Rapid Review of Locally Available Arsenic Field Testing Kits

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Executive Summary

1. Background

Arsenic contamination of drinking water has turned to be a disastrous problem in Bangladesh. Government in collaboration with NGOs and donor agencies undertook programs to identify and mark arsenic contaminated tube wells. The screening activities have been started approximately from early 1990s in our country by the participation of both the GOs and the NGOs and still it is going on. Many organizations are screening the tube wells by kit methods. Some organizations, however, are performing laboratory analysis to cross check the data with comparison to their field data. Recently, controversies arose about the accuracy of the test results. Researchers have reported that some of the arsenic test kits gave inaccurate results. This has led to think again about the reliability of previous testing results. However, one should not expect that the field test kits would give the quantitative result as obtained by the expensive AAS and ICP methods. But they should give estimates as close as possible to quantitative estimates so that the variations do not jeopardize permissible standards. Moreover, there is a concern that test kits should be manufactured locally to make them easily available to the users. In this background this piece of work has been undertaken by DFID funded APSU project to conduct a rapid review of available test kits in order to adopt an appropriate strategy as well as examine the potential of manufacturing local kits.

2. Purpose of the Study

The purpose of the review is to produce an up to date technical review of the available test kits to provide direction regarding the potential for development of locally produced kits or enhancing local provision of kits produced outside Bangladesh. Both options are important considering short and long term perspective. Local production of test kits is not unlikely if operational dynamics of test kits are known and strict quality control is maintained.

3. General Approach and Methods

The study has been conducted in four steps. Initially market has been surveyed about the kits for specific information. Then a list has been prepared by searching different reports and through communication with the organizations. Two questionnaires were sent for the collection of information from kit providing organizations and organizations that are performing tube well screening. Literature has been reviewed for the performance of the test kits and experiences of different organizations were collected about those identified test kits for comparative analysis. An immediate field-testing was done with the identified test kits at Sonargaon upazila of Narayanganj district and Singair upazila of Manikganj district. The selected tube well water of these two sites has been analyzed in the laboratory of BUET and 50% of samples have been cross-checked in another commercial analytical laboratory, the Intronics.

3. Available Test Kits

The available test kits are GPL Kit, Quantofix, Merck Sensitive, Merck Highly Sensitive, Wagtech Digital Arsenator, Wagtech VCDK, HACH Arsenic Test Kit, HACH EZ Arsenic Test Kit, Econo Quick Arsenic Test Kit Detail of the kit is presented in Annexure

4. Suitability and Accuracy

The Field testing showed the HACH EZ, Wagtech Digital Arsenator and Wagtech VCDK, HACH kits are better options to get a more dependable estimates of arsenic under field conditions. All of these kits have a good system

for the removal of sulfide interference. Quantofix and GPL give false value with the blank samples. The Merck Highly Sensitive and the Econo Quick test kit give good result but during the testing most of the test strips become damaged. The Quantofix and the Merck sensitive has no good provision for removal system for sulfide interference. The errors showed by the field kits during field-testing are due to the operational and personal errors, reagent errors, method errors, colour detection by eye errors etc. This should have to be minimized by employing trained and skilled manpower; electronic reader based colour detection apparatus with regular standardization of the reader, quality control of the reagents, commitment of the operators, etc. Consideration should also be made to man behind the instrument and his commitment, knowledge about the testing, the sensitivity of the kit and its chemistry, the color comparison with color comparator chart, cross checking options for checking results, standardization of test kit. Reliability of results will not be comparable with the laboratory analysis because there is always 10% to 15% or sometimes more than 15% differences may occur with the analytical results (e.g. AAS) due to the above mentioned errors. Comprehensive testing of different ground water quality parameters is essential for a comparative analysis of different test kits with different water quality conditions for identification of suitable kit for Bangladesh. There is need to develop locally manufactured kits considering the sources of variations as discussed in the report for ensuring market availability at reasonable price.

5. User Experience

Users' experiences were obtained through a questionnaire. BRAC, DPHE-UNICEF, NGO Forum for DWSS, DPHE-DANIDA, AAN, SDC-Watsan Partnership Project, Dhaka Ahsania Mission, and Water Aid responded to the questionnaire. OCETA's response was incomplete. BAMWSP, Dhaka Community Hospital Trust, IDE, World Vision, CARE did not responded. WSP and DPHE-WHO expressed that they were working at policy level. Users' who responded expressed the following experiences:

- There are problems of preserving the kits with its materials, testing tube-breaking and damaging zinc. Regular standardization of kit boxes is required.
- Results of test kits are sometimes inaccurate under field conditions Electronic reader based technology provides more accurate results.
- Results of replicate tests are not uniform, thread cap of the reaction vessel is not user friendly, and long intervals in the colour chart often confuse field workers.
- ‘Yes/ No’ kits at the nominal value of 0.05 mg/L needs to be developed considering 7 to 14 percentages of false negative results produced by the field kits.
- Laboratory method i. e. AAS-FIHG or other techniques should be the ultimate solution of arsenic detection in tube well water. Long term plan should be undertaken for establishing new laboratories and promoting existing laboratories for arsenic detection.
- Local production of test kit should be encouraged in Bangladesh and QA/QC mechanism should also be developed.

Literature supports these observations and suggestions of user organizations.

7. Conclusion

Field kits are useful tools for assessing arsenic concentration in water. Reviews revealed that most of the organizations use Merck and HACH EZ for screening purposes although some other kits are also used. Some of the organizations feel comfortable with Merck and some with HACH EZ. Some of the test kit providers have plan for marketing the kits in the country. Field testing in two ground water quality conditions showed a wider variation of results among the test kits probably due to variation in water quality. This is a rapid review with very few samples and locations. A comprehensive study of kits along with variable water quality parameters would help identify the best-suited kits under the prevailing water quality conditions of Bangladesh.

From the review it transpires that there is a need to develop locally manufactured kits using colorimetric method with a digital read out device or colour chart. All interfering elements should also be properly identified under Bangladesh water condition and protection mechanism is to be in-built in the test kits. Design and manufacturing of kits should take care of quality and storage of the regents and chemicals during testing under Bangladesh weather conditions. The standardization of the test kits must be done at regular intervals to check the efficiency of the test kit at the user levels. If colour chart is used employment of skilled, particularly color sensitivity and commitment should get due consideration.

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1. INTRODUCTION

1.1 Background

Since independence the use of tubewells as a source of drinking water has increased to cover most of the population of Bangladesh. The achievement has dramatically reduced the incidence of waterborne diseases such as cholera and diarrhoea. However, chemical analyses of the water were not undertaken and in the early 1990s arsenic was found in shallow ground water and patients with symptoms of arsenocosis were identified. High concentration with irregular arsenic distribution pattern has become a serious problem in Bangladesh as well as in West Bengal. The WHO Guideline Value for arsenic in potable water is 0.01 mg/l. Government of Bangladesh has enhanced this permissible limit to 0.05 mg/l considering several factors.

However, from the beginning GOs, NGOs and donor agencies are combating the problem. Different organizations are working in different issues of arsenic contamination of drinking water such as awareness campaign, screening and marking of tube wells, mitigation and training. Among these activities the most important one is the marking of contaminated tube wells in an area (e.g. an upazila, an union or a village) because this will let us know what type of measures are needed in that specific area. The screening activities have been started approximately from early 1990s in our country by the participation of both the GOs and the NGOs and still it is going on.

The concentrations of arsenic in drinking water can be determined by test kit method (semi-quantitatively at field level) and by laboratory analysis (quantitatively at laboratory). From the beginning many organizations are screening the tube wells by kit method although some organizations are performing laboratory analysis to cross check the data with comparison to their field data. Several researchers have reported that many of the arsenic test kits give inaccurate results but do not indicate why this inaccuracy occurred. It may be unrealistic to expect that the field test kits will give the quantitative result as obtained by the more expensive AAS and ICP methods. But they should give estimates as close as possible to quantitative estimates so that the variations do not jeopardize permissible standards. In this background this piece of work was undertaken to re-examine the test kits in order to adopt an appropriate strategy of using the test kits.

1.2 Importance of Study

It is highly important that people know the degree of arsenic contamination before drinking water. The problem is widespread and urgent. Quick assessment and identification of arsenic contaminated water is needed and as a result currently in Bangladesh this cannot be achieved through laboratory analysis because of high cost and lack of skilled manpower. It is, therefore, imperative that we use test kits that give results as far as possible close to laboratory assessment. Choice of user-friendly right test kits is crucial for obtaining reliable estimates of arsenic. Expensive but reliable kits are better than those that are inexpensive but give ambiguous results. Considering the gravity of the situation it is of great importance that the available test kits are tested evaluated to assess their reliability.

1.3 Purpose of the Study

The purpose of the review is to produce an up to date technical review of the available test kits to provide direction regarding the potential for development of locally produced kits or enhancing local provision of kits produced outside Bangladesh. Both options are important considering short and long term perspective. Local production of test kits is not unlikely if operational dynamics of test kits are known and strict quality control is maintained.

2. METHODS OF STUDY

2.1 General Approach

The study is divided into four steps. Initially market has been surveyed about the kits for specific information about there manufacturing origin. Then a list has been prepared by searching different reports and communication for those organizations that are screening the tube wells. Two questionnaires have been prepared for the collection of information from kit providing organizations and organizations that are performing tube well screening. The questionnaire was supplied both by email and normal postage with returned envelope. Sample questionnaires for kit providers and the organizations that are screening tube wells are presented in Annexure 1 and 2. Personal communication and visits have also been done to collect the maximum information available. Literature has been

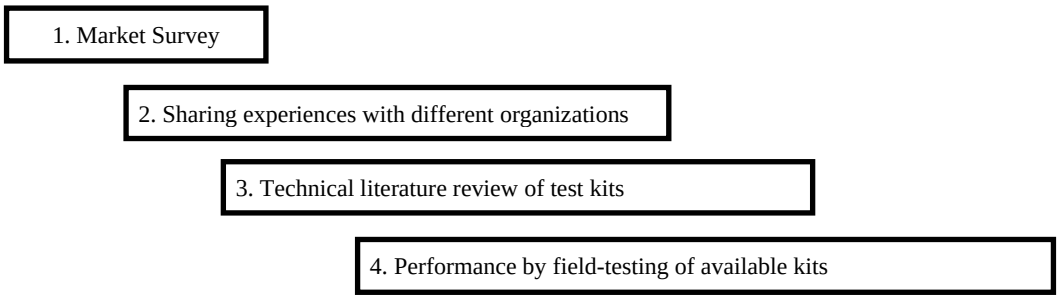

Fig. 1: Different steps of the study

reviewed for the performance of the test kits and experiences of different organizations were collected about those identified test kits for comparative analysis of available data. Limited field-testing was done with the identified test kits at Sonargaon Upazila of Narayanganj District and Singair Upazila of Manikganj District. Water from the selected tubewells were analyzed in the laboratory of BUET and 50% of the samples analysed at BUET were cross-checked in the Exonics Technology Center (former Intronics) another commercial analytical laboratory. Different step of the study is presented in the Fig. 1.

2.2 Field Testing Procedure

An immediate performance of the test kits was tested in Manikganj and Sonargaon. In each location three sites have been selected to testing all the ten kits. The low range will be form 0 to <50 ppb, the mid range will be from 50 ppb to 150 ppb and the high range will be above 150 ppb. In addition a standard solution of 25 ppb and 50 ppb and a blank (distilled water) also tested in the field condition with all test kits. 6 samples of the testing tube well water and two samples of standard arsenic solution were sent to the laboratory of BUET for AAS (hydride generation) analysis. 4 samples were sent to the laboratory of Exonics (Former Intronics) for AAS (hydride generation) analysis for cross checking. The following figure (Fig. 2) indicates the whole procedure. Findings of the field-testing are presented in the section 5.

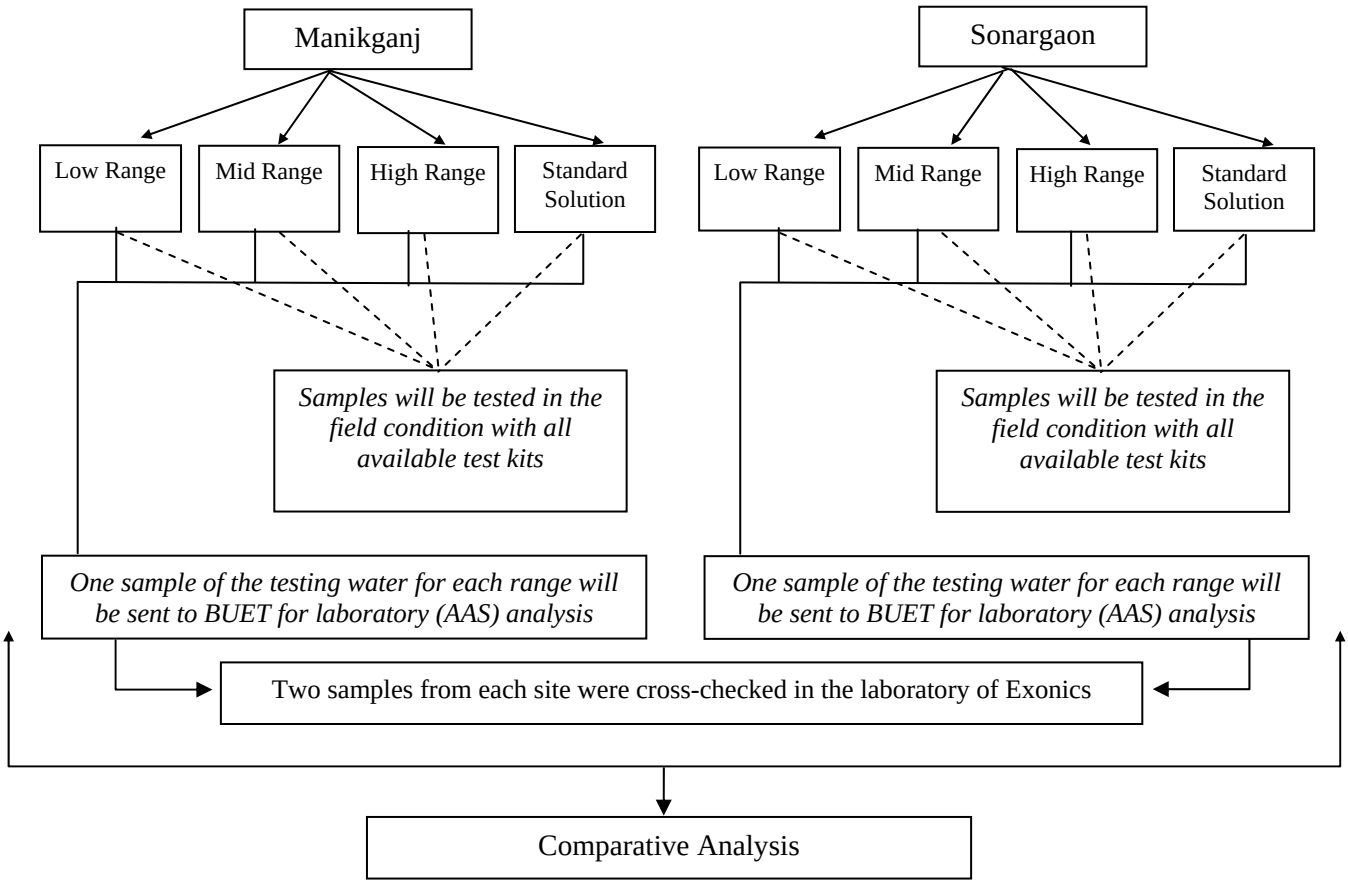

Fig. 2: Schematic figure of field testing procedure

2.3 Laboratory Analysis

The atomic absorption spectroscopy (AAS) is a technique that has most frequently used to estimate trace elements over the last two decades. The superiority of this technique over other is based on the fact that it can measure fifty to sixty elements without any interference from trace to big quantities. The AAS gives precise estimates at low-level concentration of the trace elements. Two standard solutions were prepared at concentration of 25 and 50 ppb.

Deionised water was used for the preparation of standard solutions. Eight samples were collected from the field during testing with different kits. The sample containers were washed with cleaning reagents, acids and dried. Analytical grade concentrated nitric acid is added to the each of the sample to reduce the pH below 2 and the samples were immediately transferred to the laboratory for analysis. Sample transfer kit was used to send the samples to the laboratory. The results of the laboratory analysis at BUET for all of the eight samples, those used for comparing the arsenic test kits are presented in Table 1. Results of the duplicate four samples those are analyzed in Exonics (Former Intronics) are presented in Table 2. The concentration of arsenic of different samples obtained by AAS analysis in two laboratories is mentioned in highlighted boxes inside the table.

Table 1: The results of laboratory analysis at BUET (AAS)

No.	Sample Location with Address	Sonargaon (Concentration of As in ppb)				Manikganj (Concentration As in ppb)			
		High	Medium	Low	Standard	High	Medium	Low	Standard
	Sample ID	***SHAS***	***SMAS***	***SLAS***	***SSA***	***MHAS***	***MMAS***	***MLAS***	***MSA***
1	Standard arsenic solution 25 ppb solution				25				
2	Moinuddin, Mograpara, Companiganj Sonargaon, Narayanganj, Dhaka			< 1					
3	Amzad Member, Mograpara, Companiganj, Sonargaon, Narayanganj, Dhaka		240						
4	Asgar Hossain, Mograpara, Companiganj, Sonargaon, Narayanganj, Dhaka	225							
5	Standard arsenic solution 50 ppb solution								50
6	Lal Mia, Vill: Azimpur Dakhinpara Singair, Manikganj							1	
7	Abul Basher, Vill: Azimpur Uttarpara Singair, Manikganj						160		
8	Mosque of Late Hazrat Ali Matubber Alamgir Bari, Vill: Azimpur, Singair, Manikganj					230			

Table 2: The results of laboratory analysis at Exonics (AAS) (Former Intronics)

No.	Sample Location with Address	Sonargaon (Concentration in ppb)				Manikganj (Concentration in ppb)			
		High	Medium	Low	Standard	High	Medium	Low	Standard
	Sample ID	***SHAS***	***SMAS***	***SLAS***	***SSA***	***MHAS***	***MMAS***	***MLAS***	***MSA***

No.	Sample Location with Address	Sonargaon (Concentration in ppb)				Manikganj (Concentration in ppb)			
		High	Medium	Low	Standard	High	Medium	Low	Standard
	Sample ID	***SHAS***	***SMAS***	***SLAS***	***SSA***	***MHAS***	***MMAS***	***MLAS***	***MSA***
1	Standard arsenic solution 25 ppb solution				--				
2	Moinuddin, Mograpara, Companiganj Sonargaon, Narayanganj, Dhaka			<1.0					
3	Amzad Member, Mograpara, Companiganj, Sonargaon, Narayanganj, Dhaka		226						
4	Asgar Hossain, Mograpara, Companiganj, Sonargaon, Narayanganj, Dhaka	--							
5	Standard arsenic solution 50 ppb solution								--
6	Lal Mia, Vill: Azimpur Dakhinpara Singair, Manikganj							--	
7	Abul Basher, Vill: Azimpur Uttarpara Singair, Manikganj						189		
8	Mosque of Late Hazrat Ali Matubber Alamgir Bari, Vill: Azimpur , Singair, Manikganj					246			

3. TEST KITS AND SCREENING ORGANIZATIONS

3.1 Available Test Kits

The lists of available arsenic test kits in Bangladesh those are used or will be used in future are presented in annexure TKP-1 with the names, contact persons and complete addresses. A questionnaire survey was conducted to assess the supply and use of test kits by different organizations. The sample questionnaire for the test kit provider is presented in annexure TKQ-1. The kits which are under development and not available in Bangladesh are not included with the list. The detailed descriptions of the kits including their chemistry, detection scale, procedures are annexed individually. A brief description for all of the kits is given in the following paragraphs.

Test Kit 1: GPL Kit

The manufacturing origin of GPL test kit is Bangladesh. The General Pharmaceuticals limited is manufacturing the test kit. They have a validation from Bangladesh Atomic Energy Commission. The method of arsenic detection is semi quantitative determination. They have sold about 20,000 test kits. The government organizations, local and foreign NGOs are using it. They have future plan for marketing the kit in different parts of Bangladesh. The kit has the provision for the removal of hydrogen sulphide (by lead acetate cotton) but there is no maximum limit. There are no other indications for other interference removal. Detail of the kit is presented in Annexure TK-1.

Test Kit 2: Quantofix

The manufacturing origin of Quantofix arsenic test kit is Germany. The local agent of the test kit is Alpha Scientific Company of Bangladesh. The local agent made no comments about the third party validation. The agent also did not supply kit's technical papers. The method of arsenic detection is semi-quantitative determination. The Local agent sold about 50 kits to the Bangladesh Rural Advancement Committee (BRAC), CARE and DANIDA. There is no information about the sulphide and also the other interference. The local agent has no plan for manufacturing the test kit or any part of the kit in Bangladesh and did not disclose any plan for marketing in different parts of Bangladesh. Detail of the kit is presented in Annexure TK-2.

Test Kit 3: Merck Sensitive

The manufacturing origin of Merck Sensitive arsenic test kit is Germany. The exclusive agent of the test kit is GA Traders of Bangladesh. According to the exclusive agent the kit has no third party validation and they have only a certificate of analysis from the manufacturing company. The method of arsenic detection is semi-quantitative determination. The exclusive agent has no idea about the number of kits have sold in Bangladesh. The maximum limit of interference for different elements of water is presented including the sulphide. The main user of the kits are UNICEF, NGO Forum for Drinking Water Supply and Sanitation, IDA, DANIDA, CARE, Proshika, Bangladesh, Arsenic Mitigation Water Supply Project (BAMWSP) etc. The agent has no plan for manufacturing the test kit or any part of the kit in Bangladesh and no plan for marketing in different parts of the country at present. Detail of the kit is presented in Annexure TK-3.

Test Kit 4: Merck Highly Sensitive

The manufacturing origin of Merck Sensitive arsenic test kit is Germany. The exclusive agent of the test kit is GA Traders of Bangladesh. According to the exclusive agent the kit has no third party validation and they have only a certificate of analysis from the manufacturing company. The method of arsenic detection is semi-quantitative determination. It is the new version of the Merck sensitive arsenic test kit. This kit has the increased sensitivity than Merck sensitive. The maximum limit of interference for different element of water is present, including the sulphide. The agent has no plan for manufacturing the test kit or any part of the kit in Bangladesh and no plan for marketing in different parts of the country at present. Detail of the kit is presented in Annexure TK-4.

Test Kit 5: Wagtech Digital Arsenator

The manufacturing origin of Wagtech Digital Arsenator is United Kingdom. The manufacturer of the kit is Wagtech International Ltd. of United Kingdom. According to the manufacturer the kit has an independent evaluation from Imperial College of London and also waiting for an evaluation from a UK Water Company. The kit employs the Gutzeit method and arsenator transfers the colour results to a digital value. The method of arsenic detection is semi-quantitative determination. The kit has the well-equipped provision for the removal of hydrogen sulphide (by lead acetate cotton) but there is no mention of maximum limit. There are no other indications for other interference removal. Around 500 digital arsenators have been sold to Government Ministries of Water, Engineering, Agriculture, Education and Health, UNICEF, WHO, bi and multi lateral donors, hospitals and private

sectors. The company will stock and market the arsenator in all upazilas and districts. They will supply a full marketing strategy very shortly. They have already created a joint venture with GPL in Bangladesh (Wagtech-GPL). The joint venture will manufacture sub components including tablet reagents. Substantial stock will be held throughout Bangladesh. Detail of the kit is presented in Annexure TK-5.

Test Kit 6: Wagtech VCDK

The manufacturing origin of Wagtech VCDK is United Kingdom. The manufacturer of the kit is Wagtech International Ltd. of United Kingdom. According to the manufacturer the kit has an independent evaluation from Imperial College of London and also waiting for an evaluation from a UK Water Company. The kit employs the Gutzeit method. The method of arsenic detection is semi-quantitative determination. The kit has the well-equipped provision for the removal of hydrogen sulphide (by lead acetate cotton) but there is no mention of maximum limit. There are no other indications for other interference removal. Around 2000 Wagtech VCDK have been sold to Government Ministries of Water, Engineering, Agriculture, Education and Health, UNICEF, WHO, bi and multi lateral donors, hospitals and private sectors. The company will stock and market the arsenator in all upazilas and districts. They will supply a full marketing strategy very shortly. They have already created a joint venture with GPL in Bangladesh (Wagtech-GPL). The joint venture will manufacture sub components including tablet reagents. Substantial stock will be held throughout Bangladesh. Detail of the kit is presented in Annexure TK-6.

Test Kit 7: HACH Arsenic Test Kit

The manufacturing origin of HACH arsenic test kit is United States of America. The exclusive agent of the test kit is Technoworth Associates limited of Bangladesh. According to the exclusive agent the kit's method is accepted by USEPA but no papers has been supplied regarding this. The kit employs the Gutzeit method. The method of arsenic detection is semi-quantitative determination. The exclusive agent has sold about 100 kits to different organizations of Bangladesh. The kit includes protection against interference of sulphide and also some interference from other elements of water. The agent has been negotiating with the HACH Company for packing and assembling the kit in Bangladesh to make the price competitive. Already they are distributing the kit through their twenty-one branches in Bangladesh. Detail of the kit is presented in Annexure TK-7.

Test Kit 8: HACH EZ Arsenic Test Kit

The manufacturing origin of HACH EZ arsenic test kit is United States of America. The exclusive agent of the test kit is Technoworth Associates limited of Bangladesh. According to the exclusive agent the kit's method is accepted by USEPA but no papers has been supplied regarding this. The kit employs the Gutzeit method. The method of arsenic detection is semi-quantitative determination. The exclusive agent has sold about 65000 kits in previous days to different DPHE program, BAMWSP, UNICEF, World Vision, UNDP, DPHE-DANIDA and NGO Forum for Drinking Water Supply and Sanitation etc. The maximum limit of interference for some element of water is provided including the sulphide. The agent has been negotiating with the HACH company packing and assembling

the kit in Bangladesh to make the price competitive. Already they are distributing the kit through their twenty-one branches in Bangladesh. Detail of the kit is presented in Annexure TK-8.

Test Kit 9: Econo Quick Arsenic Test Kit

The manufacturing origin of Quick Econo arsenic test kit is United States of America. The distributor/local agent of the test kit is MAGC Technologies of Bangladesh. According to the distributor agent the kit has a validation from United States Environmental Protection Agency (USEPA) The method of arsenic detection is semi-quantitative determination. The kit also has a digital readout device but it is not supplied with the kit. The distributor has not sold any kit in Bangladesh. The provision for the removal of sulphide interference is present. The distributor will make future plan if enough demand is created and they are planning to market the kit to all parts of Bangladesh. Detail of the kit is presented in Annexure TK-9.

3.2 Screening Organizations

The lists of reputed organizations that are engaged in tube well screening program are presented in annexure SO-1 with the names, contact persons and complete addresses. There may be some other organizations dealing the tube well screening. They were asked some specific questions about their activity, test kits they are using, experiences about their used test kit etc. The questionnaire has been supplied through email and normal postage and also direct communication. A sample questionnaire is shown in annexure SO-2. Users' experiences have been presented in the following section of this report.

4 PERFORMANCE OF THE TEST KITS

4.1 User Experience

The users were asked to express their experiences and opinions about the arsenic test kits they were using. Their responses are briefly summarized here.

4.1.1 BRAC

BRAC is using Merck and NIPSOM (not included in the study, because of its unavailability at the time of testing) arsenic field testing kits for 6 and 3 years respectively. Around 185,000 tube wells were screened with these test kits. They will continue the using of the mentioned test kits. They have been experiencing problems of preserving the kits with its materials, tube breaking and damaging zinc. They do not standardize the kit boxes regularly. In other words they did not estimate arsenic of known concentration at certain intervals to ensure its effectiveness. BRAC suggested that Electronic reader based technology should be used for the accuracy.

4.1.2 DPHE-UNICEF

DPHE-UNICEF is using Merck, HACH EZ, GPL, AAN, and NIPSOM arsenic field testing kits. Around 1,110.000 tube wells were screened with these test kits. They told that HACH and Merck and recently developed Wagtech kits are well. Critical test should be done at Upazila level using arsenator. In its opinion results of test kits are

sometimes inaccurate under field conditions. They conducted blanket testing in the hot spot areas using arsenator and spectrophotometric system and found good results.

4.1.3 NGO Forum for DWSS

NGO Forum for DWSS is using Merck, HACH EZ and NIPSOM. Around 120,700 tube wells were screened with these arsenic field-testing kits. They have compared the field testing kits with the FIHG-AAS method. They will prefer to use the AAS for arsenic analysis. It experienced that results of replicate tests were not uniform, thread cap of the reaction vessel is not user friendly, and long intervals in the colour chart often confuse field workers. It suggests that field kits may be used as 'Yes/ No' kits at the nominal value of 0.05 mg/L considering 7 to 14 percentages of false negative results produced by the field kits. Grading of water according to different level of arsenic by the field kits doesn't work effectively. In its opinion laboratory method i.e. AAS-FIHG or other techniques should be the ultimate solution of arsenic detection in tube well water. Long term plan should be undertaken for establishing new laboratories and promoting existing laboratories for arsenic detection.

4.1.4 DPHE-DANIDA

DPHE-DANIDA is using Merck for two years and HACH for 1 years. Around 161,775 tube wells were screened with these test kits. They did not standardize their test kits. They are comfortable to use the Merck kit. DPHE-DANIDA said that they are facing the problem of eye estimation of concentration and effectiveness of the chemicals and there were 15-20% errors in estimation. They also suggested that HACH is better than Merck, but HACH is more costly.

4.1.5 SDC-Watsan Partnership Project

They are using Merck arsenic field testing kits for 3.5 years and around 215,287 tube wells were screened. They found that the field testing kits are consistent at the different stage of their work. They reported that Merck has some limitations such as storage of chemicals, number of test, colour blindness of people, etc. They suggested that the number of testing of the kit boxes should be reduced to 25 or 50 and made available in the market. They also suggested cross checking of certain percentage of the testing results in established laboratory. They suggested that the production of test kits should be in Bangladesh and QC mechanism must be developed.

4.1.6 Water Aid

Water Aid is using HACH EZ for 1.5 years and about 1510 tube wells have been screened. They have faced problems of colour detection by eye, the H_2S detection and the controlling process. They found problems of accuracy. They wish to use the kit further and also searching for more improved field test methods with more accuracy, lower cost and easier to use. They also suggested that the field testing kits should be used for regular testing of tube wells and more accurate digital methods/laboratory analysis should be used for monitoring purposes.

4.1.7 AAN

AAN is using NIPSOM test kit for 7 years and about 40,000+ tube wells have been screened. Thy checked the efficiency of the test kits in between 50-100 test with standard solution. They faced problem of deterioration of

bromide disk paper when used after a certain period, problems of liquid HCl, Cumbersomeness of putting three different reagents into a test tube and adding HCl. They suggested for the improvement of the NIPSOM test kit by making a mixed tablet of three reagents and powdered hydrochloric acid.

4.2 Comments of User Organizations

Summary of the important comments of different user organizations is presented in the Table 14.

Table 3: Summary of comments of different organizations

No.	*Name of Organization*	*Important Comments regarding test kits*
1	BRAC	Electronic reader based technology should be used for accuracy
2	DPHE-UNICEF	Test kits need to be further developed to get accurate results. Since blanket testing in the hot spot area are done we can use arsenator and spectrophotometric system
3	NGO Forum for DWSS	Field kits may be used as 'Yes/ No' kits at the nominal value of 0.05 mg/L considering 7 to 14 percentages of false negative results produced by the field kits. Grading of water according to different level of arsenic by the field kits doesn't work effectively. Laboratory method i. e. - AAS-FIHG or other techniques should be the ultimate solution of arsenic detection in tube well water. Long term plan should be undertaken for establishing new laboratories and promoting existing laboratories for arsenic detection.
4	SDC Watsan Partnership Project	A certain percentage of testing must be cross checked in the laboratory
5	DPHE-DANIDA	HACH is better than Merck but it is costly
6	Asia Arsenic Network (AAN)	The NIPSOM kit can be improved by; for instance, making a tablet of three reagents mixed and devising powdered HCl instead of liquid HCl. HACH should make additional chemicals available in the market.

4.3 Literature Review

Kinniburg, D.G and Smedley P.L. reported[1] that an arsenic field test kit specification with a detection limit of 5-10 μgm/l is highly desirable. By 'reliable' they suggested that a determination should give results within ± 20% of the true value or ± 5 μgm/l (whichever is greater), 95% of the time. The kit should be robust and simple to use so that it can withstand the rigorous of continuous use in Bangladesh and elsewhere. They also suggested that ideally the kit should be able to be manufactured in Bangladesh and the quality of the chemicals should be assured.

The comparison of different test kits[2] has been performed by several organizations. A panel of experts of Bangladeshi scientists and practitioners evaluated five arsenic test field kits with reference to minimum detection level required for screening of rural tube wells in a meeting held on December 31, 1998 at the office of the

BAMWSP. The findings of five field test kits used so far in Bangladesh are presented in Box 1. They have stated that AAN Kit and NIPSOM Kit can be used for arsenic project in Bangladesh. They also suggested the local manufacturers to produce suitable arsenic field-testing kit.

Box-1

Kit Description	*Lowest Level of Detection*
The AAN Kit, M/S Asia Arsenic Network, Japan	*0.02 mg/l*
The E-Merck Kit, M/S E. Merck, Germany	*0.10 mg/l*
The Aqua Kit, M/S AQUA, Consortium, India	*> 0.05 mg/l*
The NIPSOM Kit, NIPSOM, Bangladesh	*0.02 to 0.7 mg/l*
The AIIH & PH Kits, All India Institute of Hygiene and Public Health, India	*> 0.05 mg/l*

As part of the ongoing Environmental Technology Verification (ETV) program, the USEPA[3] has recently conducted rigorous reviews of four potable arsenic analyzers. These are PeCO 75 and As 75 of Peters Engineering, Top Water Arsenic Test Kit of Envitop Ltd., QuickT test kit arsenic analysis system of Industrial Test Systems and Potable water analyzer of NANO-BAND EXPLORER. The first three are based on arsine generation, while the fourth uses anodic stripping voltammetry. They reported that out of the four AS 75 and Quick Test got the best results.

The Merck kit is widely used in Bangladesh from the beginning of screening activities and Dhaka Community Hospital (DCH) also suggested in an arsenic conference at DCH that it is the only kit widely recommended. But at that time its sensitivity is 100 microgm/l. In January 2003 some investigators trust it to 50 ppb but this does not seems to have been proven.

Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP), DFID and Water Aid evaluated the HACH, Merck, GPL and the PeCO75 arsenic test kit.[4] They reported that at high concentration Merck tended to give slightly high results whilst the other kits were fairly similar to each other. Merck also had the largest standard deviation. At low range Merck also gives slightly higher results than the other kits and at low range the Merck and the GPL has the higher standard deviation. In both high and low ranges, the PeCo75 had the smallest standard deviation. They also reported that there is a considerable variation of results within the test kits and at low range the variation is more evident.

The NGO Forum for Drinking Water supply and Sanitation in collaboration with School of Environmental Studies, Jadavpur University conducted an evaluation of the performance of field tests kit for arsenic detection in ground water and they also compared the field test kits with the AAS-FIHG methods[5]. In that evaluation they reported that the performance of the field test kits are well at low (less than 0.01 mg/l) and at very high concentration. The studied the performance of the NIPSOM, GPL, Merck arsenic field-testing kits. They reported that at the cut off level 50 ppb and 100 ppb the sensitivity and specificity is more than or close to 80%. But the percentage of false negative samples is significantly present in all the three kits as well as there are also few false positive samples. The false positive samples are particularly of concern programmatically as they identify safe tube wells as arsenic contaminated. But from the public point of view they are more concerned about the false negative as they are identifying the contaminated tube well as safe. Hence the false negative samples for NIPSOM, GPL and Merck kits

at 0.05 mg/l (50 ppb) level are 13.67%, 9.4%, 6.83% and at 0.1 mg/l (100 ppb) level 20%, 10.9%, 20.9% respectively. It means 7-20% tube wells are being identified as safe while they are really not and thus a large number of people are drinking arsenic contaminated water. NGO Forum for DWSS have questioned whether the field kit methods should be used as a large number of people will be drinking arsenic contaminated water knowing it as arsenic free safe water. They also showed that the AAS-FIHG method can measure arsenic at 5 ppb level with a confidence level of 95% and the method is also cost effective.

The NGO's Arsenic Information and Support Unit (NAISU)[6] reported that a semi quantitative result of arsenic concentration could be obtained using the arsenic field test kits. Most of which depend on comparing the colour during the test to a color chart with the kit. They indicated the weakness of the field test kits. These are fluctuation in sensitivity and accuracy. It depends on the model of the kit, excess light and certain parameter of water quality can interfere the analysis at field level, differences between the operators of the field testing, when colour comparison is related with the results and the storage condition of the reagents of the field testing kits can dramatically decrease the working life of the reagents.

Hassan, M.M. reported[7] that reliability of different kits at lower level of arsenic concentration is unsatisfactory, but for concentrations of 0.1 ppm and above it always measures arsenic >0.05 ppm except Merck kit. Field kits results are inconsistent when the arsenic concentration is low but can measure arsenic when the concentration is high, though can not measure the exact amount. Most of the field kits do not give reproducible results except Merck kit. The arsenic field kits are based on mercuric bromide stain method. The mercuric bromide stain method was evaluated in a Round Robin Exercise. The arsenic concentration of a solution at 0.05 ppm in distilled water had relative standard deviation of 75%.[8] This method is incapable of providing quantitative meaningful results (results with RSD <=10%) below concentration of 0.150 ppm[9]. The method also provides the highly toxic arsenic gas, which is harmful for health. Although quick and simple, at the initial stage of arsenic scare in Bangladesh, results obtained by this method created confusion. Apart from the semi quantitative nature, the method also carried some inherent danger for the operator. Firstly during the examination of highly contaminated water samples AsH_3 may escape from the reaction vessel without being reacted with the mercuric bromide paper. Secondly the disposal of the mercuric bromide paper itself may pose environmental hazard.

Bangladesh Arsenic Mitigation Water Supply Project[10] conducted another evaluation on five test kits. These are GPL (old version), Macherey-Nagel, Merck, HACH and Industrial test systems. They reported that sulphide is the main interference and HACH test kit showed reproducible results with field samples and also with the standard samples. The performance of the other kits with respect to standard samples and field samples are not satisfactory.

The literature review shows that test kits were evaluated in different context using different locations and samples with different kits. Consequently results are not comparable and general conclusions can not also be drawn. The test kits, once recommended for use, were eventually become out of use due to difficulties. However, there is an effort to make the kits adaptable under Bangladesh condition by different manufacturers.

5. FIELD PERFORMANCE OF THE TEST KIT

5.1 Field Performance

Field performance of the 9 test kits was tested in Sonargaon and Manikganj by drawing 270 samples of different arsenic concentrations. 162 samples were tube well water samples, 54 samples were standard solutions samples of arsenic and 54 samples were blank samples (deionised water) with three replicates. The test kits-wise results are briefly presented.

Test Kit 1: GPL Kit

Field performance of the kit is presented in Table 4. It is observed that there is no definite pattern of variation of estimates from high to low concentration. The kit showed -2.3% lower value for 25 ppb standard and -3.4% lower for 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives average concentration of 3 ppb in samples of both sites. No problem of physical conditions of the kits test strip was found during the test.

Table 4: Field performance of GPL arsenic test kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	336	+111	+32.9	MHAS	230	372	+142	+38.2
SMAS	240	172	-68	-39.4	MMAS	160	261	+101	+38.7
SLAS	0	0	0	0.0	MLAS	1	29	+28	+96.5
SSA	25	24	-1	-2.3	MSA	50	48	-2	-3.4
Blank	0	3	+3	+100.0	Blank	0	3	+3	+100.0

Test Kit 2: Quantofix Arsenic Test Kit

Field performance of the kit is presented in Table 5. It is observed that there is no definite pattern of variation of estimates from high to low concentration. The kit showed increased value from the original value at high concentration. Also the kit showed +2.2% higher value for 25 ppb standard and -20.0% lower for 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives arsenic of 11 ppb and 10 ppb in both the sites respectively. The test strip become damaged in some of the field test because of the water particles and the particles of zinc are found on the test strip

Table 5: Field performance of Quantofix arsenic test kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	313	+88	+28.2	MHAS	230	417	+187	+44.8
SMAS	240	174	-66	-37.6	MMAS	160	283	+123	+43.5
SLAS	0	5	+5	+100.0	MLAS	1	0	-1	0.0
SSA	25	26	+1	+2.2	MSA	50	42	-8	-20.0
Blank	0	11	+11	+100.0	Blank	0	12	+12	+100.0

Test Kit 3: Merck Sensitive

Field performance of the kit is presented in Table 6. It is observed that there is no definite pattern of variation of estimates from high to low concentration. But at site 2 the kit gave lower value from the laboratory value. The kit showed -2.2% lower value for 25 ppb standard and -3.4% lower for 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives no arsenic in both the sites. No problems found during the test about the physical conditions of the kits test strip.

Table 6: Field performance of Merck Sensitive arsenic test kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	319	-94	-29.4	MHAS	230	411	-181	-44.1
SMAS	240	197	+43	+22.0	MMAS	160	283	-123	-43.5
SLAS	0	0	0	0.0	MLAS	1	0	-1	-0.0
SSA	25	26	-1	-2.2	MSA	50	48	-2	-3.4
Blank	0	0	0	0.0	Blank	0	0	0	0.0

Test Kit 4: Merck Highly Sensitive

Field performance of the kit is presented in Table 7. It is observed that there is no definite pattern of variation of estimates from high to low concentration. But at site 2 the kit gave higher value from the original value from high to low concentrations. The kit showed -8.0% lower value for 25 ppb standard and -3.4% lower for 50 ppb standard. The test strip become damaged in some of the Field test because of the water particles and the particles of zinc are found on the kit's test strip.

Table 7: Field performance of Merck Highly Sensitive arsenic test kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	339	+114	+33.6	MHAS	230	489	+259	+53.0
SMAS	240	86	-154	-180.5	MMAS	160	372	+212	+57.0
SLAS	0	4	+4	+100.0	MLAS	1	5	+4	+80.0
SSA	25	17	-8	-50.0	MSA	50	48	-2	-3.4
Blank	0	0	0	0.0	Blank	0	0	0	0.0

Test Kit 5: Wagtech Digital Arsenator

Field performance of the kit is presented in Table 8. It is observed that the kit gave a lower value at site: 1 and higher value in site: 2. But the variation is small. The also kit showed +29.3% lower value for 25 ppb standard and +14.3% higher lower for 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives no arsenic in both the sites respectively. No problems found during the test about the physical conditions of the kits test strip.

Table 8: Field performance of Wagtech Digital Arsenator

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	205	-20	-9.9	MHAS	230	397	+167	+42.0
SMAS	240	199	-41	-20.4	MMAS	160	197	+37	+18.6
SLAS	0	0	0	0.0	MLAS	1	0	1	0.0
SSA	25	19	6	-29.3	MSA	50	58	+8	+14.3
Blank	0	0	0	0.0	Blank	0	0	0	0.0

Test Kit 6: Wagtech VCDK

Field performance of the kit is presented in Table 9. The kit has a colour comparison chart that has ranges. But in a range we had to consider a value to make it consistent with other test kits and laboratory values. It is observed that there is no definite pattern of variation of estimates from high to low concentration. But the variation is very small at site 2. The kit also showed +2.2% higher value for 25 ppb standard and -0.05% lower for 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives no arsenic in both the sites respectively. No problems found during the test about the physical conditions of the kits test strip.

Table 9: Field performance of Wagtech VCDK

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	338	+113	+33.4	MHAS	230	424	+194	+0.46
SMAS	240	121	-119	-99.1	MMAS	160	269	+109	+0.40
SLAS	0	0	0	0.0	MLAS	1	0	-1	0.00
SSA	25	26	+1	+2.2	MSA	50	48	-2	-0.05
Blank	0	0	0	0.0	Blank	0	0	0	0.00

Test Kit 7: HACH Arsenic Test Kit

Field performance of the kit is presented in Table 10. It is observed that there is no definite pattern of variation of estimates from high to low concentration. The kit showed -15.4% lower value for 25 ppb standard and -32.4% lower for 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives no arsenic in both the sites. No problems found during the test about the physical conditions of the kits test strip.

Table 10: Field performance of HACH arsenic test kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	252	+27	+10.8	MHAS	230	350	+120	+34.3
SMAS	240	78	-162	-208.6	MMAS	160	147	-13	-9.1
SLAS	0	0	0	0.0	MLAS	1	4	+3	+74.3
SSA	25	22	-3	-15.4	MSA	50	38	-12	-32.4
Blank	0	0	0	0.0	Blank	0	0	0	0.0

Test Kit 8: HACH EZ Arsenic Test Kit

Field performance of the kit is presented in Table 11. It is observed that there is no definite pattern of variation of estimates from high to low concentration. The kit showed increased value from the original value. Also the kit showed -12.5% lower value from 25 ppb standard and -9.8% lower at 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives no arsenic in both the sites. No problems found during the test about the physical conditions of the kits test strip.

Table 11: Field performance of HACH EZ arsenic test kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	83	-142	-170.0	MHAS	230	413	+183	+44.4
SMAS	240	81	-159	-197.9	MMAS	160	180	+20	+11.1
SLAS	0	0	0	0.0	MLAS	1	0	-1	-0.0
SSA	25	22	-3	-12.5	MSA	50	46	-4	-9.8
Blank	0	0	0	0.0	Blank	0	0	0	0.0

Test Kit 9: Econo Quick

Field performance of the kit is presented in Table 12. It is observed that there is no definite pattern of variation of estimates from high to low concentration at site 1 and site 2 higher value is obtained. Also the kit showed -9.82% lower value at 25 ppb standard and -34.35% lower at 50 ppb standard. The blank sample (0 ppb arsenic concentration) gives no arsenic in both the sites respectively. The test strip become damaged in some of the field test because of the water particles and the particles of zinc are found on the test strip

Table 12: Field performance of Econo Quick Arsenic Field Testing Kit

Site 1: Sonargaon					Site 2: Manikganj				
Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation	Sample ID	AAS (ppb)	Mean of 3 Replicates	Deviation from Laboratory Analysis	(%) of Deviation
SHAS	225	378	+153	+40.4	MHAS	230	411	+181	+44.1
SMAS	240	161	-79	-49.5	MMAS	160	356	+196	+55.0
SLAS	0	0	0	0.0	MLAS	1	5	+4	+80.0
SSA	25	23	-2	-9.8	MSA	50	37	-13	-34.3
Blank	0	0	0	0.0	Blank	0	0	0	0.0

5.2 Comparison with Laboratory Performance

The % of variation of the results from the AAS analysis for site 1 and site 2 are presented in Table 13 and 14 respectively. This variation was calculated from the mean value of the three replicates for each of the test kit from the AAS analysis. The comparisons are made to assess the relative position of different kits as a means of selecting better performed test kits. Three criteria are used in making the judgements:

(1) the kits showing arsenic in known arsenic free sample,

(2) variation from the laboratory test results and

(3) variation from standard solutions. Both site Quantofix and GPL gives arsenic in known arsenic free sample.

The overall results showed that Wagtech Digital Arsenator and Merck Sensitive have the least deviation from the laboratory analysis at site 1 (Sonargaon) and Wagtech VCDK and HACH EZ have showed least deviation from the laboratory analysis at site 2 (Manikganj). The results of inter laboratory analysis of arsenic concentration showed a wider variation at site 2 (Manikganj) than site 1 (Sonargaon).

Table 13: Deviation of results for each of the kit from BUET analysis results at site 1 (Sonargaon)

Sample ID	Laboratory Analysis			Kit Method (Deviation from Laboratory Method %)								
	BUET Results AAS (ppb)	Exonics Results AAS in (ppb)	Differences	Merck S	Merck HS	HACH	HACH ez	Quantofix	Wagtech Arsenator	Wagtech VCDK	GPL	Econo Quick
SHAS	225			+29	+34	+11	-170	+28	+10	+33	+33	+40
SMAS	240	226	14	-22	-181	-209	-198	-38	+20	-99	-39	-49
SLAS	0	0	0	0	+100	0	0	+100	0	0	0	0
SSA	25			+2	-50	-15	-13	+2	+29	+2	-2	+10
Blank	0			0	0	0	0	+100	0	0	+100	0

Table 14: Deviation of results for each of the kit from BUET analysis results at site 2 (Manikganj)

Sample ID	Laboratory Analysis			Kit Method (Deviation from Laboratory Method) %								
	BUET Results AAS (ppb)	Exonics Results AAS in (ppb)	Difference	Merck S	Merck HS	HACH	HACH ez	Quantofix	Wagtech Arsenator	Wagtech VCDK	GPL	Econo Quick
MHAS	230	246	16	-44.1	+53	+34.3	+44	+44.8	-42	+0.46	+38.2	+44
MMAS	160	189	29	-43.5	+57	-9.1	+11	+43.5	-19	+0.40	+38.7	+55
MLAS	1			-0.0	+80	+74.3	0	0.0	0	0.00	+96.5	+80
MSA	50			-3.4	-3	-32.4	-10	-20.0	-14	-0.05	-3.4	-34
Blank	0			0.0	0	0.0	0	+100.0	0	0.00	+100.0	0

6. DISCUSSION

6.1 Method of Analysis

Hydride generation technique is commonly used for the determination of trace amounts of arsenic.[11] The process is combined with many different detection systems and becomes the standard. Only the difference is the generation technique. The arsine could be produced by zinc with hydrochloric acid and sodium borohydride with an acidic solution. During hydride generation with sodium borohydride, sometimes an additional pre-reductant is used to reduce the arsenic As(V) to As(III) though sodium borohydride is able to reduce. Inorganic materials can interfere with generation of arsine with sodium borohydride. Arsine generated from zinc and hydrochloric acid, stannous chloride and potassium iodide is used as a reductant in many systems. The general process is the production of hydrogen gas in its nascent state, then the nascent hydrogen deoxygenate the arsenic and finally produces arsenuretted hydrogen and separate itself from the liquor. The arsine gas then goes upward in the reaction chamber

and reacts with mercury bromide strip or paper placed there and produces the yellow to brown colour. All of the available test kits in the review follows the same. Only the difference is the generation of hydrides. The Wagtech VCDK and the Wagtech Digital Arsenator uses the sodium borohydride and a sulphamic acid for the generation of nascent hydrogen and rest of the kits uses zinc and an acid. The 100% arsenic free zinc must be ensued because during the commercial production of zinc some trace amounts of arsenic is associated with the zinc. May be for this reason the Quantofix, Merck and GPL gives arsenic with blank samples during the field testing.

6.2 Limit of Interfering Elements for Different Arsenic Field Testing Kits

Different elements of the natural water could interfere the testing. The test kit provider's supplied the interference limit for their test kits, summarized in the following Table 15. Some test kit providers do not indicate the limit of some parameters. The standard list of interfering elements must be generated through comprehensive water quality monitoring of Bangladesh ground water. That will also helpful for the test kit provider to rebuild their kit for Bangladesh. We should never think that only sulphide is interfering element for these test kits.

Table 15: Interference limit of different parameters of natural water provided by the test kit provider

Merck S	Merck HS	HACH	HACH ez	Quantofix	Wagtech Digital Arsenator	Wagtech VCDK	GPL	Econo Quick
S^{2-} = 0.5 mg/l SO_3^{2-} > 1 mg/l SO_4^{2-} > 1000 mg/l $S_2O_3^{2-}$ > 0.5 mg/l Cl^- > 1000 mg/l Fe^{2+} > 1000 mg/l Fe^{3+} > 1000 mg/l ClO_3^- > 25 mg/l Ag^+ > 1 mg/l Al^{3+} > 100 mg/l Ca^{2+} > 1000 mg/l CN^- > 1000 mg/l Co^{2+} > 5 mg/l Co_3^{2-} > 1000 mg/l CrO_4^{2-} > 1000 mg/l Cu^{2+} > 0.5 mg/l F^- > 500 mg/l Hg^{2+} > 5 mg/l K^+ > 1000 mg/l Mg^{2+} > 1000 mg/l MnO_4^- > 500 mg/l Na^+ > 1000 mg/l Ni^{2+} > 10 mg/l NO_2^- > 100 mg/l NO_3^- > 100 mg/l PO_4^{3-} > 100 mg/l Sb^{3+} > 1 mg/l SeO_3^{2-} > 1 mg/l Sn^{2+} > 100 mg/l Zn^{2+} > 1000 mg/l EDTA > 1000 mg/l	Fe^{2+} > 500 mg/l Fe^{3+} > 500 mg/l Cl^- > 1000 mg/l S^{2-} > 2 mg/l SO_3^{2-} > 2 mg/l SO_4^{2-} > 1000 mg/l Ag^+ > 0.5 mg/l Al^{3+} > 100 mg/l Ca^{2+} > 1000 mg/l CN^- > 500 mg/l Co_3^{2-} > 100 mg/l CrO_4^{2-} > 250 mg/l Cu^{2+} > 0.5 mg/l F^- > 100 mg/l K^+ > 1000 mg/l Mg^{2+} > 1000 mg/l MnO_4^- > 500 mg/l Na^+ > 1000 mg/l Ni^{2+} > 1 mg/l NO_2^- > 100 mg/l NO_3^- > 100 mg/l PO_4^{3-} > 100 mg/l Sb^{3+} > 1 mg/l SeO_3^{2-} > 1 mg/l EDTA > 1000 mg/l NaCl > 20%	S^{2-} > 5 mg/l Selenium >1 ppm Tellurium Likely to Interfere, but not tested Other interferes are unlikely Hardness 1000 ppm as $CaCO_3$ Alkalinity 1000 ppm as $CaCO_3$ Iron 10 ppm	S^{2-} > 15 ppb Selenium >1 ppm Antimony > 250 ppb Tellurium Likely to Interfere, but not tested Other interferes are unlikely Hardness 1000 ppm as $CaCO_3$ Alkalinity 1000 ppm as $CaCO_3$ Iron 100 ppm	No information was obtained because the provider does not give any technical paper	S^{2-}	S^{2-}	S^{2-}	S^{2-} > 2 mg/l Antimony > 0.5 mg/l

6.3 Sources of Errors

In selecting or developing a arsenic test kit for Bangladesh or any other arsenic contaminated place in the world, one should consider the variability of water quality in different areas of the country or out of the country with some seasonal responses. Because there are some elements in water, which may interfere with testing accuracy. Table 16 has been generated with some of water quality parameters and elements of water from the final report of a study (volume 2) of Arsenic Contamination of Ground Water in Bangladesh conducted by, British Geological Survey in collaboration with LGRD and DPHE. Sulfide is identified as one of the major element in the ground water. It can interfere with arsenic testing of most of the test kits. Antimony is another element, which gives stibine (SbH_3) and interferes giving the same stain on the mercury bromide paper. The other elements like copper, lead, bismuth, phosphorous may also interfere with arsine generation. Another important thing is the sensitivity of the mercuric halide towards the light. If bromide paper is exposed to light for a long time it will generate colour automatically. The sensitivity of the mercuric halide is linked with mercuric chloride < mercuric bromide < mercuric iodide. Robust and reliable water quality monitoring is other important factor for arsenic analysis by kit methods because every methods used by the kit has some limitations with of interfering elements.

Table 16: Concentration of different elements in shallow and deep aquifers of Bangladesh

Parameter (mg/l)	Shallow Aquifer (Concentration)			Deep Aquifer (Concentration)		
	Lowest	Highest	Median	Lowest	Highest	Median
Barium	< 0.06	1.4		< 0.06	1	
Boron	< 0.01	1.6		< 0.01	2.2	
Calcium	0.01	336		0.4	280	
Iron	< 0.004	61	1.4	< 0.004	61	0.2
Magnesium	< 0.04	305	16	0.7	137	11
Manganese	< 0.002	20	0.34			0.03
Phosphorous	< 0.01	19	0.29	0.1	6.1	0.33
Potassium	< 0.6	4	2.2	< 0.6	4	3.3
Silicone	10	21	20	2	6	30
Sodium	0.7	73		2.5	251	
Strontium	< 0.2	1.6		0.2	3	
Sulphate	< 0.2	753		0.2	96	

6.4 Colour Chart Combination

Colour combination chart for each of the test kit is shown in annexure form Tk-1 to Tk-9. At lower range and higher range it is very difficult for an operator for some of the test kits to identify the numerical value of concentration. The colour charts are prepared with the standard samples of arsenic. The real water samples sometimes or most of the times give the distorted colour because of the interference. Moreover, if the person who is engaged with the testing is not very sensitive to colour then there is possibility of getting wrong results especially at

lower concentrations. The other issue during testing, when an operator find a colour slightly raised from 50 ppb or slightly down from 50 ppb then it is very difficult for him to make a conclusion about the concentration. Such type of samples must be analyzed in laboratory. The following table (Table 17) shows the intermediate ranges of colour chart for different arsenic field testing kits.

Table 17: Colour comparison chart for different arsenic field testing kits

Wagtech Digital (ppb)	[<10 20-40 50 60-80 100 100-200 200-300 300-400 400-500]	
	Arsenator (0 to 100+)	
Wagtech VCDK (ppb)	[<10 20-40 50 60-80 100 100-200 200-300 300-400 400-500]	
GPL (ppb)	[0 10 50]	[100 500 1000 1500 2000 2500]
	50 ml sample	***5 ml sample***
HACH (ppb)	[0 10 30 50 70 300 500]	
HACH EZ (ppb)	[0 10 25 50 100 250 500]	[0 35 75 175 500 1000 4000]
	50 ml sample	***9.6 ml sample***
Merck Sensitive (mg/l)	[0 0.01 .0.025 0.05 0.1 0.5]	
Merck Highly Sensitive (mg/l)	[0 0.005 0.01 0.025 0.05 0.1 0.25 0.5]	
Quantofix (mg/l)	[0 0.01 0.025 0.05 0.1 0.5]	
Econo Quick (mg/l)	[0 0.010 0.025 0.050 0.1 0.2 0.3 0.5 1.0]	

6.5 Suitability and Accuracy

The errors showed by the field kits during field-testing are due to the operational and personnel errors, reagent errors, method errors[12] and colour detection by eye errors etc. This should have to be minimized by employing trained and skilled manpower; electronic reader based colour detection apparatus with regular standardization of the reader, quality control of the reagents, commitment of the person to testing etc. The following important issues should be considered relating to screening done by using kits weather it is manufactured in our country or imported from outside the country;

1. The man behind the instrument and his commitment, knowledge about the testing
2. The sensitivity of the kit and its chemistry
3. The color comparison with color comparator chart
4. Cross checking options for checking results
5. Standardization test kit regularly
6. The reliability of result, which will not be comparable with the laboratory analysis[13] because there is always 10% to 15% or sometimes more than 15% differences with the analytical results (e.g. AAS).
7. For keeping the quality of reagents the number of the test should be 50 or less.
8. Comprehensive testing of different ground water quality parameters
9. Comprehensive and comparative analysis of different test kits with different water quality conditions for identification of the suitable kit for Bangladesh

7. CONCLUSION

This review has observed that different organizations have their own opinion about the arsenic field testing kits and most of the organizations used Merck and HACH EZ for screening purposes although some small number of other kits are also used. Some of the organizations feel comfort with Merck and some with HACH EZ. The review has also found that some the test kit providers have a plan for manufacturing/marketing the kits in the country. The literature review provides an indication for a comparative analysis of different arsenic field testing kits. The field testing in two ground water quality conditions showed a wider variation of results among the test kits, although there are limitations in the study. The information from all sources allow a comparative picture as follows:

Table 18. A comparative picture of test kits

Test Kits	**Country of Origin**	**Third Party Validation**	**Cost per unit (US $)**	**Refilling Cost (US $)**	**Availability**	**Dependability**
Merck (Sensitive)	Germany	No Validation	0.50-0.52		Available	Less Dependable
Merck (Highly Sensitive)	Germany	No Validation	0.70-0.73		Will be available	Less Dependable
GPL	Bangladesh	Validation from Bangladesh Atomic Energy Center	0.40-0.45		Available	Not Dependable
Wagtech Digital Arsenator	United Kingdom	Waiting for Validation from UK Water Company	5.9-6.0	0.64-0.66	Will be available	More Dependable
Wagtech VCDK	United Kingdom	Waiting for Validation from UK Water Company	0.92-0.93	0.64-0.66	Will be available	More Dependable
HACH (5 Stage)	United States of America	No Validation	1.70-1.75		Available	More Dependable
HACH EZ	United States of America	No Validation	0.84-0.86		Available	More Dependable
Econo Quick	United States of America	Validation from USEPA but paper not supplied	0.64-0.65		Will be available	Less Dependable
Quantofix	Germany	Not Mentioned	0.52-0.55		Will be available	Not Dependable

The field testing showed the HACH EZ, Wagtech Digital Arsenator and Wagtech VCDK, HACH kits are better options to get a more dependable estimate of arsenic under field conditions. All of these kits have a good system for the removal of sulfide interference. Quantofix and GPL give false value with the blank samples. The Merck Highly Sensitive and the Econo Quick test kit gives good result but during the testing most of the test strips become damaged. The Quantofix and the Merck sensitive has no provision for removal system for sulfide interference.

There is a need to develop locally manufactured kits using colorimetric method with a digital read out device or colour chart. All interfering elements should also be properly identified under Bangladesh water condition and protection mechanism is to be in-built in the test kits. Design and manufacturing of kits should take care of quality and storage of the regents and chemicals during testing under Bangladesh weather conditions. The standardization of the test kits must be done at regular intervals to check the efficiency of the test kit at the user levels. If colour chart is used employment of skilled, particularly coloru sensitivity and commitment should get due consideration.

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