FEASIBILITY REPORT ON RURAL WATER SUPPLY IN BANGLADESH

JUNE-2015

Department of Public Health Engineering (DPHE)

Government of the People's Republic of Bangladesh

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Department of Public Health Engineering (DPHE)
Local Government Division
Ministry of LG, RD & Co-operatives

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EXECUTIVE SUMMARY

After achieving 97% water supply coverage, in mid-nineties, identification of arsenic in groundwater particularly in shallow aquifer emerged as a great threat for groundwater based drinking water system in Bangladesh. At present safe water coverage is 88% (JMP 2012) and in other way 92 person per public water point. Development of water source is not uniform in Bangladesh due to its hydro-geological and hydro-chemical diversification. In this context DPHE prepared the "Feasibility Report" for rural water supply system explaining the feasibility of different option based on hydro-geological and hydro-chemical consideration including harmonizing the policies, studies, DPHE's available data and consultation with the expertise of the sector.

Different studies carried out, such as, BGS-DPHE (2001), DPHE- JICA (2002) concluded that occurrence of arsenic is the result of a natural geochemical processes that probably occur to some extent in all alluvial and deltaic sediments. The distribution of arsenic has no uniform pattern, rather sporadic having local variation even. The two studies suggested Deep tubewell, Dug well, Pond sand filter and Rainwater harvesting as mitigation options. It is opined that deep aquifer is arsenic safe if aquifer is separated by one or more sufficiently thick (~10m) clay/silty clay layers. DPHE-JICA (2009) assessed the mitigation status and found that Deep tubewell contributed 70% of alternate options. The study also mentioned that piped water supply can be effective and BCSIR approved ART may be deployed where no other options are successful. DPHE-IWM study conducted in part of three districts (Jessore, Khulna and Satkhira), found that Deep tubewell, PSF and Shallow shrouded well are the technologies of that area. Rainwater harvesting is also potential option. Reverse osmosis (Desalination) and Artificial recharge of groundwater technologies can be scaled up based on its evaluation following long term monitoring.

DPHE-JICA (2009) estimated that 19 million population need arsenic safe water. Even 92 persons per water option are considered on the contrast of 50 people per water point as policy target, 0.2 million water options will be required. Apart from that, to maintain the same ratio (92 persons/option), about 53,000 water options are required annually to be installed considering the population growth rate 1.5% and rate of de-functioning (approx. 2%) of water point per annum. It is also urgent to gradually replace the suction mode (No. 6) pump by Tara (deep-set pump) in low water table area to ensure the safe water availabilibity round the year particularly in dry season.

Review and analyzing the development studies and available information, feasible options for the Arsenic, saline prone area, non-arsenic and non-saline area along with

the low water table area has been determined. Feasibility for the major mitigation option has been demonstrated to ensure its proper application in the field, considering its hydrogeological and hydro-chemical condition.

Furthermore, piped water systems to be gradually increased as recommended by SDP (2015-25). Deep aquifer investigation is to undertaken including development of drilling technology to penetrate gravel or stony layer in arsenic and other water sacred areas. The technologies under piloting are to be scaled up after its performance evaluation. Action researches are to be strengthened to explore the appropriate technologies, in terms of technical and social aspects, for arsenic and saline prone areas.

Abbreviations

AAN	Asia Arsenic Network
ART	Arsenic Removal Technology
As	Arsenic
BADC	Bangladesh Agricultural Development Corporation
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BBS	Bangladesh Bureau of Statistics
BCSIR	Bangladesh Council of Science and Industrial Research
BGS	British Geological Survey
BWDB	Bangladesh Water Development Board
DANIDA	Danish International Development Agency
DFID	Department for International Development (UK)
DGL	Declining Groundwater Level
DHTW	Deep Hand Tubewell
DPHE	Department of Public Health Engineering
DTWs	Deep Tubewells
DW	Dug Well
DWSS	Drinking Water Supply and Sanitation
EC	Electric Conductivity
GIS	Geographic Information System
GoB	Government of Bangladesh
GW	Ground Water

GWL	Ground Water Level
IDW	Improved Deep Well
IRP	Iron Removal Plant
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
LGD	Local Government Division
LGI	Local Government Institutes
LGED	Local Government Engineering Department
Lpcd	liter per capita per day
MIS Unit	Management Information System UnitMLGRD&C Ministry of Local Government, Rural Development & Cooperatives
NAMIC	National Arsenic Mitigation Information Center
NGO	Non-governmental Organizations
NWP	National Water Policy
NWMP	National Water Management Plan
ppb	parts per billion
ppm	parts per million
PSF	Pond Sand Filter
RWH	Rain Water Harvesting
SDP	Sector Development Plan
SDW	Shallow Dug Well
SHTW	Shallow Hand Tubewell
STW	Shallow Tubewell
TDS	Total Dissolved Solids
TW	Tubewell
UNICEF	United Nations Children's Fund
VSST	Very Shallow Shrouded Tubewell
WHO	World Health Organization
WSS	Water Supply and Sanitation
WT	Water Table

1. Introduction

Bangladesh, with a population of over 156 million living on a total land area of 147, 570 square kilometers, is one of the most densely populated countries in the world. In this contexts there is grave concern over the high morbidity and mortality related to water borne diseases. Government of Bangladesh (GoB) has installed more than 1.4 million hand pump tubewells in the rural areas and six times more tubewells have been installed by private individuals, NGOs and other agencies which are mostly shallow tube wells with No-6 pump. Piped water systems have been installed in some core areas of Pourashavas whilst fringe areas rely mostly on tubewells.

The introduction of drinking water through tube wells, some higher sanitation coverage and improved primary health care has contributed to a significant drop in mortality from diarrheal diseases from 300,000 deaths per year in 1990 to 125000 in 2013. However, the overall situation is yet to be much improved. Mortality rates of infants and children under five years are 40.9 per 1,000 live births (Report 2014, UNICEF).

At the mid-nineties, a great public health challenge related to water supply has been emerged in the groundwater based water supply system through detection of arsenic particularly in shallow aquifer which is termed as single largest problem for safe water supply. About 30 million people were exposed to arsenic contaminated water containing more than the Bangladesh National Standard of 50 micrograms per liter. Bangladesh Government has taken a number of initiatives, such as, awareness campaign, arsenic test of tubewells, providing alternate safe options and patient management.

At present, Bangladesh achieved 88 percent safe water supply coverage. About 1.4 million public water options installed resulting 92 persons per option.

Development of water source is not uniform in Bangladesh due to its hydro-geological and hydro-chemical diversification. So, different types of options are required to be identified properly considering the characteristics of on area. In this context DPHE has taken initiative to prepare the “Feasibility Report” identifying safe water technologies and explaining the feasibility of different option based to hydro-geological and hydro-chemical consideration including harmonizing the policies, studies, DPHE’s available data and consultation with the expertise of the sector.

2. Purpose of the Report

i. *To define the different hydro geological and hydro-chemical areas;*

ii. *To picture the present water supply situation in Bangladesh;*

iii *To estimate the need for provision of water supply;*

iv. *To identify the safe water option for different hydrogeological and hydro-chemical areas;*

v. *To define the Feasibility of different options for the specific areas.*

3. Approach and Methodology for Preparing the Report

i. *Review of the policies.*

Relevant policies and strategies provide legitimate requirement of the sector in terms of target & goal, intervention and institutional need of the sector as well. It also provides the guiding principles towards the implementation of the project.

ii. *Review of development studies.*

Development studies and survey contributed to define the extent of arsenic or other contamination and also useful to develop the mitigation approach in different situation.

iii. Review the DPHE Data

DPHE data on water option, groundwater level, water quality and lithology provides a great support to assess the present water supply situation in particular to performance of each water point option for particular area.

iv. *Consultation*

Consultation with DPHE and other experts of the sector provides valuable contribution in identifying the mitigation options for the particular areas. Sharing of experiences was found useful regarding defining the mitigation approach.

v. Formulation of Findings along with feasibility of water option

Adopting the above steps (i to iv), findings has been outlined on need for water supply provision, challenges of water source development, delineating the different areas based on hydro-geological and hydro-chemical characteristics, defining the mitigation options on characteristics of the areas and finally feasibility assessment of major mitigation option.

4. Policies and Strategies

4.1 National Policy For Drinking Water Supply And Sanitation (DWSS policy) 1998

The National Policy for Drinking Water Supply and Sanitation 1998 is the most significant policy for the sector. Through this policy, the Government of Bangladesh has set a goal to ensure access of safe water and sanitation services for all with an affordable cost.

The policy aims to bring changes in the traditional service delivery arrangement and to increase the capacity of the sector. It calls for decentralization and emphasizes the participation of users in planning, development, operation and maintenance of WSS facilities through local government and community-based organizations. It also recognizes the important roles of the NGOs & private sector in service development and delivery. The policy set a target of 50 users for one water point in the near future.

4.2 National Water Policy 1999

The NWP elaborated by the Ministry of Water Resources and approved in 1999 outlines the national policy for management of water resources. In relation to the water supply and sanitation sector, the NWP aims to:

- Facilitate availability of safe and affordable drinking water supplies through various means, including rainwater harvesting and conservation;
- Mandate relevant public water and sewerage institutions to provide necessary drainage and sanitation, including treatment of domestic wastewater and sewage and replacement of open defecation.

- Empower, and hold responsible, municipalities and urban water and sewerage institutions to regulate the use of water for preventing wastage and pollution by human action;
- Mandate local government institutions to create awareness among the people in checking water pollution and wastage.
- Public agencies.

4.3 National Water Management Plan (NWMP) 2004

Ministry of Water Resources has prepared the National Water Management Plan with the intention to implement the directives given by the NWP. The plan states that future irrigation mainly based on groundwater would not be sustainable as the amount of groundwater recharged each year is finite, and the dangerous phenomenon of arsenic contamination of groundwater.

4.4 National Policy for Arsenic Mitigation 2004 and Implementation Plan

LGD formulated a policy guideline for arsenic mitigation programs for arsenic affected areas to guide and co-ordinate all arsenic mitigation activities. The Policy supplements the National Water Policy, 1999 and the National Policy For Safe Water Supply and Sanitation 1998.

The policy states that access to safe water for drinking and cooking shall be ensured through implementation of alternative water supply options in all arsenic affected areas.

The arsenic mitigation policy provides guidelines for:

- Assessment of arsenic in water, soil and agricultural products
- Public awareness building
- Technology choice:

Preference will be given to surface water over groundwater as source for water supply. On an emergency basis, safe source of drinking water at a reasonable distance should be ensured

4.5 Pro Poor Strategy 2005

About 22 million households of the country get drinking water from about 10 million tube wells. However, 9 million of these tube wells are 'privately' owned. Thus, it leaves only 1 million 'community' tube wells for about 13 million households in the country, conveying that a large number of poor in the country do not have ownership of a drinking water asset and that they are dependent largely on economically well to do people for their drinking water needs.

The minimum level for drinking water is defined as 20 lpcd. Furthermore, the water should be within 50 meters of household premise and meet the national water quality standards.

4.6 Sector Development Plan (2011-2025), Water Supply and Sanitation Sector

The objective of the SDP is to provide a framework for planning, implementing, coordinating and monitoring all activities in the WSS sector. As a strategic planning document, the SDP is expected to address the emerging and the future challenges of the WSS sector. The Plan also provides a road map for the development of the sector and a corresponding sector investment plan. It lays emphasis on institutional and legal reforms, strengthening the capacities of the public institutions, establishing a better sector coordination and monitoring system, managing the water resources effectively, stimulating the private sector, safeguarding the environment and tackling the climate change, increasing fund, and above all expanding coverage, increasing service levels, and ensuring sustainability.

4.7 Water Acts, 2013

Water Act 2013 has been promulgated with a view to ensure the co-ordinated development, management, abstraction, usage, security and preservation of water resource. The Act provided utmost priority on domestic water supply over other uses.

5. Review of Development Studies and Surveys

5.1 Study to Forecast Declining Groundwater Table (DPHE-UNICEF)

Since 1970 and particularly 1980's, the growth of minor irrigation was rapid. Due to large scale abstraction of groundwater for irrigation, groundwater level have lowered in many areas rendering a large number of tubewells fitted with suction mode (#6) pumps started to becoming inoperable particularly during dry months.

DPHE-UNICEF carried out study during 1994 to identify the areas for phase-wise requirement and installation of Tara (Deep-set) pump. The areas under study covered all of Bangladesh excepting the coastal areas, greater Chittagong Hill Tract and part of greater Sylhet district. The main reason for exclusion of the areas was the absence of adequate database. The total number of studied thanas was 349.

The study predicted population to be served by different type of Hand Pump System based on depth of water table is given below:

Table-1: Predicted Population to be Served by Different type of Hand Pump

Type of Pump	Population			
	1995	2000	2010	Full Development
Nr. 6	48,532,153 (42%)	42,721,984(33%)	42,954,119 (26%)	51,198,190 (23%)
Marginal Tara	14,364,087 (12%)	15,170,195 (12%)	17,073,078 (11%)	17,993,789 (8%)
Tara	23,198,103 (20%)	37,447,596 (29%	56,652,766 (35%)	87,205,995 (39%)
Mrg. S. Tara	642,013 (1%)	1,366,725 (1%)	2,560,423 (2%)	5,398,370 (3%)
Super Tara	0	0	976, 250 (1%)	4,823,991(2%)
Sub-total :	86,736,356 (75%)	96,706,500 (75%)	120,216,636 (75%)	166,620,335 (75%)
Population outside DGL Study Area	29,247,647 (25%)	32,609,592 (25%)	40,537,269 (25%)	56,184,683 (25%)
Total :	115,984,003	129,316,092	160,753,905	222,805,018

Note: No. 6 (up to 6m), Marginal Tara (6-8m), Mrg. Super- Tara (15-16m), Super Tara (> 16m)

It is predicted in the above table the trend of decreasing the area of **suction mode pump (Nr 6)** and increasing trend of deep-set pump particularly **Tara (15-16m)** hand pump

The predicted areas under different category of pump have been shown in the following Map.

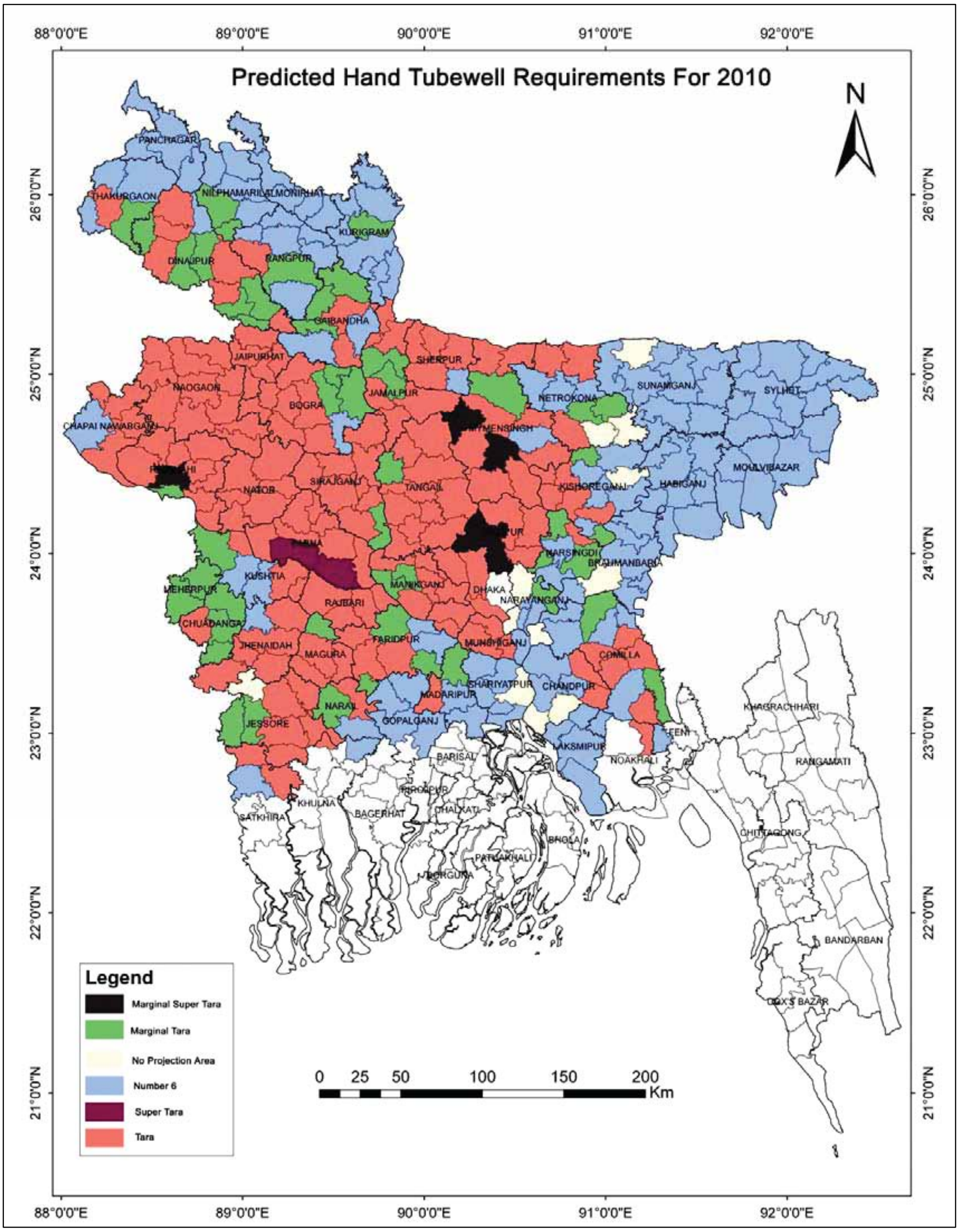


Figure-1: Predicted Hand tubewell requirements

Note that Map on water table has been prepared based on water monitoring data of DPHE in 2009-10 showed similarity with the predicted map up to large extent.

5.2 Arsenic contamination of Groundwater in Bangladesh (DPHE- BGS)

Groundwater arsenic contamination was officially announced in 1993 in Bangladesh. DPHE-UNICEF carried out a testing program for arsenic across the whole of Bangladesh using field kits covering 23,000 samples. The result of the survey showed for the first time the scale of problem. Followed by the survey, DPHE-BGS undertook the scientific study under the finance from DFID with objectives; (i) Review geological and hydrology of Bangladesh (ii) carry out a systematic ground water quality testing (iii) carry out detailed geochemical investigation in three Special Study Area (iv) model the movement of groundwater and arsenic in typical Bangladesh situation. The final data set for this survey consisted of sample from 3534 tubewells in 61 districts covering 433 upazilas. The sample density was 8 samples per upazila or one sample per 37 km^2. The Technical Report (February 2001) described the hypothesis of arsenic occurrence & movement, spatial distribution of arsenic and mitigation approach.

Occurrence of Arsenic in Ground water

The high correlation between arsenic and iron in Bangladesh sediments and the known strong sorption of As (V) and As (III) by iron (III) oxides suggests that these oxides play an important role in creating the high arsenic groundwater in Bangladesh.

When sediment is buried, the oxidation of fresh organic matter rapidly leads to the development of anaerobic conditions suspecting, there lease of arsenic.

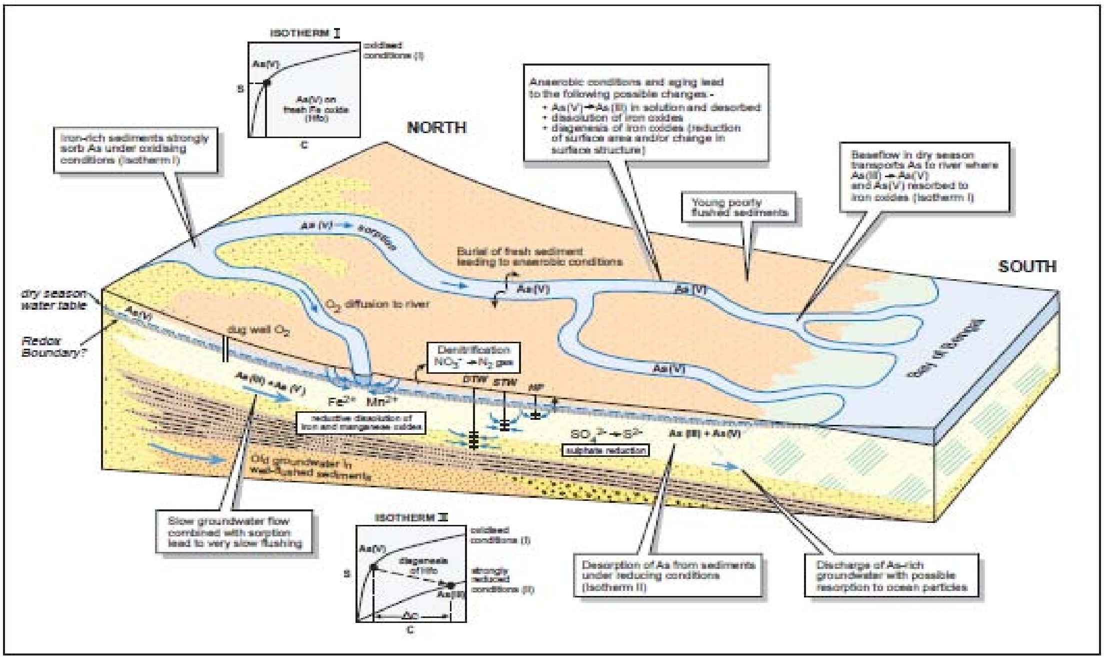


Figure-2: Block diagram showing the basic geology and hydrogeology of the Bengal Basin

The precise mechanism of arsenic release is still unknown. It probably occurs by a variety of mechanisms including the reducive desorption of arsenic due to the transformation of As(V) to As(III), the reducive dissolution of iron oxides, and a change in surface structure and specific surface area of the iron oxides due to digenetic reactions. This is collectively described all of these processes as the *iron oxide reduction hypothesis.* The low hydraulic gradients and the strongly stratified nature of the Bangladesh aquifers means that in the absence of pumping, the flushing of the released arsenic and other solutes is likely to be very slow.

Finally, it is concluded that the generation of high arsenic in groundwater in Bangladesh is therefore believed to occur as a result of a natural geochemical processes that probably occur to some extent in all alluvial and deltaic sediments but are exacerbated in the Bay of Bengal because of the large volume of young sediments. All similarly exploited aquifers must be considered to be 'at risk' from arsenic contamination and, where they are exploited for drinking water, need to be tested for arsenic by random survey.

Arsenic Contamination Ratio and Spatial Distribution

The results from the 3534 wells sampled through Bangladesh (apart from the Chittagong Hill Tracts) showed that 27% of all shallow wells (<150 m depth) were contaminated with arsenic (As) above the Bangladesh standard (50μg L^{-1}). This increases to 46% when the more stringent WHO guideline value (10μg L^{-1}) is used. 9% of all sampled wells exceeded 200 μg L^{-1} and 1.8% exceeded 500μg L^{-1}. The population exposed to drinking water in excess of the Bangladesh arsenic standard was estimated in two slightly different ways. One estimate gave a population of about 35 million and the other gave an estimate of 28 million. These figures increase to some 57 and 46 million people, respectively, when the WHO guideline value is used. Only 1% of 'deep' wells (depth >150 m) exceeded the Bangladesh standard and 5% exceeded the WHO guideline value. So, deep groundwater, where available, appear to offer a long-term source of safe drinking water. There is a distinct regional pattern of arsenic contamination with the greatest contamination in the south and south-east of the country and the least contamination in the north-west and in the uplifted areas of north-central Bangladesh. However, there are occasional arsenic 'hot spots' in the generally low-arsenic regions of northern Bangladesh.

Mitigation Approach

Mitigation approach recommended in the study described in brief as below;

- in affected areas, an immediate interim source of 'arsenic safe' water should be indentified and the implementation of a long-term solution begun.
- patients' progress should be monitored and the continued, use of the interim source of water has to be ensured until the long-term source becomes available;
- There are four possible sources of low-arsenic water in Bangladesh:
  - (i) rainwater;
  - (ii) treated surface (river or pond) water;
  - (iii) dug well water;
  - (iv) deep tubewell water.

5.3 The Study on the Groundwater Development of Deep Aquifers for safe Drinking Water Supply to Arsenic affected areas in Western Bangladesh (DPHE-JICA).

The study project was carried out during May 2000 to November 2002 with the overall objectives of the study are 1) to formulate the master plan for the development of groundwater resources in arsenic affected areas in western Bangladesh, 2) to conduct a pre-feasibility study on the projects with higher priority, and 3) to transfer technology. The study area comprises the Jessore, Jenaidah and Chuadanga district. Extensive deep aquifer was investigated through core drilling, geo-physical logging and water quality sampling. The study provides the hypothesis of arsenic occurrence and mitigation plan explaining surface & sub-surface geology, aquifer classification & characteristics, hydro-chemical analysis and simulation of groundwater contamination.

Distribution of Arsenic Source, Dissolution and its Transport Mechanism

The possible arsenic source in geologic layers was found not only in the shallow portion but also in the deeper portions. However, it is evaluated that the shallow arsenic source in active at present, because the arsenic concentration is high in the shallow portion, and it generally decreases with depth. In addition, the horizontal distribution of arsenic concentrations in groundwater suggests that the distribution of the arsenic sources in the shallow portion is not uniform in the study area. They mainly occur in the western part of the study area. Further, the distribution of arsenic concentrations in groundwater significantly varies even within a village, indicated that the occurrence of arsenic sources is not uniform in a small area.

It is presumed that the distribution of arsenic sources in the shallow portion is geologically and geomorphologically controlled. The depositional environment, sedimentary history and delta evolution should be further studied in the Ganges Delta. It was found that most of the arsenic contaminated groundwater in the study area is characterized by a low Eh (redox potential) and high iron concentration. This indicates the dissociation of ferric oxyhydroxide and release of iron and arsenic ion into the groundwater. The reduction of iron oxyhydroxide is the most likely mechanism taking place at the present moment.

After the dissolution of arsenic in to groundwater, the arsenic contaminated groundwater basically moves along with the groundwater flow. Under natural conditions without any groundwater pumpage by human beings, the velocity of groundwater flow is estimated to be very low because the hydraulic gradient in the Ganges delta and in the study area is comparatively flat. However, if the groundwater is extracted by wells, the natural groundwater system will be disturbed. Although it is estimated that some portions of pumped groundwater again infiltrate into the ground and return back to the groundwater body, the accelerated circulation of groundwater in the shallow portion could cause changes in the physical and chemical conditions of the underground environment. Therefore, it is implied by the study results that the increase in groundwater pumpage for irrigation use has had some impact on the groundwater conditions in the study area, and the occurrence of groundwater contamination by arsenic might have also been caused by the impact.

Proposed Master plan

The basic policies are described in brief as below:

(1) Measures against arsenic contamination in the rural area are planned at each arsenic contaminated zone based on the contamination map, which was prepared by the Study. The screening of all existing wells will be conducted for detailed planning.

(2) The groundwater in the deep aquifers will be the main water source. In the areas not supplied by the deep groundwater, alternative plans for water sources such as improved deep wells, arsenic removal devices, pond sand filtration, shallow dug wells, etc. will be applied.

(3) A safe water quality will be secured by monitoring the arsenic concentration of groundwater throughout the Master Plan period.

Construction of alternative water source has been recommended as a part of mitigation measures, which are;

(1) Improved Deep Well (IDW)s are to be constructed in the southern area of Jessore District where this method is thought to be applicable considering the hydrogeological conditions.

(2) Pond Sand Filter (PSF)s are to be constructed utilizing the ponds, which are applicable for drinking water all year round.

(3) Rain Water Harvesting (RWH)s are to be constructed at the official facilities in the mouzas.

(4) Shallow Dug Well (SDW)s are to be protected from surface water infiltration.

5.4 NAMIC Data base on Arsenic contamination (2003)

Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) was undertaken in 1998, which completed a screening of all water supply wells in rural areas of the arsenic affected upazilas as identified by DPHE- BGS study. BAMWSP, along with UNICEF, World Vision, DANIDA and AAN tested all wells (public and private) in 270 Upazilas of the country during the period 2001 to 2003. Based on blanket screening of arsenic by field kits, National Arsenic Mitigation Information Center (NAMIC) database was established.

Around 4,943,225 wells were tested using field test kits (HACH). The survey collected information of wells and identified patients with visible arsenicosis symptoms. 1,440,409 (29%) tested wells were found to exceed the Bangladesh drinking water limit of 50 ppb.

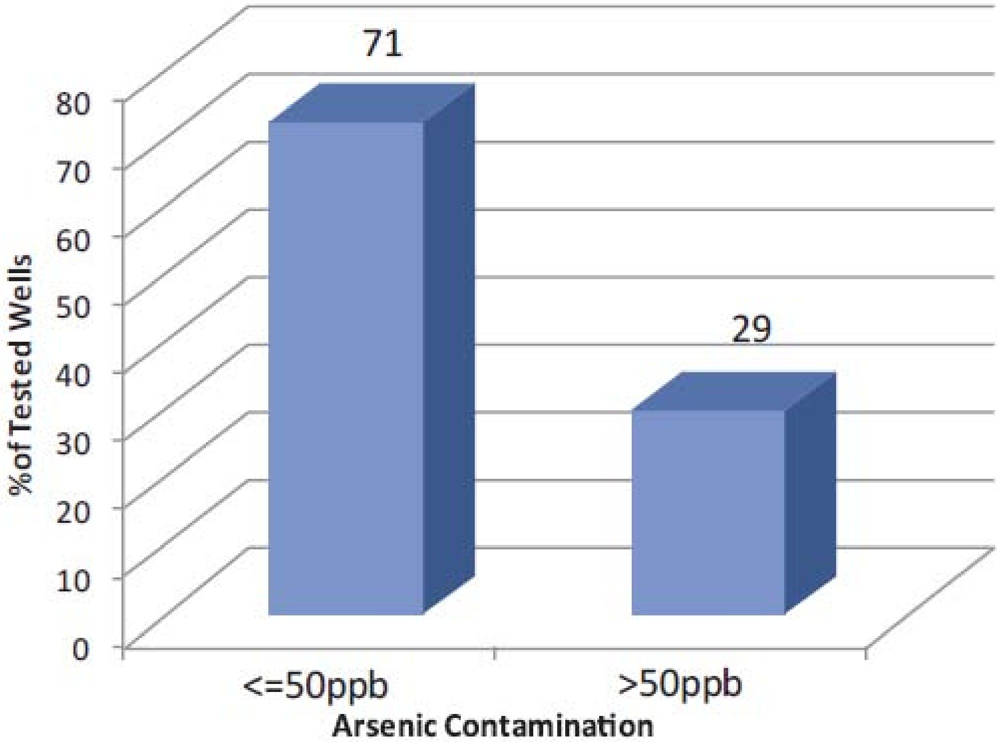


Figure-3: Summary of BAMWSP screening data on 270 Upazila

One important outcome of the survey was the identification of about 8540 villages where more than 80% wells exceeded the Bangladesh drinking water limit of arsenic. These villages were recommended to be incorporated under the emergency mitigation plan.

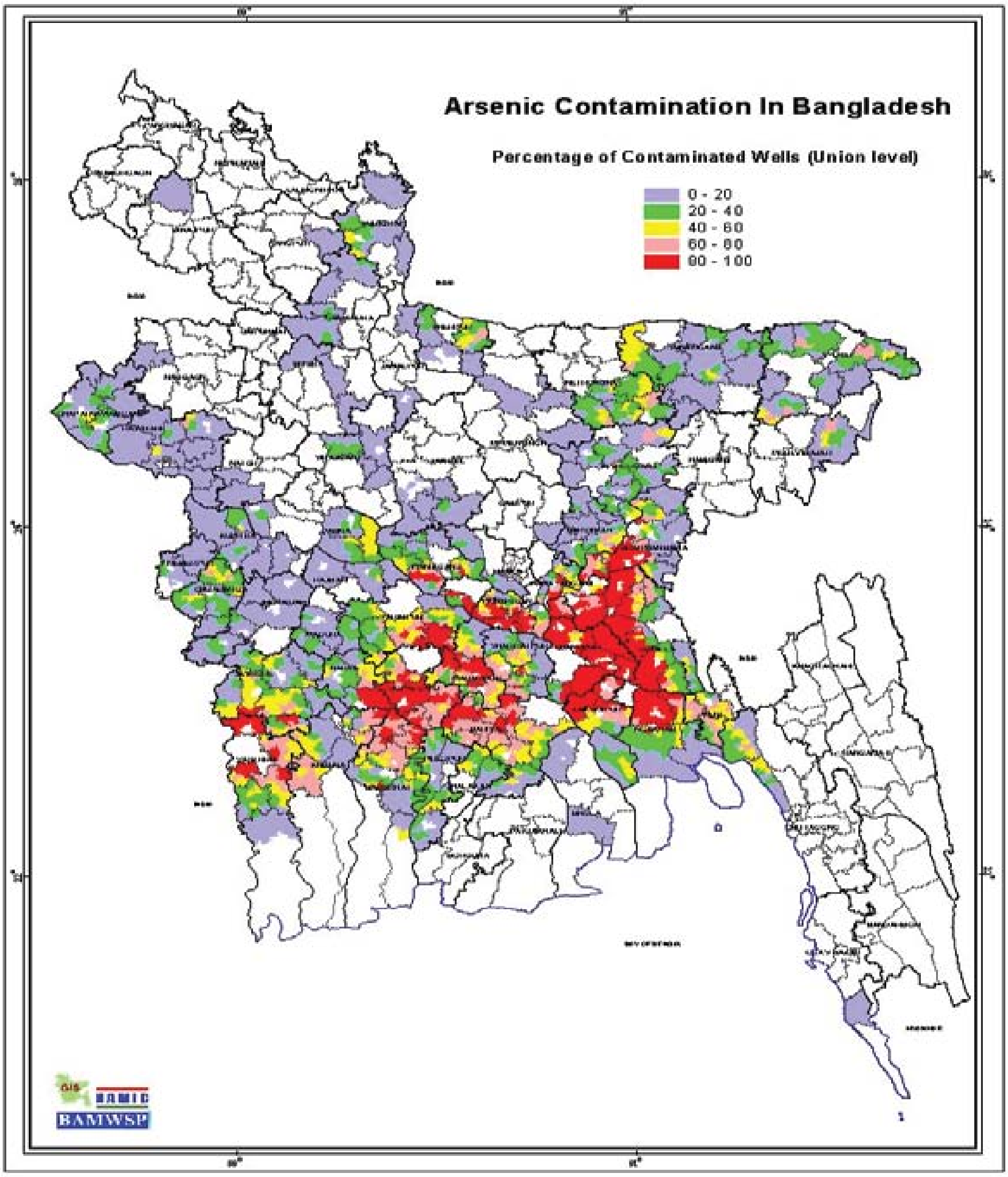


Figure-4: Arsenic contamination Map

NAMIC database also supports the findings of DPHE- BGS and DPHE-JICA that arsenic distribution is not uniform but there is a distinct regional pattern. However, geographically, the highest contamination was observed in the central part of the country, particularly in the eastern section. The northern part generally has a lesser degree of arsenic contamination.

5.5 Situation Analysis of Arsenic Mitigation 2009 (DPHE-JICA)

The study conducted a survey in arsenic affected unions of the country with an objective to determine the current situation of the arsenic mitigation through public (DPHE, NGO) intervention. The survey was supervised by DPHE with assistance from JICA. The Data was analysed and mapped using GIS techniques by a group of experts from the Department of Geology, University of Dhaka. The study was conducted for 3132 unions in 301 upazilas covering 55 districts within the 6 divisions.

The study revealed the arsenic ***mitigation situation*** and ***need for provision of safe water supply*** as well.

Safe water supply coverage under different categories of union based on arsenic contamination ratio has been given below:

Arsenic Contamination %	Number of Union	Total Population	% of Union Population with Total Population	No. of provided Active SWO	Population with Safe Water Coverage (Averaged for the unions)	% of Union Population with Safe Water Coverage
< 20%	1,574	43,646,588	53.18%	420,907	27,189,925	62.3%
>=20% to <40%	449	11,681,173	14.23%	110,161	7,067,935	60.5%
>=40% to <60%	307	7,614,753	9.28%	52,959	3,397,355	44.6%
>=60% to <80%	324	7,572,934	9.23%	52,772	3,364,915	44.4%
>=80%	466	11,004,897	13.41%	53,191	3,433,845	31.2%
No Data	12	554,648	0.68%	2,498	161,170	29.1%
Total	**3,132**	**82,074,993**	**100.00%**	**692,488**	**44,615,145**	**54.4%**

Table-2: Safe water coverage percentage for population within different categories of arsenic contamination

Regarding water supply technologies the study provided the following observations as described below:

Surface water based options are very limited and only suitable in a few pockets. In general the overall contribution from surface water source to arsenic mitigation is small. Rainwater harvesting also can provide safe water in certain part of the country for certain seasons of the year. Groundwater based options have been the most significant for arsenic mitigation over most of the arsenic affected regions. Dug wells are limited to certain pockets where geological conditions are favorable for construction of such wells. Shallow tubewells comes as the number one option (68%) in terms of coverage by area. They are the most widespread among all arsenic safe water options. Deep water, except in a few areas, provides arsenic safe water. They have been the main source of safe water in the coastal regions and remain to be good so far. Among the arsenic mitigation option, Deep tubewell become the largest one (70%) of alternative options

Rural piped water systems are emerging as a mode of safe water supply in many parts of the country including arsenic affected regions. The source of water in most cases is deep groundwater. There are also systems based on surface water.

In areas where there are no other alternative safe water options, Arsenic Removal Technology (ART) may be used until a better solution is found. There is a better prospect for community level ARTs as demonstrated by SIDKO plants. Noted that other five BCSIR approved ARTs are household type.

Majority of the arsenic mitigation options (more than 80%) were installed under regular water supply programs of DPHE (Position Paper, 2005).

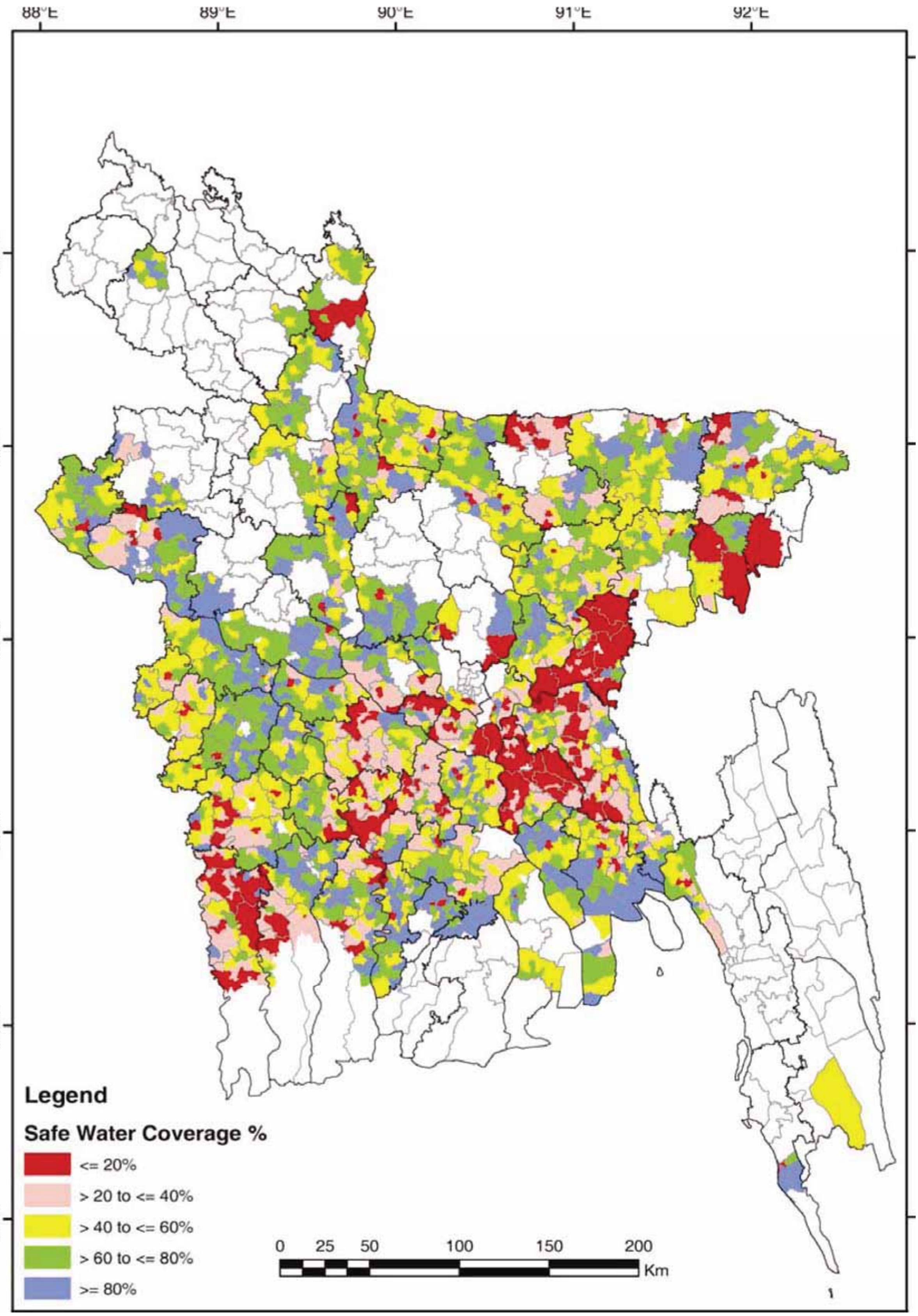


Figure-5: Map showing different catagories of service coverage

The study estimated 19 million population in need of public safe water option in 2009 considering the private water option identified as safe by the previous screening program. In respect to different arsenic and service coverage ratio, the population to be served by the public option is given below;

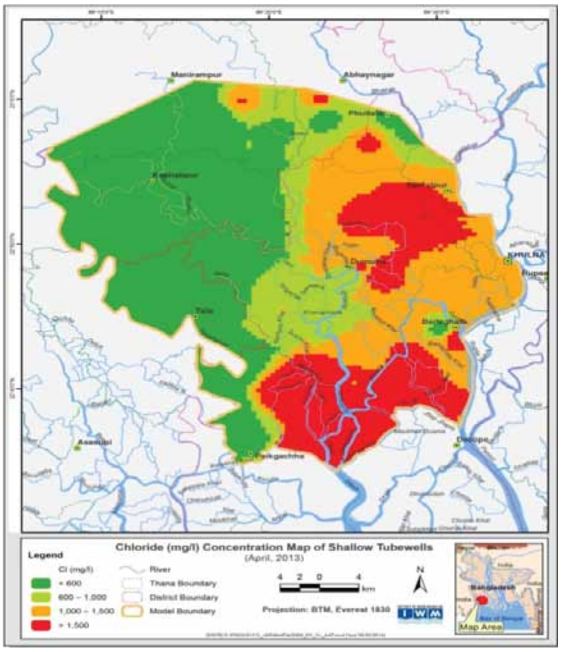
Table-3: No. of population need safe water option (Public)

SWD cover ratio	Arsenic Contamination ratio								
	0%	<20%	>=20%to <40%	>=40%to <60%	>=60%to <80%	>=80%	No data	Total	% of total
<20%	0	723,258	377,703	864,303	1,265.383	4,029.565	66,481	7,326,694	38.5%
>=20% to <40%	0	378,384	553,346	941,.891	1,221.526	2,354.326	5.689	5,455.162	28.6%
>=40% to <60%	0	1,171,328	737,102	603,691	631,842	948,870	6,509	4,099,342	21.5%
>=60% to <80%	0	797,730	390.759	151,594	319,620	251,456	2,823	1,913,982	10.0%
>=80% to <100%	0	111,811	53,615	29,293	21,882	32,264	723	249,587	13%
>=100%	0	0	0	0	0	0	0	0	00%
Total	0 0.0%	3,182,512 16.7%	2,112,525 11.1%	2,590,772 13.6%	3,460,254 18.2%	7,616,481 40.0%	82,224 0.4%	19,044,768 100.0%	100.0%

5.6 Joint Action Research on Salt Water Intrusion in Groundwater in the Coastal Area (DPHE-IWM, 2011-14)

The study carried out having objectives (I) assessment of salinity extent in the study area, (II) assessment of aquifer vulnerability, (III) assessment of salinity intrusion due to sea level rise caused by climate change,(IV) identification of fresh water pockets during 2011-2014. The study areas covered part of Jessore, Satkhira and Khulna district.

The extent of salinity over the study area was shown seperatly for shallow and deep aquifer. It was revealed that in case of STWs, salinity increases from north-west towards north east and south. In case of TDS values it is revealed that it increases from north towards south in case of DTWs. In case of STWs, it is high in two areas in the south and in the east with no significant variation between pre and post monsoon conditions.



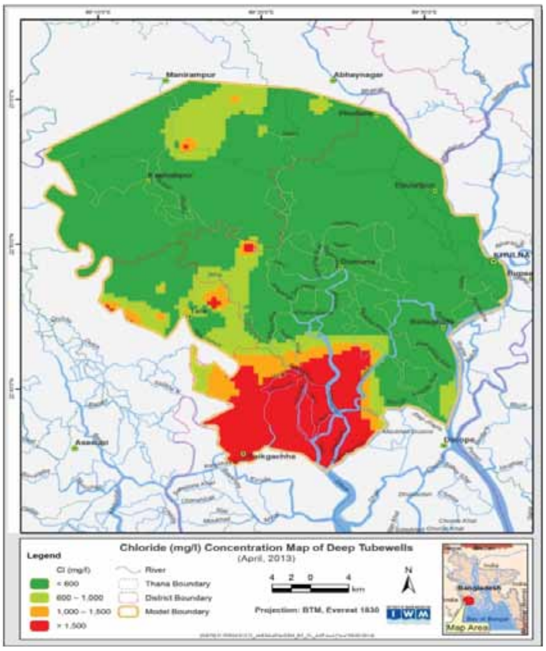


Figure-6: Chloride Concentration Map of Map of STWs in Study Area

Figure-7-: Chloride Concentration DTWs in Study Area

Regarding present existing water supply in this water scared area, study found that in Khulna, 48% use Deep Hand Tubewell (DHTW), Pond Sand Filter, (PSF)-22% and Very Shallow Shrouded Tubewell -(VSST) -22%. Most of the people (98%) of Jessore district use DHTW. In Satkhira, majority (60%) people use VSST which is followed by SHTW (30.0%). As for drinking water source irrespective of district 89% option provided by government.

The study findings described in brief;

- Shallow aquifer is more saline than deep aquifer with exception of Paikgacha, where shallow aquifer is relatively less saline. In major cases salinity of shallow aquifer exceeded allowable limit of 1000 mg/l.

- Under climate change condition in the year 2050, area of fresh water zone (salinity < 1000 ppm) decreases compared to present condition. Within the saline zone, area under severe salinity (salinity > 2000 ppm) will be increased by 14%.

- Further research is needed to accurately define the fresh water-saline water interface and to monitor its seasonal and long term movements.

5.7 Union Wise Water Technology Mapping (DPHE –UNICEF), 2008 and Manual on Feasibility Survey for Safe Water Options (DPHE-JICA), 2011

The two reports were reviewed and analyzed to define the basic principle of its functioning and criteria for suitability of different water technologies and also define its feasibility application based on hydro-geological and hydro-chemical conditions.

6. Findings

Need for provision of Public safe water option

Situation Analysis of Arsenic Mitigation 2009 (DPHE-JICA) estimated that 19.million population (Ref. Table-3) need public water options.This estimate is an excellent agreement with the 20 million people exposed to arsenic in household drinking water obtained during the 2009 BBS/UNICEF multiple cluster indicator cluster survey.

Even 92 persons per water option is considered on the contrast of 50 people per water point as policy target (ref. para-4.1), 2.00 lakh water options will be required for the estimated population. Apart from that, to maintain the same ratio (92persons/option), about 50,000 water options are required to be installed annually considering the population growth rate and rate of de-functioning (approx. 2%) per annum. So, installation of 50 thousand water option will contribute to increase the service coverage by decreasing no of user per water option.

Referring the Fig-1 and Table -1 (Predicted Population to be served by different type of Hand Pump), it is also urgent to gradually replace the suction mode (Nr 6) pump by Tara (deep-set pump) in low water table area to ensure the safe water round the year in particular to dry season.

More importantly it is to be noted that different studies revealed that in difficult areas in particular to arsenic and saline prone areas, safe water is being provided mostly (more than 80-90%) by public option (ref., para-5.5 and, para-5.6). In this context, Government intervention is required to be intensified to provide safe water to population living in those water scared areas. It is noted that most of private tubewells are shallow with No.6. Hand pump However, to ensure the quality of water, there should be some kind of linkage between well drillers and DPHE/LGIs.

Identification of Feasible Safe water option

In ordered to identify the safe water option, the main focus was given on the following issues;

i. Arsenic contamination in ground water particularly in shallow aquifer
ii. Salinity in ground water
iii. Lowering of water table
iv. Non availability of suitable aquifer
iv. Non-availability of protected and perennial surface water source round the year

Taking above issues into account, the feasible technolgies fall under the following boarder heading:

Arsenic contaminated Area

The Study on the Groundwater Development of Deep Aquifers for safe Drinking Water Supply to Arsenic affected areas in Western Bangladesh (DPHE-JICA), 2002. Arsenic contamination of Groundwater in Bangladesh (BGS-DPHE) suggested Deep tubewell, Improved Dug well, Rainwater Harvesting are the feasible option for arsenic mitigation (ref. 5.2 and para-5.3). Survey under Situation Analysis (DPHE-JICA), 2009 also found the functionality of those items in the field as arsenic mitigation options among which contribution of deep tubewell is highest (70%). Apart from above technologies, village piped water supply using either groundwater or surface water was also found promising. Where no technology was found feasible, community based ART may be considered as last escort until a better solution is discovered. Bangladesh Arsenic Mitigation Policy 2004 also supports these technologies as arsenic mitigation option.

Saline Prone areas

Joint Action Research on Salt Water Intrusion (para-5.6) mentioned that Deep TW is the main source for providing safe water. Pond Sand Filter and Shallow shrouded TWs are also the others mode of option for providing safe water. Apart from that, Rainwater harvesting is another option successfully using in coastal belt particularly where rainwater harvesting is practicing. PSF with solar power is also found efficient in terms of covering more population and easy access. Reverse osmosis (desalination) and managed aquifer recharge is being explored to evaluate its technical feasibility and social acceptance along with its capacity. Scale up of these technologies should be done based on the findings of piloting.

Non-Arsenic and Non- Saline Areas

Situation Analysis on Arsenic mitigatigation (DPHE –JICA), 2009 shows that shallow tubewell are still providing largest contibution to safe water (para-5.5). So this technology may be continued in arsenic safe fresh water (non saline) areas after taking precautionary measures, such as, arsenic testing of existing nearby tubewellls (ref 8.b).

Low water table area

If the water table remain within 6 metre during dry season, suction mode (Nr.6) pump is to be fitted with shallow tubewell, deep tubewell and ring well. But water table exceeding the depth 6m, different type of tara pumps (ref. table-1) are to be fitted with tubewell and ring wells.

7. Feasibilty Applications for Major Mitigation Technologies

Improved Deep tubewell

The deep aquifers in Bangladesh have been found to be relatively free from arsenic contamination. The aquifers in Bangladesh are stratified and in some places the aquifers are separated by relatively impermeable strata. Deep tubewells installed in those protected deeper aquifers are producing arsenic safe and less saline water as well. Sealing in the impervious layer is done to prevent the leaching of arsenic and even salinity through path way created during drilling of the well.

Feasibility criteria/ Requirements

- It can be installed where shallow aquifer is separated from deeper aquifer by substantially thick impervious layer.
- The entire tube well should be installed straight and vertically deep bore hole is required therefore.
- The annular space of bore holes of the deep tube wells are required to be sealed at the level of impermeable strata.

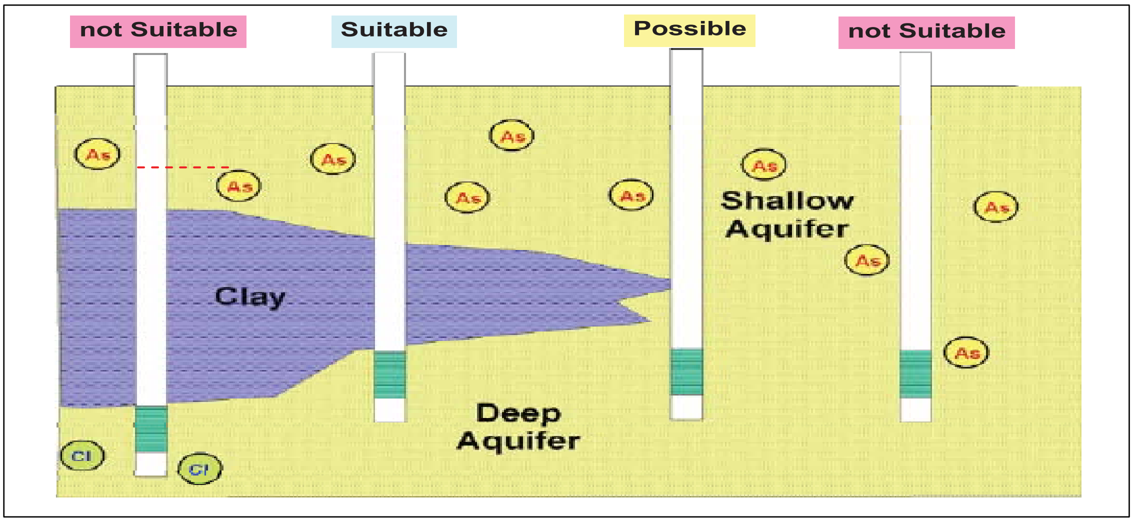


Figure-8: Feasible option for DTW in different situation

Pond Sand Filter:

Pond sand filter is a surface water treatment option which is primarily a slow sand filter unit. If the turbidity of water is high then, there is necessity to use horizontal roughing filter.

Raw water from pond is pumped up from a pond; the turbidity gets down through the roughing filter and then discharged into the filtration unit. The water is filtered and then collected in a clear water reservoir by an under drainage system.

<u>Feasibility Criteria/requirement</u>

- Viable alternative water supply option where perennial rivers, canals, fresh water lakes and ponds of acceptable water quality are available.
- Bottom of pond should have 3-6 ft or above clay layer
- The horizontal roughing filter is divided into 3 parts: inlet tank, gravel zone and outlet tank. The gravel zone consists of 3 chambers loaded by different size of gravel (5-15 mm).
- The Sand Filter bed should be composed of 0.22 mm – 0.35 mm fine sand with a thickness of 60 to 120 cm. There is also a layer of coarse aggregate below the fine sand to support the sand against washing out through under drainage system.

- The filtration rate through SF is 0.2 – 0.3 m/hr and through roughing filters 1.5-2.0 m/hr.

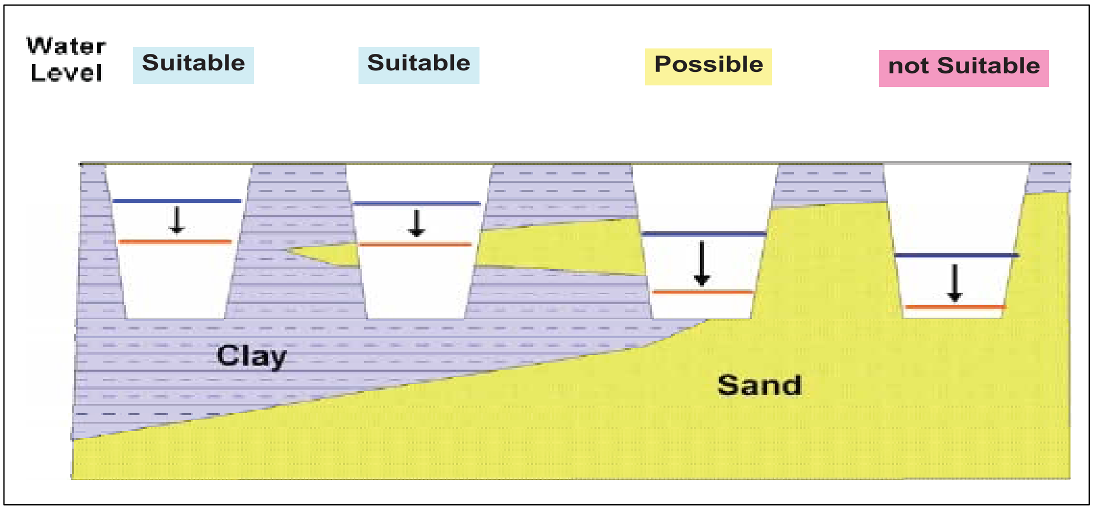


Figure-9: Feasible option of the pond for PSF in different situation

Dug Well:

Dug well is the oldest method of groundwater withdrawal for water supplies. The water of the dug well has been found to be free from dissolved arsenic and iron even in locations where tubewells particularly in shallow aquifer are contaminated.

<u>Feasibility Criteria/requirement</u>

- There should be stable soil layer at the top (3 to 6 ft or above)
- There should be clay layer at the bottom (3 to 6 ft or above)
- Presence of sandy layer within preferably 9 to 12 m

- It is <u>**Not Feasible**</u> in areas with loose sandy soil, more than 15m consolidated clay, Tidal zones and area of peaty soil should be avoided for DW as these cause an unpleasant taste and smell

- Wells should be at least 1.0 to 1.5 m deeper than the lowest water table in the driest month.

- Dug well should be constructed in the dry season to ensure availability of water round the year.

- Test well to be drilled prior to construction of ring well to make sure about the soil condition and water quality.

- The well lining should be extended at least 0.5m above the ground to form a ‘head wall’ around the outer rim of the well.
- A concrete apron, about 2 m in width, should be constructed on the ground surface extending all around the outer rim of the ring well.

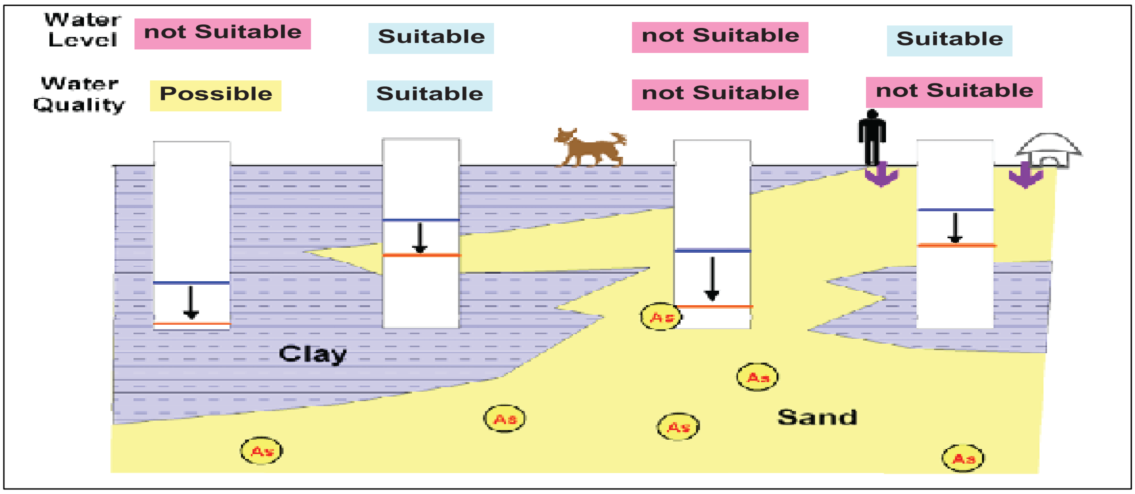


Figure-10: Feasible option for the Dug well an different situation

Rainwater

Rainwater harvesting is a technology to collect rainwater for its use in drinking purposes. The rain water is safe if it is maintained hygienically. The main limitation of this option is non-availability of rain water round the year. But it can be widely used as supplementary source.

Feasibility Criteria/requirement

Feasible where average rainfall is 1600 mm per annum considering intraseasonal and interannual variability of the summer monsoon rainfall.

- There should have required catchment area for rain water harvesting.
- Rain water has 3 basic units. 1. The catchment area (like corrugated roof top) and 2. Supporting collection system (gutter and pipe collection pipe) and 3. Storage tank.

Arsenic Removal Technology (ART):

ARTs are the chemical options which remove arsenic mainly using media. Five options are provisionally certified by BCSIR of which four are house hold and one is community based. These can be selected as a last assorts particularly where deep tubewell and Dug well is not feasible. For ART filter media have to be changed after the media being clogged. The quality of raw water is specified for each technology.

8. Conclusion and Recommendation

a) In all cases arsenic and other required water quality parameters need to be tested before the system is brought to operation.

b) In the villages/unions where there is presence of arsenic but the average contamination level is less than 5-10%, the existing technology is recommended as STW. In that case, before going for installation of STW, arsenic of 5 to 10 tube wells within 500 meters of the site need to be tested.

c) Dug well and PSF should be investigated as the feasible option of alternative of STW following the criteria as mentioned in para-7.

d) In case of non-successful of non- chemical based option (STW, DW, PSF and DTW) chemical based option for Arsenic Removal Technology may be used.

e) In all cases in problem areas promotional activities on RWHS should be done.

f) In many parts of the country, in particular to arsenic affected areas, such as, Pabna, Manikgang, Jessore, Faridpur, ChapaiNawabganj etc., deep drilling is encountered by gravel or stony layer making difficult to develop the mitigation option. In that case drilling technologies is to be developed to penetrate those layers.

g) In some part of coastal belt, such as, Paikgacha, Terakhada, Ashashuni, Shamnagar, either deep aquifer upto 350 meter is unavailable or saline. In those areas, extensive investigation is to be carried out at deeper depth to identify the fresh aquifer. Even pocket aquifer can be identified; which can be used for domestic purpose.

h) Piped water supply should be gradually expanded as recommended by Sector Development Plan 2011-25.

i) Action research is to be strengthed to explore the appropriate technologies in terms of technical and social aspects for arsenic and saline prone areas.

j) A large number of tubewells are being installed by the private drillers. So some kind of institutional linkage between drillers and DPHE/LGIs should be established to ensure arsenic safe water and also to disseminate the message regarding safety of drinking water.

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