Estimated capital expenses for the construction of this proposed earth-raised pit latrine is BDT 55000, with additional cost for access-friendly ramps. Annex 2 shows the calculation of each description. The time it takes to construct this pit latrine is relatively short, It makes it a suitable solution for emergency preparedness activities.

1.1.3. *Fecal sludge management (biogas generation)*

Biogas digesters are vital in waste management. They have proven to be a cheaper and efficient way of reusing biomass waste. Biogas digesters have been adopted in the least developed countries, where the use of gas for cooking is progressively replacing the use of firewood and charcoal. Concisely, biogas digesters are vital in both sustainable energy and environmental management.

The economic and environmental sustainability of biodigesters cannot be overlooked. Ajieh et al., [10] reported that the biogas produced from the biogas digester contains 56.4% methane gas, 35% carbon dioxide, and 6.9% nitrogen. This bioenergy recovery technology significantly contributes to the reduction of the carbon footprint and accumulation of waste. The biomass waste from households, agricultural waste and human fecal matter from the pit latrines, septic tanks, holding tanks, and the animal dung from kraals is the available source of waste to be used in the biogas reactor. Emptying pit latrines not only curb the practice of capping latrines when filled up but also saves space and prevents the overflow of human waste into water sources and groundwater.

In order to calculate the sizing for the digester, volume (V_d) is made based on the daily charge of sludge (Q_{is}) [11]. Considering the source of animal dung, and which design was in use every kind of livestock excreta provides different amounts of sludge which in return varies in gas yield [12]. To calculate the flow of the daily charge (Q_{is}) the mass of the water (m_w) and excreta (m_e) are added, then divided by the density of the slurry (ρ_s) (equation *4)* [13]. Thereafter, the *HTR* in combination with the daily charge (Q_{is}) decides the size of the digester (V_d) as per (equation 5) [13].

$$Q_{is}\ [m^3/day] = \frac{m_w + m_m\ [kg/day]}{(\rho_s)\ [kg/m^3]} \tag{4}$$

$$V_d\ [m^3] = HTR\ [days] \times\ Q_{is}\ [m^3/day] \tag{5}$$

Calculating the cost of the biogas plants was made by reviewing construction manuals for the KVIC-plant [13] and the Chinese fixed dome plant. Using the manuals material lists and applying market prices for each individual building part in combination with cross-referencing the Bangladesh Journal of Rates [14] and the US army manpower requirements [15].

Surveys have shown there are 4 cows and 5 chickens per household, cows produce 10 kg of dung per day while chicken excrete 0.18 kg of manure daily. Considering 3000 people in the area, each person producing 0.4 kg feces per person every day [13], and assuming there are five people per household. Daily produced excreta is calculated below:

$$m_e = 3000 \times \left(0.4 + \frac{1}{5} \times (4 * 10 + 5 * 0.18)\right) = 25740\ [kg/day]$$

Using equation 4 calculating daily flow of waste, the waste is mixed with a 4:5 dung/water ratio and the slurries density as 1090 kg/m^3 [13].

$$Q_{is} = \frac{25740 \times (\frac{5}{4} + 1)}{1090} \approx 53.13\ [m^3/day]$$

Knowing the waste flow, the required digestor space can be estimated using equation 5.

$$V_d = 30 \times 53.13 \approx 1593\ m^3$$

If a digester size of 23 m^3 is chosen the required number of digesters (N) would be:

$$N = \frac{1593}{23} \approx 69\ [digesters]$$

Collecting excreta at a centralised location is a massive task and requires social mobilisation, public awareness and administrative infrastructure. It is also noted that, animal waste is used as manure for the fields and hence the prospective collection is expected to be muted compared to mathematical calculation. In the given scenario we recommend to pilot fixed dome plants at public places like markets, bus stands, railway stations and increase the number of digesters as per increased footprint. Awareness campaigns can be done to promote adoption of KVIC (floating drum) household scale digesters of 2-4m3 size. This can offset the energy charges and additionally provide fertilisers.

Table 4: KVIC-pattern (floating drum) digester sizewise cost comparison

	Size digestor [m^3]					
	5	7	9	14	19	23
Total cost [BDT]	85871	104301	113080	139848	152955	167487

For the fixed dome reactor, the cost to digester size comparison is presented in table 5, observing that the digester sizing is not the same as in table 1.

Table 5: Fixed dome digester sizewise cost comparison

	Size digestor [m^3]		
	10	15	20
Total cost [BDT]	93964	116679	169950

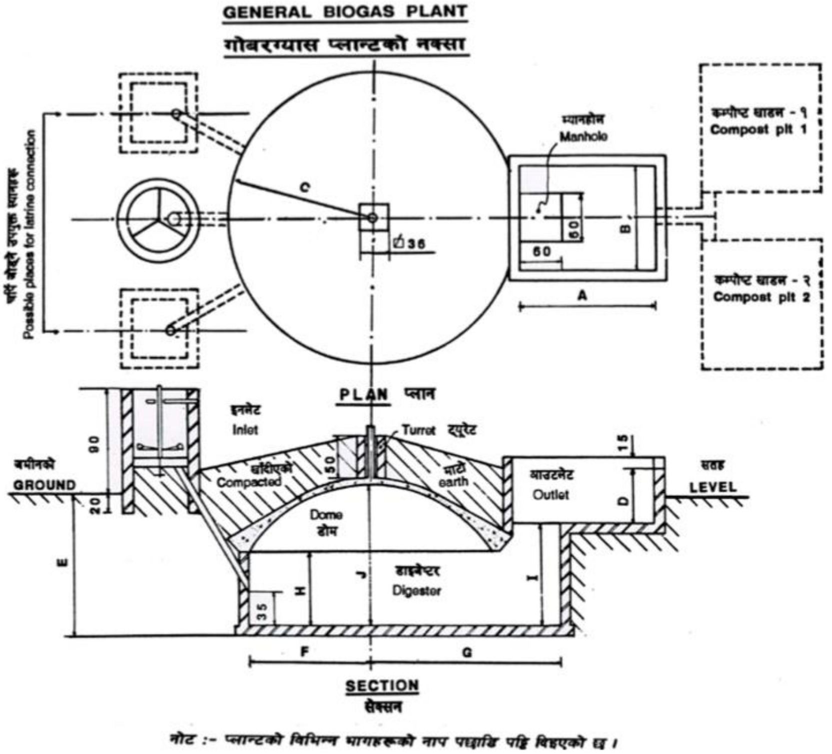

Figure 3: The Gobal Fixed Dome Biogas Digester [16]

Table 6: Working Dimensions for the Gobal Biogas Digester [16]

Part of the plant	Plants size in Cubic meter					
	4	6	8	10	15	20
A	140	150	174	180	248	264
B	120	120	130	125	125	176
C	135	151	170	183	205	233
D	50	60	65	68	84	86
E	154	155	172	168	180	203
F	102	122	135	154	175	199
G	185	211	221	240	261	288
H	86	92	105	94	115	115
I	112	116	127	124	132	137
J	151	110	175	171	193	203

1.1.4. *Raised tubewells*

In Bangladesh, the majority of households are using tubewells as a drinking water source. During floods the wells can get submerged in water, which causes a challenge in retrieving water from the source. With global warming and an estimated increase flood level around the area, the risk of flooding increases. Also, runoff from surface water mixed with human and animal excreta can reach the tubewell water through unprotected wellheads, which increases the risk of microbial contamination. Literature review revealed several case studies that found links between microbial contamination and wellhead protection. Also, raising the tubewell is a common action for flood affected areas. Based on these findings, the proposed solution was explored. The solution includes one; raising the tubewell platform and two; making sure the platform is intact and of recommended size. Additionally, two separate designs were made, where one is built to be accessible for physically challenged people. The platform sizes for both designs are within the recommended size according to the sanitary inspection and the height of the platform takes estimated rise in flood level into consideration.

The total cost for materials and labor for the standard design and the design accessible for physically challenged was estimated to be around BDT 23788 BDT and BDT 127528 respectively. The estimated payback time based on severe diarrhea cases is 11.1 years for the standard design and 58.9 years for the design suitable for physically disabled.

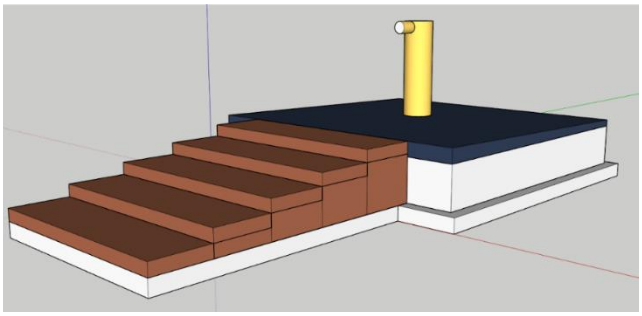

Figure 4: Raised tubewell design 1 illustrated in Sketchup

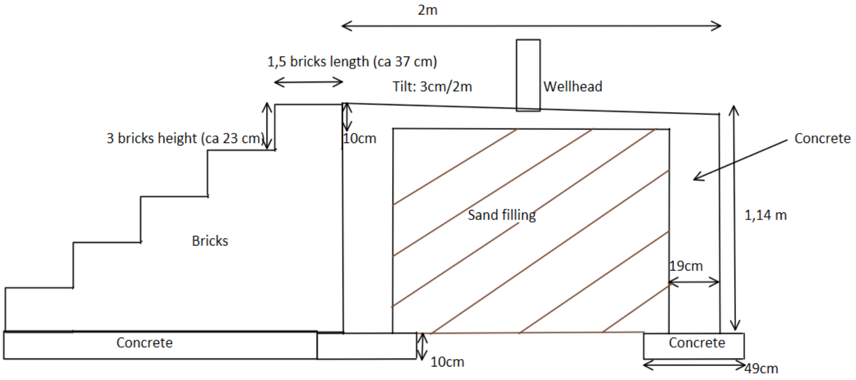

Figure 5: Raised tubewell design 1 with dimensions.

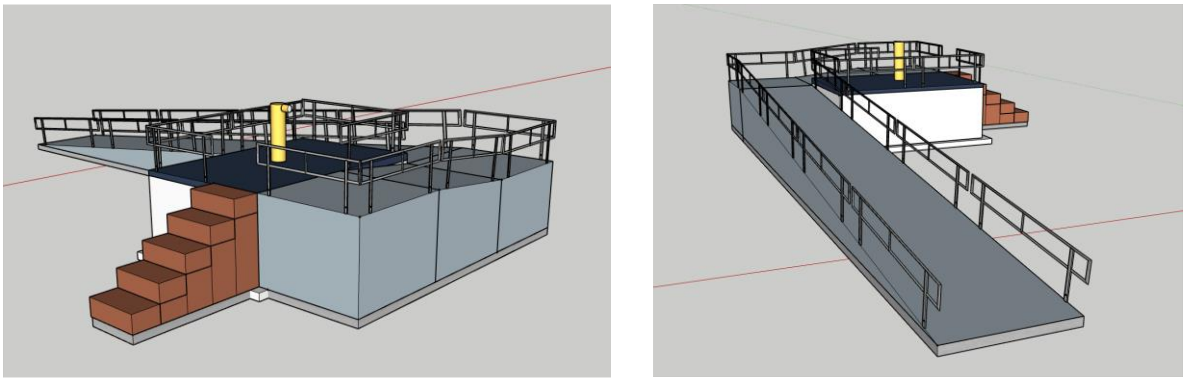

Figure 6: Raised tubewell platform design 2 illustrated in Sketchup.

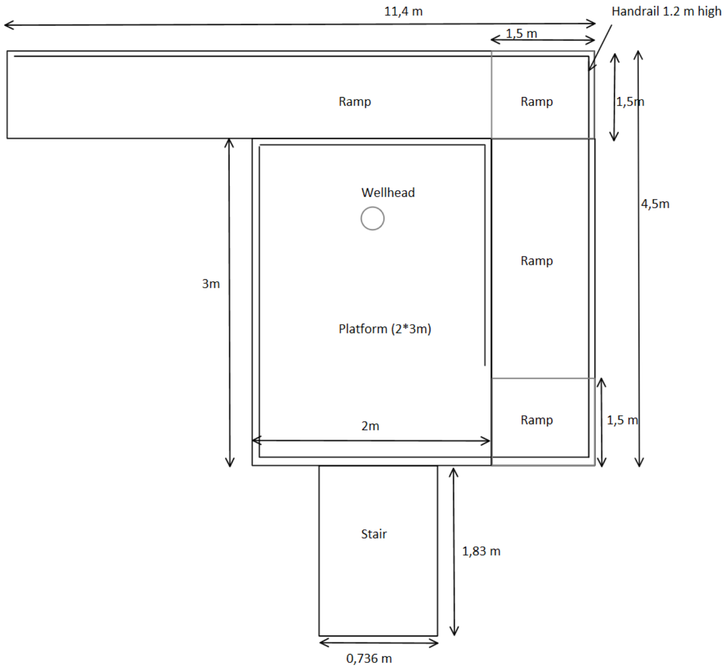

Figure 7: Raised tubewell design 2 with dimensions.

The proposed designs are inspired from construction picture [17] and the sanitary inspection requirement of at least 2*2 m platform for tubewells. The first design is 2*2 m with a height of 1.14 m with a brick stair attached to be able to reach the wellhead. The second design is constructed with features like a 1,5 m wide ramp, handrails of 1.2 m in height along the ramp and around the platform. The platform is 2*3 m with a height of 1.14 m. The features of the second design were implemented to make it accessible for physically challenged people.

Depending on the preconditions for the local people in the village, one of the two designs can be chosen. The solution would improve the possibility to access water during floods and could also decrease the risk of microbial contaminants entering the tubewell. Additional sanitation routines are encouraged to keep the platform clean, like clearing away animal waste or dirt. Also, other measures should be making sure the platform is intact, prevention of standing water around the tubewell and also ensuring that the wellhead is secured after construction. The increased cost when making the solution accessibility-friendly could change significantly with changed elevation of the tubewell, therefore further investigation of maximum flood level in the area is encouraged if there is a need for this solution in the area.

1.1.5. *Ceramic Filtration*

Ceramic Pot Filters (CPF) is a point of use water treatment system that is used around the globe [18]. The method consists of water filtering through a ceramic pot that is treated with silver. Filtration without treatment with colloidal silver removes a significant amount of bacteria, but to ensure complete removal silver is applied to the filter [19]. The method is an efficient method for removing Escherichia coli with reduction rates between 88-99.9 % according to a summary of studies conducted [20][21] [22]

Instead of buying out ceramic pot filters, to ensure steady availability of ceramic pot filters that are suitable for local requirements, a small-scale ceramic pot factory was designed drawing ideas from already successful programs run by 'Potters for Peace' across the world.

According to the survey conducted in the area, 38% of households suffered from Diarrheal disease. Ceramic clay filters have proven efficient in reducing the occurrence of Diarrheal disease. Different studies have shown reduction rates between 49 % to 70 % when ceramic filters are used [23]

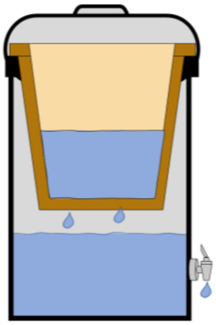

Figure 8: an overview of a possible filtration set up

To produce the ceramic filter pot a small-scale factory will be required. One of the structures in the factory is one, or several, kilns to season the ceramic clays. The dimension for a kiln to produce 50 filter pots in one firing is shown in Figure 9.

The small-scale factory would not only provide a robust access to drinking water treatment for a growing population in the area, but also provide an opportunity for local entrepreneurship and local development. In the report a factory producing 150 filters per week is suggested, with potential to increase production if needed, and the estimated investment cost is approximately BDT53 000.

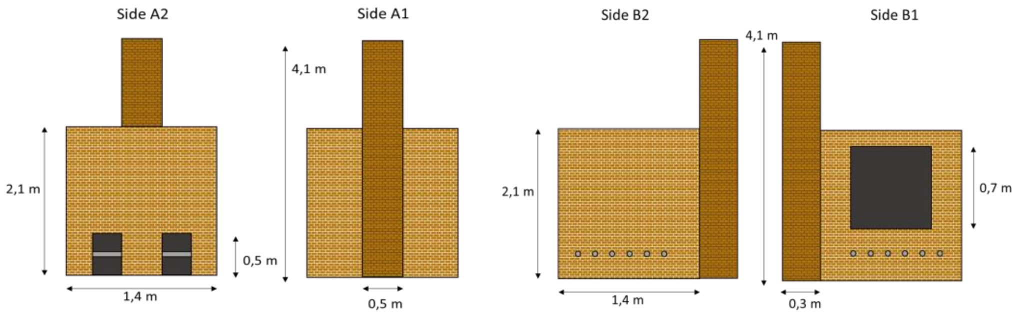

Figure 9: Dimensions for the kiln used for cost estimation. (A1-A2 lateral sides, B1-B2 front and back

The average household is assumed to consist of six persons. The daily consumption of drinking water is assumed to be 2.5 liters [24] Therefore, the drinking water demand of an average household will need two ceramic filters to cater to the daily need. It is assumed that a suitable clay for pottery is locally available. If there is a positive attitude towards the solution from the local community and if the investment cost for the factory is secured; the locally produced ceramic pot filters are a suitable solution to ensure healthy drinking water as well as promote local growth.

Manuals with instructions on the production of CPF are widely available. Helpful instructions for the person responsible for the setting of a small-scale production can be found [23] [25]

Acknowledgements

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Appendix A. Detailed Costing for each solution

A.1. Composting Toilet

Table 7: Cost estimation of compost toilet with standard design

Detail	Quantity	Unit	Rate [Taka]	Cost [Taka]
Cost one compost toilet				
MATERIAL				
Hard core stones (medium size)				
Cement	26.00	bags	410	10660
Sand	1568.00	L	0.77	1207
Gravel	301.37	L	0	0
Polythene sheet	3.00	m	340	1020
Welded mesh	1.00	piece	283	283
Welded mesh	2.00	pieces	150	300
Iron bars	8.00	pieces	57	456
Iron bars	8.00	pieces	57	456
Iron bars	4.00	pieces	57	228
Binding wire	1.00	kg	66	66
Bricks	1160.00	pieces	9.5	11020
Hoop iron	68.00	m	1	68

Timber	2.00	pieces	278	556
Timber	2.00	pieces	427	855
Timber	2.00	pieces	88	176
Timber	2.00	pieces	76	152
Timber	4.00	pieces	46	182
Timber	4.00	pieces	21	82
Suporting poles (formwork)	8.00	poles	0	0
PVC Tee	4.00	pieces	5.7	22.8
PVC Bend	4.00	pieces	11	44
PVC Pipe	5.00	m	17	85
PVC Pipe	3.00	m	17	51
PVC glue	1.00	tin	34	34
PVC plug	2.00	pieces	2	4
Iron sheet	3.00	sheets	73	219
Roofing nails	45.00	pieces	0.002	0.09
Timber	5.00	pieces	247	1235
Timber	2.00	pieces	266	532
Metal rain stopper	1.00	piece	0	0
Nails	2.00	kg	0.005	0.01
TOTAL (Material)				29994
LABOR				
Mason	2.69	day	770	3756
Mason helper	2.69	day	650	3171
Fitter	0.67	day	700	1015
Hand mixing concrete (12p) (Ord. labor)	0.29	day	490	901
Conrete (substructure) (7p) (skilled labour)	0.17	day	570	225
Concrete (superstructure)(7p)				
Curing concrete (7p) (ord. labour)	5.03	day	570	185
Excavation (ord. labour)	0.07	day	490	91
Plastering (5p) (skilled labour)	2.69	day	570	735
TOTAL (Labour)				10079
GRAND TOTAL				40073

Table 8: Cost estimation of elevated compost toilet for flood protection and ramp for disabled friendly accessibility

Part	Detail	Measurements [cm]	Estimated resources	Unit	Cost [Taka]
Elevation (1.5 m flooding)					
Material					
Superstructure	Cement (masonry)		3.78	bags	1549
	Sand (masonry)		0.39	L	0
	Bricks		971.61	pieces	9230
	Hooping iron		37.02	m	37
	Cement (plastering)		5.72	bags	2346
	Sand (plastering)		670.41	L	516
	Polythene sheet (masonry)	w=200	0.75	m	255
Material total [Taka]					13934
Labour					
	Mortar/plaster mixing (ord. labour)		10.07	hours	718
	Mason		3.95	hours	380
	Mason helper		3.95	hours	321
	Plastering (skilled labour)		2.53	hours	180
Labour total [Taka]					1598
Elevation total [Taka]					15532
Ramp (availabilitiy)					
Ramp slabs	Cement (contrete)		3.99	bags	1634
	Sand (contrete)		717.50	L	552
	Gravel (contrete)		1076.24	L	
	Timber (formwork)	w= 6x2.5 L= 166	8.00	pieces	378
	Timber (formwork)	w= 6x2.5 L= 542	8.00	pieces	1236
	Welded mesh	w=166x542	4.00	pieces	3962
Ramp filling	Sand		14176.32	L	10916
Side walls	Cement (masonry)		22.82	bags	9357
	Sand (masonry)		2640.89	L	2033
	Bricks		4890.53	pieces	46460
	Hooping iron		182.02	m	182
	Cement (plastering)		28.80	bags	11808
	Sand (plastering)		3374.46	L	2598
	Polythene sheet (masonry)	w=200	1.50	m	510
Bottom slab	Cement (contrete)		21.60	bags	8856
	Sand (contrete)		3888.00	L	2994

	Gravel (contrete)		5832.00	L	
	Timber (formwork)	w=30x2.5 L= 180	2.00	pieces	513
	Timber (formwork)	w= 30x2.5 L= 542	8.00	pieces	6179
	Polythene sheet	w= 200	21.60	m	7344
Foundation	Hard core stones		5832.00	L	
	Sand		1944.00	L	1497
Material total					119010
Labour					
	Exavation (ord. labour)		9.91	hours	706
	Contrete mixing (ord. labour)		79.15	hours	4848
	Concrete pouring (skilled labour)		28.27	hours	2014
	Concrete curing (ord. labour)		1.44	hours	88
	Mortar/plaster mixing (ord. labour)		70.36	hours	4310
	Mason		47.69	hours	4590
	Mason helper		47.69	hours	4590
	Plastering (skilled labour)		12.72	hours	906
Labour total [Taka]					22054
Ramp total [Taka]					141063
Grand total [Taka]					156596

A.2. Elevated pit latrines

Table 9: Labour cost estimation of elevated pit latrines

LABOUR COST					
Code	Description	Unit	Quantity	Man hours	Cost (Taka)
Pit chamber	Brick works (2 layers)	m3	1.65	3.99	304.47
	Mortar	m3	1.33	5.85	377.94
Earth mound	Dirt filling & compacting	m3	12.00	1.44	95.40
Stairs	Brick works (2 layers)	m3	0.27	0.65	49.82
	Mortar	m3	0.25	1.10	71.04
	Concrete slab	m3	0.45	1.88	143.43
	Timber wood	m	4.80	13.30	1055.37
Ramp	Concrete slab	m3	2.00	8.36	637.45

	Handrails	m	26.00	61.88	4911.73
Squatting slab	Concrete slab	m3	0.15	0.63	47.81
	Timber wood	m2	1.50	4.16	329.80
Superstructure	Walls	m2	15.00	8.10	642.94
	Roof	m2	2.00	0.76	50.35
TOTAL					8717.54

Table 10: Material cost estimation of elevated pit latrines

MATERIAL COST					
Code	Description	Unit	Quantity	Rate(taka)	Cost (taka)
	Material				
Pit chamber (1m x 1.5m x 1.7m)= 8.5 m2	Brick 2 layers (241mmx114mmx71mm)	piece	850	9.5	8075
	Mortar 1:2	m3	1.33	4689.3	6236.769
Earth mound 3m x 1.5 x 1m (4 sides)	Filling dirt	m3	12	600	7200
	Holding wire mesh	m2	12	8.88	106.56
Stairs	Brick (241mmx114mmx71mm)	piece	140	9.5	1330
	mortar 1:2	m3	0.25	4689.3	1172.325
	Suport concrete slab (8cm)	m3	0.45	1330	598.5
	Reinforcement wire mesh	m2	5	8.88	44.4
	Timber 20x2.5	piece	2	2020	4040
Ramp	Concrete	m3	2	1330	2660
	Handrails	m	44	11.11	488.84
Squatting slab	Concrete slab (8cm)	m3	0.15	1330	199.5
	Reinforcement wire mesh	m2	1.5	8.88	13.32
	Squatting interface(sanplat)	piece	1	646.65	646.65

	Timber 30x2.5	piece	1	2020	2020
Superstructure	Walls & door Mango timber Plank	m2	15	475.25	7128.75
	Roof	m2	2	3935.48	7870.96
TOTAL					49831.57

A.3. Faecal sludge management (Biogas)

Table 11: Labour cost estimation of floating gas biogas generator (KVIC)

Code	Units	Manhours/ Unit	Rate [Taka]/ day	Quantity for each size of gas holder [m^3]					
				2	3	4	6	8	10
General clearing (ord. labour)	m^2	0.004	490	10.13	24.50	28.13	30.42	36.13	40.50
Mason	m^2	2.420	770	25.25	47.50	55.40	63.97	76.54	86.99
Mason helper	m^2	2.420	650	25.25	47.50	55.40	63.97	76.54	86.99
Fitter	m	1.450	700	8.39	9.20	10.45	10.55	11.55	11.30
Hand mixing concrete	m^3	4.190	490	1.57	2.14	2.29	2.73	3.16	3.32
Concrete (substructre)	m^3	1.520	570	1.19	2.89	3.31	3.58	4.26	4.77
Curing concrete (ord. labour)	m^2	0.043	490	1.94	2.92	3.12	3.24	3.51	3.71
Exavation (ord. labour)	m^3	1.790	490	11.18	10.15	12.54	18.01	21.85	25.66
Plastering	m^2	0.320	570	25.25	47.50	55.40	63.97	76.54	86.99

(skilled labour)									
Welder	m	5.820	700	17.75	23.00	24.75	31.75	33.50	38.75
Welder helper	m	5.820	490	17.75	23.00	24.75	31.75	33.50	38.75
Labour Cost gas holder Size wise (Taka)				29618.89	44553.76	50147.47	60840.11	68777.10	78532.93

Table 12: Material cost estimation of floating gas biogas generator (KVIC)

Material	Dimensions (mm)	Cost for each size of gas holder (m3) in BDT					
		2	3	4	6	8	10
Angle Iron	w= 35x35x5	2537	2930	3171	4621	5323	6554
Bricks		19570	21565	23845	27550	32395	33820
Cement		4510	6150	6560	7790	9020	9430
Clips		77	77	77	77	77	77
Flange plates	d= 250 w= 6	478	478	478	478	478	478
Flats	w= 40x6						
G.I Bend	d= 25	36	36	36	36	36	36
Gas outlet pipe flange	d= 25	57	57	57	57	57	57
Heavy duty gas valve	d= 25	48	48	48	48	48	48
Long bolt nuts	d= 14 L= 32	63	63	63	63	63	63
M.S Pipe	d= 40	162	175	180	180	206	210
M.S Pipe	d= 50	141	141	153	153	177	184
Mild steel sheets	w= 2500x1000x2.5	8831	11775	12756	16681	17663	20606
G.I Pipe	d= 100	2327	2833	3751	3828	4364	4134
Pipe nipple	d= 25 L= 100	2020	2020	2020	2020	2020	2020
Pipe nipple	d= 25 L= 150	6120	6120	6120	6120	6120	6120
Polyethene pipe	d= 25 L= 3000	196	196	196	196	196	196
Sand		1	2	2	2	3	3
Square plates	w= 250x250x6	471	471	471	471	471	471
Stone chips	1/2 inch						

Union joint	d= 25	290	290	290	290	290	290
	Total [Taka]	47935	55426	60274	70661	79006	84796

Table 13: Labour cost estimation of fixed dome biogas generator

Labor	Man hours/unit	Unit	Rate [Taka]/day	Required Quantity of manhours			Cost [Taka]		
				20	15	10	20	15	10
General clearing (ord. labour)	0.004	m^2	490	40	33.9	27	77.87	66.00	52.57
Steel Fixer	1.450	m	700	44	18	13.5	44660.00	18270.00	13702.50
Hand mixing concrete	4.190	m^3	490	6.57	5.16	3.85	13488.87	10594.00	7904.44
Concrete (substructre)	1.520	m^3	8841.11	2.03	1.43	1.06	27280.13	19217.04	14244.80
Curing concrete (ord. labour)	0.043	m^2	490	6.57	5.16	3.85	138.43	108.72	81.12
Exavation (ord. labour)	2.000	m^3	205.01	42.34	35.63	29.72	17360.25	14609.01	12185.79
Backfilling	0.004	m^3	973.58	9.15	5.82	4.73	35.63	22.66	18.42
Compaction	0.750	m^3	2750.5	2.71	1.9	1.43	5590.39	3919.46	2949.91
Hardcore filling	1.400	m^3	455.47	2.03	1.43	1.07	1294.45	911.85	682.29
Plumber	1.000	m	700	12	12	12	8400	8400	8400
						Total [Taka]	118326.02	76118.743	60221.836

Table 14: Material cost estimation of fixed dome biogas generator

Material	Materials (quantity)			Cost for gas holder size M3		
	20	15	10	20	15	10
Sand [bags]	120	110	90	92.4	84.7	69.3
Aggregates	70	60	50	14350	12300	10250
Reinforcement Bars, R8	44	18	13.5	10384	4248	3186
Cement [bags]	37	30	21	15170	12300	8610

PVC Pipe, 200mm	2	2	2	2425.1	2425.1	2425.1
Manhole Covers	2	2	2	5057.02	5057.02	5057.02
Gas Outlet pipe GI 25mm diameter, 300mm long	1	1	1	57	57	57
PVC Ball Valve, 25mm diameter	1	1	1	48	48	48
GI nipples 25mm diameter, 100mm long	2	2	2	4040	4040	4040
			Total:	51623.52	40559.82	33742.42

A.4. Raised tubewell

Table 15: Material cost estimation of elevated tube-wells without ramp

MATERIAL COST (Standard design)						
Materials needed:	Measurements:	Quantity:	Units:	Cost Taka:	Unit (per):	Cost
Cement	50 kg bag	12.00	bags	460	bag	5520.00
Sand (cement mix)		34.14	cf	25	cf	853.50
Sand filling		134.30	cf	25	L	3357.50
Bricks for stair	Size 241 mm x 114 mm x 69 mm	405.00	bricks	9.5	brick	3847.50
Steel pipe	0.9 m long, 65mm diameter, 3mm thick	3.25	kg	71.6	kg	232.63
Flange	65mm diameter	2.00	piece	611	piece	1222.00
TOTAL						15033.13

Table 16: Labour cost estimation of elevated tubewells without ramp

LABOUR COST (Standard design)							
Labor	Required	Unit	Man hour	Unit [per]	Rate [Taka]	Unit	Cost [Taka]
Handmixing Concrete	2.3897	m^3	10.00	m^3	490	day	612.64

Concrete substructure	0.2548	m^3	0.39	m^3	570	day	27.62
Concrete superstructure	2.1349	m^3	8.27	m^3	570	day	589.52
Curing Concrete	13.2	m^2	0.57	m^2	570	day	40.44
Excavation	0.18	m^3	0.31	m^3	490	day	19.18
Plastering	13.2	m^2	4.21	m^2	570	day	300.21
Masonry	19.92	m^2	48.21	m^2	770	day	4639.87
Sand filling	3.801	m3	15.20	m3	570	day	2241.19
Bolting	2	pieces	4.00	pieces	570	day	285.00
Total Cost							8755.67

Table 17: Material cost estimation of elevated tubewells with ramp

MATERIAL COST (With ramp)						
Materials needed:	Measurements:	Quantity:	Units:	Cost Taka:	Unit (per):	Cost (per material):
Cement	50 kg bag	44	bags	460	bag	20240
Sand (cement mix)		133.26	cf	25	cf	3331.50
Sand filling (both ramp and around wellhead)		628.54	cf	25	cf	15713.50
Bricks for stair	Size 241 mm x 114 mm x 69 mm	405.00	bricks	9.5	brick	3847.50
Steel pipe	1.14 m long, 65mm diameter, 3mm thick	3.25	kg	71.6	kg	232.63
Flange	65mm diameter	2.00	piece	611	piece	1222.00
Hand rail (steel pipes)	Steel pipes 69mm OD, 3mm thick	643.50	kg	71.6	kg	52985.79
Total Cost						97572.92

Table 18: Labour cost estimation of elevated tubewells with ramp

LABOUR COST (With Ramp)							
Labor	Required	Unit	Man hour	Unit [per]	Rate [Taka]	Unit	Cost [Taka]
Handmixing Concrete	8.36	m^3	34.99	m^3	490	day	2143.24
Concrete substructure	2.278	m^3	3.47	m^3	570	day	246.90
Concrete superstructure	6.082	m^3	23.57	m^3	570	day	1679.46
Curing Concrete	56.71	m^2	2.44	m^2	570	day	173.75
Excavation	2.31	m^3	4.02	m^3	490	day	246.19
Plastering	56.71	m^2	18.10	m^2	570	day	1289.76
Masonry	19.91884	m^2	48.20	m^2	770	day	4639.60
Sand filling	17.8	m3	71.20	m^3	570	day	6230.90
Bolting	2	pieces	4.00	pieces	570	day	285.00
Welding handrails	62.8	m	182.75	m	570	day	13020.80
Total Cost							29955.58

A.5. Ceramic Filtration (Pot filters)

Table 19: Material cost estimation for erection of ceramic pot firing kiln

Material cost for the kiln						
Code	Quantity	Unit	Cost Taka:	Cost(per) unit:	Equivalent Kg	Cost
Number regular bricks	1520.5	Nos.	9.5	brick	-	14449.50
Number of longer bricks	19	Nos.	46.62	block	-	885.78
TMT round bar, recommended 3/4-1 inch, calculations based on d=16 mm	5.4864	m	49.02	kg	8.49	416.37
Required number rods (two slightly different lengths)	10.9728	m	49.02	kg	16.99	832.74
Number of corner brackets	8	Nos.				NA
Number of nuts	16	Nos.				NA
NICETY DT1311 DIGITAL LCD INDUSTRIAL THERMOCOUPLE THERMOMETER IN BANGLADESH	1	Nos.				6500.00
Mortar	2033.8	kg	15.90	kg		32345.54

Total cost (Taka)	55429.93

Table 20: Labour cost estimation for erection of ceramic pot firing kiln

Labor cost for building the kiln					
	Unit	Man hours for structure	Rate [Taka]	Unit	Total Cost
Mortar mixing, mason	m3	4.14	770	day	398.76
Mortar mixing, mason helper	m3	8.29	650	day	673.23
Masonry, Mason	per m3	3.42	770	day	328.98
Masonry, Mason helper	per m3	3.42	650	day	277.71
Total cost (Taka)					1678.67

Table 21: Ceramic pot making cost

Running costs - Material cost per pot and wood used for firing					
Colloidal silver brushed on the pots for increased reduction of bacteria					
	ml / pot	Cost per litre Colloidal silver liquid (2000 ppm) [Taka]	Cost, Diluted to 200 ppm, 0,1 l and 0,9 l solution [Taka]	Cost per pot [taka]	
Colloidal silver	2	2964	2667.6	53.352	
Wood as fuel for burning the kiln (50 pots in single charge)					
	kg/ pot in one firing	kg wood/ firing	Average price firewood, India, Taka per kg	Cost per charge, Taka	Cost per Pot
Wood	4.8	240	285	1368	27.36
Clay mixture - Ingredients to the clay mixture that the pots are created from					
	kg/pot	Taka / kg	Taka / pot		
Clay	5	Locally available	0		
Rice husk	1.62	0.12	0.194		
Laterite	0.17	0.684	0.114		
Running material and fuel cost per pot: (BDT)				81.02	