RAPID ASSESSMENT OF HOUSEHOLD LEVEL ARSENIC REMOVAL TECHNOLOGIES

Phase I - Final Draft Report

January 2001

WS Atkins

BAMWSP/DFID/WaterAid

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JOB NUMBER: AK2671			DOCUMENT REF: AK2671\17\DG\			
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		D. Sutherland	S. Wood	Prof. J. Monhemius Imperial College	M. Woolgar	22 Dec 2000
		Originated	Checked	Reviewed	Authorised	Date
Revision	Purpose Description	WS ATKINS INTERNATIONAL LIMITED				

BAMWSP/DFID/WaterAid

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APPENDICES

The dissemination strategy for this information will attempt to reach as broad a stakeholder forum as possible (including Government, national and international NGOs, bilateral and multi-lateral donors, development banks, private sector and other interested parties). It will do this through the following channels:

The report is being published on several web sites. The confirmed site on which the report will be available shortly is WaterAid (http://www.wateraid.co.uk). There will be links and/or documents available on the Arsenic Crisis Information Centre site (http://bicn.com/acic/). Links and/or information will also become available on a WS Atkins site and are likely to be put on to the DFID and BAMWSP sites in the future.

Notification and links will be made through the IRC SOURCE Bulletin on http://www.wsscc.org/source/.

It is anticipated that a summary document at the end of Phase II, published in Bengali, will be distributed widely by an appropriate umbrella NGO within Bangladesh.

Acknowledgements

This is an exercise that has required the intensive input of a large number of people and timely inputs from many more. The contractors would like to thank all those who have contributed to the successful completion of the field work for Phase I.

The support and encouragement from many at BAMWSP, at a difficult time, has been greatly appreciated. This project has been carried out under the BAMWSP umbrella and the help from Farid Udin Ahmed Mia (Project Director) and Dr. Nurruzaman has been invaluable, particularly during start up.

The TAG to BAMWSP have provided comments on the Phase I draft report, which have been included, and their insight, help and time are much appreciated.

We would also like to thank Peregrine Swann from DFID and Elizabeth Jones from WaterAid for their patience, support and frequent and friendly advice. The sub-contractors for this project, Bangladesh Engineering and Technological Services (BETS), supplied us with an enthusiastic and talented field survey team and assisted frequently on logistical issues. We could not have done it without them and the support of Dr. Shabur and Md. Jahangir Chowdury, Obaidul Kabir and Rezaul Hassan.

Enormous pressure was put upon the Intronics laboratory staff to provide results and they delivered by working all hours of the day under the close supervision of Dr. Peter Swash. Our gratitude goes to Tipu, Kamal, Dulaly and Hawa for their sterling work.

LIST OF ACRONYMS

AAS-HG	Atomic Adsorption Spectrophotometer – Hydride Generator
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BETS	Bangladesh Engineering and Technological Services
BGS	British Geological Survey
BUET	Bangladesh University of Engineering and Technology
CIDA	Canadian International Development Agency
DFID	Department for International Development
DPHE	Department for Public Health Engineering
ETV	Environmental Technology Verification
GPL	General Pharmaceuticals Limited
ICP	Inductively Coupled Plasma (Mass Spectrophotometer)
MDL	Method Detection Limit
ppb	parts per billion
OCETA	Ontario Centre for Environmental Technology Advancement
TAG	Technical Advisory Group

TERMINOLOGY

Unpurged well water	Water in the well which has been left standing over night
Purged well water	Water taken from the well after the well has been pumped to waste - one pump for every foot depth of the well
Unfiltered water	Water as it comes from the well
Filtered	Water after it has been filtered through a 0.2µm filter
Feed Waters	Water direct from the well before going through technologies
Treated Waters	Water after it has passed through the technologies

INTRODUCTION

Context

1. The extent of the arsenic problem in Bangladesh is without doubt. The focus must now shift, and is shifting, away from identification of the problem towards finding solutions to the problem. There needs to be a parallel emphasis on both short and long term solutions to the arsenic problem. This project focuses upon the urgent response needed in the short term. The project is designed to be a first pass comparative evaluation of arsenic mitigation technologies, specifically household level removal technologies (or 'filters').

2. This report represents the conclusion of Phase I of a two phase project looking at the performance and acceptability of nine household level arsenic removal technologies currently available in Bangladesh. 'Performance' relates to the ability of the technologies to remove arsenic, at the well head, from groundwater. 'Acceptability' is concerned primarily with ease of use, user preference, day-to-day and health consequences for users, environmental impact and affordability.

3. Phase I has concentrated upon the technical performance of the technologies, in terms of their ability to remove arsenic. Phase II will continue to do this but will shift the focus away from performance and towards acceptability.

4. In addition to the specific and urgent focus of the technology performance assessment, this project is providing inputs to (i) a longer term Environmental Technology Verification (ETV) Protocol, being funded by CIDA and developed by OCETA and BAMWSP, and (ii) World Health Organisation generic ETV for arsenic. BAMWSP and OCETA have contributed in the development of the survey methodology for this project. The results, and comments on the feasibility, practicality, and effectiveness of the survey methods, will be fed into the BAMWSP / OCETA ETV Protocol.

Phase I Aim and Objectives

5. The overall aim of Phase I is to provide an independent, comparative assessment of the ability of the nine technologies selected to reduce arsenic concentrations to below the Bangladesh Guideline Standard of 50 parts per billion (ppb).

6. The specific objectives of Phase I are:

   - To identify which of the nine technologies reduce arsenic to below 50ppb for specific water chemistries or for all water chemistries tested;
   - To assess possible reasons for poor performance, for example, the influence of other water chemistry parameters that may inhibit arsenic removal;
   - To provide output, in terms of results and comments on survey methods, and help guide other, longer term, technology verification programmes.

Phase I Approach

7. The approach taken in this project was to carry out as much of the research as possible in the field, to demonstrate that results can be provided rapidly without the need for transportation of samples and laboratory analysis.

8. Under Phase I, wells selected in the survey were used as field laboratories. Three replicates of each of the nine technologies (27 units in all) were set up at each of the 20 wells and the well users gave the survey teams free access to the well. The feed waters were then able to be analysed as required (unpurged and purged). Unrestricted access also enabled the teams to prepare a programme based only on the length of time for one batch to pass through the different technologies and the time taken for each analysis.

9. The survey was carried out in four areas, with each area surveyed in series, to provide flexibility in the management of, and logistical support for, the five teams working on assessment. Discussion between teams also ensured that quality assurance standards were maintained and were uniform. With five wells in each area, this meant that each team was working on one well at a time.

10. The analysis of arsenic in feed and treated waters in the first two areas was, however, carried out predominantly through laboratory analysis. This was done to provide both a confident assessment of the performance of the technologies and an evaluation of the PeCo 75 arsenic field testing kit. The early results from the PeCo 75 were highly encouraging but it had never been used in the field. Comparative laboratory testing was seen as key to establish the accuracy and precision of the field testing kit chosen for this project. All other water chemistry parameters were tested in the field.

Technologies

- The nine technologies finally included in this project were selected after discussions between DFID, WaterAid, contractors, the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) and other stakeholders. Previous results were encouraging;
- Technology appeared relatively user-friendly;
- Technology readily available in country (21 units of each technology were required for this project);
- Promoting organisation was open and interested in participating in the study.

11. The number of technologies selected for this project was set at nine. This was seen as the maximum number of technologies that could be assessed in a short period. Ideally, for a rapid assessment, the number would be lower, but an attempt has been made to maximise the number assessed to give the most comprehensive advice at the earliest opportunity, given the urgency of the situation. It is acknowledged that a number of other household level arsenic removal units exist All proponents of other technologies are assured that this study is just a first pass, and that the ETV Protocol project of BAMWSP / OCETA will be evaluating 13 technologies over the next three years.

12. The technologies finally selected for this project are, in alphabetical order, as follows:

- Alcan enhanced activated alumina filter
- Ardasha filter
- BUET activated alumina filter
- DPHE/Danida two bucket system
- GARNET home-made filter
- Passive sedimentation
- Sono 3-kolshi method
- Stevens Institute technology
- TetraHedron ion exchange resin filter

13. A two to three page explanation of each of the technologies is provided in Appendix 1. The explanation includes chemical and physical processes, existing research, physical performance (e.g. flow rates), cost information, details on installation, operation and maintenance. Photographs and diagrams are also included.

Survey Areas

14. Four different geographical regions of Bangladesh were selected after discussions between the project team, BAMWSP and members of the BAMWSP Technical Advisory Group (TAG). Each of the areas is situated on a discrete flood plain and exhibits different water chemistry attributes. The survey was carried out in each area consecutively, in the order shown below:

15. The four areas are:

- Sitakunda south of Feni river and north of Karnaphuli river
- Hajiganj east of the Meghna
- Iswardi north of the Padma and west of the Jamuna
- Kalaroa south of the Padma, towards the coastal Sundarbans

Phase I Programme

16. The start of field testing in this project was delayed because of unexpected problems associated with the production and distribution of the PeCo 75. The programme of main events under Phase I was therefore as follows:

- 28th August — Introductory Workshop, BAMWSP
- 15th – 24th September, — Well selection and laboratory evaluation & selection
- 21st Nov. – 15th Dec. — Field survey programme

22nd Nov:	Setting up filters	Sitakunda
23rd – 25th Nov:	Testing	Sitakunda
26th Nov:	Testing and demobilisation	Sitakunda
27th Nov:	Transfer and setting up	Hajiganj
28th – 30th Nov:	Testing	Hajiganj
1st Dec:	Testing and demobilisation	Hajiganj
4th Dec:	Transfer	Iswardi
5th Dec:	Setting up	Iswardi
6th – 8th Dec:	Testing	Iswardi
9th Dec:	Testing and demobilisation	Iswardi
10th Dec:	Transfer and setting up	Kalaroa
11th – 13th Dec:	Testing	Kalaroa
14th Dec:	Testing and demobilisation	Kalaroa

- 29th November — Open Field Visit Day
- 12th December — Preliminary results presented at Workshop

Report Structure

17. This report comprises:

- Introduction;
- Detailed methodology describing logistical, analytical and statistical methods for the wells, technologies and the field testing kits;
- Results from the field survey of the wells, technologies and field test kits;
- Conclusions on the effectiveness of the technologies in reducing arsenic below 50ppb and, where possible, reasons for differences in the behaviour of the technologies in different locations;
- Recommendations for which technologies should go forward to Phase II, based on the criterion that all three replicates of a technology at one well or more reduce arsenic to below 50ppb;
- A summary of Phase II content.

18. This report seeks to keep the presentation of the results to a clear and coherent minimum. Therefore, only the summary data and interpretation will be presented within the main body of the report. Much of the information will be presented in a series of supporting Appendices. The raw data will be made available on the BAMWSP and WS Atkins web-sites and, possibly, WaterAid and DFID web-sites. All who receive this report will be informed of the web-site addresses when the data has been set up on them.

19. The Appendices provide descriptions of the technologies, a detailed explanation of field procedures and quality control measures, technology results and correlations, and a generic discussion of the issues relating to the waste produced by these filters, in terms of back wash and the disposal of the filter material.

METHODOLOGY

Introduction

20. This section presents the methodology for the field and laboratory surveys carried out during the well selection process, the arsenic removal technology assessment and the arsenic field test kit evaluation. The methodology, as presented here, relates to overall planning of the survey, the water chemistry analysis and the statistical analysis used in the determination of assessment results.

Reconnaissance Survey for Well Selection

Procedure and criteria

21. The main criterion used in the selection of wells was the level of arsenic in the groundwater. In each area, where possible, the final selection of five wells was distributed as follows:

• Arsenic concentration:	50 to 100 ppb	- one well
	100 to 250 ppb	- two wells
	>250 ppb	- two wells

22. In the immediate vicinity of Hajiganj, it was not possible, in the short time available, to find wells with arsenic concentrations of less than 100ppb, so an additional well with arsenic concentration of >250 ppb was selected, as this was seen as representative of the area.

23. The general locations in each area were selected with advice from BAMWSP. The wells selected for testing were chosen either based on data from the BGS/Mott MacDonalds survey, DPHE data (from the thana offices), BAMWSP data or, failing these, at random.

24. In addition to arsenic concentrations, the other criteria for selection were variability in other key water quality parameters, ease of access, and sufficient area to place 27 units. The water quality variables tested for in the field were total iron, pH, conductivity and dissolved oxygen. Smell and colour were also recorded.

25. Samples from each well were acidified with 1mL of nitric acid (to keep elements in solution) and taken back to the UK for standard metal characterisation by inductively coupled plasma (ICP) analysis. This enabled a detailed characterisation of each well to be made.

26. A total of 40 wells were tested, from which 20 were selected for Phase I.

Equipment

27. The kits used in the field for testing the various parameters were as follows:

- Arsenic: Merck Strips (US) GPL Testing Kit (Bangladesh)
- Total Iron: Hach Iron Testing Kit (US)
- pH, conductivity and dissolved oxygen probes

28. Laboratory testing of arsenic and a standard suite of metals was done through ICP at Imperial College in London.

Field Testing of Arsenic Removal Technologies

29. This section presents detail on the logistical considerations in field testing and the protocols followed when in the field.

Procedure

Survey teams

30. The survey team was split into five sub-teams, comprising one team leader and three field surveyors. At least two people with technical experience in analytical chemistry were assigned to each sub-team. At least two teams were working in close proximity at any one time, to enable an exchange of ideas as and when necessary.

31. Before moving to the field, three main exercises were carried out in parallel. These were surveyor training, protocol development and the production of handbooks and data record sheets.

Training

32. The survey teams were trained in the use of the field survey equipment, by both designated Hach trainers from the Bangladesh Hach agents (Technoworth Ltd.) and by the overseas contractors. In addition, intensive training was carried out on the setting up and operation of the arsenic removal technologies. The arsenic removal and field survey technology training also included two days of practical in-field training. This helped in the development of the field testing protocol and ensured that the equipment was operated in a consistent way.

Protocol development

33. In addition to in-field training and resultant information, there were two key elements in the development of the field testing protocol. The first was laboratory testing of the arsenic removal technologies to establish flow rates and, hence, the length of time for each technology to pass a batch of water. The second was the assessment of the length of time needed to test each water quality parameter.

34. The key parameter to be tested was arsenic, but the following parameters were also tested in the feed water:

- Ferrous Iron
- Total Iron
- Total Manganese
- Total Aluminium
- Phosphate
- Nitrate
- Fluoride
- Chloride
- Sulphide
- Turbidity
- Redox
- pH
- Conductivity
- Dissolved Oxygen
- Sulphate
- Alkalinity

35. Treated water was also tested from those technologies where chemicals with potential health effects were added or intrinsic within the treatment process. The parameters tested were manganese and aluminium. The technologies tested were the Alcan Enhanced Activated Alumina, BUET Activated Alumina and DPHE/Danida 2-bucket.

36. The field testing protocols that were developed for arsenic and non-arsenic testing are shown in Appendix 2. These protocols were designed to take into account the time

taken for batches to pass through the filters and the time for testing. The protocol was developed so that the technology testing schedule at each well could be completed in three days. This was reduced from four days because of the extreme urgency attached to the results from this project. The statistical significance of the results was not seriously reduced through this.

Sampling procedure

Arsenic

37. In the case of arsenic, at each well site the following samples were tested:

- Unpurged water from the well at the start of the day, when possible
- Purged water direct from the well (after one pump for every foot depth of the well had been pumped to waste)
- Purged water was filtered through a 0.2µm syringe filter (to remove suspended solids) to see what proportion of arsenic was in solution and attached to suspended solids
- Feed waters for each of the three technology replicates (four feeds)
- Treated water for each of the three technology replicates (four treated waters)

38. The last two samples in the list above provide four paired samples of feed and treated water for each replicate, amounting to 12 paired samples for each technology at each well. This means a total of 60 paired samples for each technology in each area and 240 paired samples for each technology in total. The data sheets used to record when the technologies were filled (and who filled them), when the feed waters were tested (and who tested them), and which samples went to the laboratory are shown in Appendix 2.

Non-arsenic parameters

39. In the case of the non-arsenic parameters, all parameters shown above were tested once each day. Testing was also carried out on treated waters to assess:

- the level of manganese and aluminium produced by each of the three replicates of the DPHE/Danida Two Bucket Method and the BUET Activated Alumina Filter
- the level of aluminium produced by each of the three replicates of the Alcan Enhanced Activated Alumina Filter.

40. The data sheets used to record when sampling and testing was done, who did it, and what the results were are shown in Appendix 2. Method detection limits (MDLs) are shown under Quality Control in Appendix 3.

Equipment

41. The following equipment was used in the field for testing non-arsenic parameters:

- Hach Spectrophotometer (DREL-2010) for:
  - total iron, ferrous iron, manganese, aluminium, phosphate, nitrate, sulphide, fluoride, chloride, sulphate
- Hach Portable Turbidimeter for Turbidity
- PH/Redox meter
- Conductivity meter
- Dissolved oxygen meter
- Hach alkalinity test kit

42. Arsenic was tested using the PeCo 75 (replacement for the Arsenator 510), which uses a photometer, created by Professor Walter Kosmus, University of Graz, Austria and produced by Peters Engineering. This was chosen because the Arsenator 510 received the highest endorsements in the literature of any of the arsenic field-test kits.

Quality control

43. Quality Control relates to issues of equipment, the sample numbering system, standard operating procedures, chemical determination in the field and chemical determination in the laboratory. The Quality Control Procedures for all field and laboratory testing are explained in Appendix 3.

Presentation of results

Technology flow rates

44. The laboratory analysis of flow rates, carried out as part of the sampling protocol development, are presented. These take the form of a flow rate (for low and high turbidity waters) and a volume of water passed, on average, in a 12 hour period of continuous operation.

Water chemistry in the four areas

45. The results from the non-arsenic and arsenic field testing of the raw waters are presented for each of the four areas. These are presented as mean values for the three days on which raw water quality testing was completed and with a standard deviation to illustrate the degree to which these parameters changed over the three days. The results are presented on an area basis in the report and on a well by well basis in Appendix 4a.

Evaluation of arsenic field testing kit

46. The field testing kit which was selected for this project is the PeCo 75 from Austria. The reason for the selection for this kit is outlined above. This has not been used in the field before, so an assessment of the performance of the PeCo 75 against the AAS-HG in the laboratory is presented in the results.

Arsenic removal by the technologies

47. The results from the field and from the laboratory are presented in a simple format with little in the way of statistical analysis in Phase I. The statistical analysis seeks to address two specific questions:

   a. Do the technologies reduce arsenic concentrations to below 50ppp?

b. If they do not reduce arsenic concentrations below 50ppb, what water chemistry parameters could be inhibiting performance?

48. To answer the first question, the results for each technology at each of the wells are presented in the form of a table, showing a mean and standard deviation for feed waters and for treated waters. The mean states whether the technology has, on average, reduced arsenic to below 50ppp. This average treated water figure is a mean of 12 treated water samples (four samples for three replicates of each technology). The standard deviation illustrates the range of treated arsenic concentrations from the individual batches from each replicate. The standard deviation may suggest that some or many samples failed to pass the 50ppb threshold. The final result in the table indicates the percentage of samples that passed the 50ppb threshold (indicating the amount of time that the technologies are succeeding or failing in meeting the Guideline Standard). This is illustrated in Table 2.1 below for a theoretical technology. In this example, Technology X passed the Guideline Standard at Well 3 only, where 75% of samples passed the threshold. Summary tables are presented in the main report and more detailed tables for each replicate of each technology are presented in Appendix 4.

Table 2.1: Format for presentation of arsenic removal results – Technology X

Area 1	**Mean As in feed water (ppb)**	**Std.Dev.**	**Mean As in treated water (ppb)**	**Std. Dev.**	**% samples passed**
Well 1	**400**	60	**150**	21	0%
Well 2	**350**	74	**100**	18	5%
Well 3	**125**	45	**43**	26	75%
Well 4	**450**	57	**160**	70	0%
Well5	**375**	67	**165**	42	0%

49. To try and address the second question, simple x-y plots have been prepared for percentage arsenic removed against other parameters (such as competing anions like phosphate, chloride and sulphate).

Aluminium and manganese in treated waters

50. In addition to arsenic testing, at least three batches of treated water from each of the DPHE/Danida and BUET technologies were tested for their aluminium and manganese concentrations using the Hach Spectrophotometer. Treated waters from the Alcan technology replicates were also analysed for aluminium only. High levels of manganese in drinking water are toxic and high levels of aluminium have been associated with adverse health affects. The purpose of this testing was therefore to make an initial assessment of the potential introduction of these elements by those technologies using either aluminium or manganese within the arsenic removal process.

RESULTS

Technology flow rates

51. The technology flow rates are presented for both low and high turbidity waters, and in terms of an average volume of water available for use in a 12 hour period (see Table 1). The technologies with the quickest flow rates are the Alcan and Tetra Hedron (both producing well in excess of 1000 litres every 12 hours). The slowest filters were the Ardasha and GARNET. Most technologies performed at a similar rate in the field to what they had in the laboratory, with the exception of the Ardasha which slowed significantly during the survey period, to about 0.3 L/hr.

Table 1: Technology flow rates and daily water volumes produced

Technology	Flow rate (L/hour) (Turbidity 1.9 NTU)	Flow rate (L/hour) (Turbidity 9.6 NTU)	Volume of water in 12 hour period (litres)
Alcan enhanced activated alumina	>300	>300	>3600
Ardasha	1.1	1.1	13
BUET activated alumina	4 (including 1hr waiting time)	4 (including 1hr waiting time)	48
DPHE/Danida 2-bucket	23 (including 2hrs waiting time)	17 (including 2hrs waiting time)	240 approx.
GARNET	0.7	0.4	7
Passive sedimentation	Not applicable	Not applicable	Depends on kolshi size (2/3rds kolshi)
Sono 3-kolshi	5	5	60
Stevens Institute	18	18	240
Tetra Hedron	90	85	1080

Water chemistry in the four survey areas

52. The water chemistry parameter results for each well, when averaged for the area indicate significant differences between the areas for many of the parameters surveyed (see Table 2). A key variable in the effectiveness of arsenic removal is iron and this was low in all areas except for Kalaroa. For most technologies, high natural iron concentrations will generally improve arsenic removal, whilst some technologies may be hindered by the lack of iron (for co-precipitation) in the groundwater.

53. Differing concentrations of competing anions, such as phosphate, chloride and sulphate may also reduce the effectiveness of many of the technologies and these too varied between the areas. Sitakunda on the whole had higher levels of anions, particularly phosphate. The correlation graphs between arsenic and non-arsenic variables are shown in Appendix 5.

Table 2: Mean non-arsenic water quality parameters by area

pH

Area	Mean	Std. Dev.
Sitakunda	7.53	0.32
Hajiganj	7.34	0.31
Iswardi	7.11	0.12
Kalaroa	6.96	0.10

(Acceptable range 6.5-8.5)

Eh (mV)

	Mean	Std. Dev.
Sitakunda	-14.27	12.21
Hajiganj	2.00	14.92
Iswardi	15.00	11.20
Kalaroa	25.14	3.70

Conductivity (mS/cm)

	Mean	Std. Dev.
Sitakunda	1.03	0.52
Hajiganj	0.61	0.23
Iswardi	1.11	0.38
Kalaroa	0.95	0.09

Temperature (oC)

	Mean	Std. Dev.
Sitakunda	26.33	0.56
Hajiganj	23.92	5.95
Iswardi	25.58	0.97
Kalaroa	25.95	1.03

Dissolved oxygen (mg/l)

	Mean	Std. Dev.
Sitakunda	3.35	1.59
Hajiganj	2.86	1.15
Iswardi	3.63	1.81
Kalaroa	3.33	1.94

Total iron (mg/l)

	Mean	Std. Dev.
Sitakunda	0.34	0.31
Hajiganj	1.35	0.95
Iswardi	1.08	1.13
Kalaroa	5.54	3.20

(Acceptable range 0.3-9)

Ferrous iron (mg/l)

	Mean	Std. Dev.
Sitakunda	0.29	0.41
Hajiganj	1.08	1.10
Iswardi	0.32	0.41
Kalaroa	1.75	1.66

Turbidity (NTU)

	Mean	Std. Dev.
Sitakunda	3.04	3.32
Hajiganj	8.51	16.22
Iswardi	3.98	6.05
Kalaroa	7.75	10.81

Sulphide (mg/l)

	Mean	Std. Dev.
Sitakunda	0.00	0.01
Hajiganj	0.00	0.00
Iswardi	0.00	0.00
Kalaroa	0.01	0.01

Alkalinity (mg/l)

	Mean	Std. Dev.
Sitakunda	462.00	123.76
Hajiganj	276.00	46.72
Iswardi	535.71	126.53
Kalaroa	457.14	110.06

Manganese (mg/l)

	Mean	Std. Dev.
Sitakunda	0.31	0.32
Hajiganj	0.08	0.05
Iswardi	0.54	0.36
Kalaroa	0.25	0.36

(Bangladesh Guideline Standard 0.1)

Phosphate (mg/l)

	Mean	Std. Dev.
Sitakunda	10.88	10.19
Hajiganj	6.39	2.19
Iswardi	3.30	2.27
Kalaroa	3.96	1.97

(Bangladesh Guideline Standard 6)

Chloride (mg/l)

	Mean	Std. Dev.
Sitakunda	66.10	75.51
Hajiganj	19.99	29.62
Iswardi	15.44	15.13
Kalaroa	12.05	9.67

(Acceptable range 150-600)

Fluoride (mg/l)

	Mean	Std. Dev.
Sitakunda	0.80	0.70
Hajiganj	0.24	0.21
Iswardi	0.34	0.20
Kalaroa	0.43	0.39

(Bangladesh Guideline Standard 1)

Aluminium (mg/l)

	Mean	Std. Dev.
Sitakunda	0.01	0.02
Hajiganj	0.01	0.01
Iswardi	0.02	0.03
Kalaroa	0.06	0.08

(Bangladesh Guideline Standard 0.2)

Nitrate (mg/l)

	Mean	Std. Dev.
Sitakunda	0.15	0.25
Hajiganj	0.03	0.08
Iswardi	0.08	0.09
Kalaroa	0.23	0.42

(Bangladesh Guideline Standard 10)

Sulphate (mg/l)

	Mean	Std. Dev.
Sitakunda	7.38	10.36
Hajiganj	8.36	15.74
Iswardi	11.79	14.49
Kalaroa	0.00	0.00

(Bangladesh Guideline Standard 100)

Arsenic field testing kit evaluation

54. The evaluation of the PeCo 75 field testing kit was done through a comparison of the PeCo 75 data with laboratory results for the same samples in Hajiganj and Iswardi. The graphs showing the relationship between field and laboratory based testing are shown in Figures 1 and 2 below.

Figure 1: Comparison of PeCo 75 results with laboratory results for Hajiganj

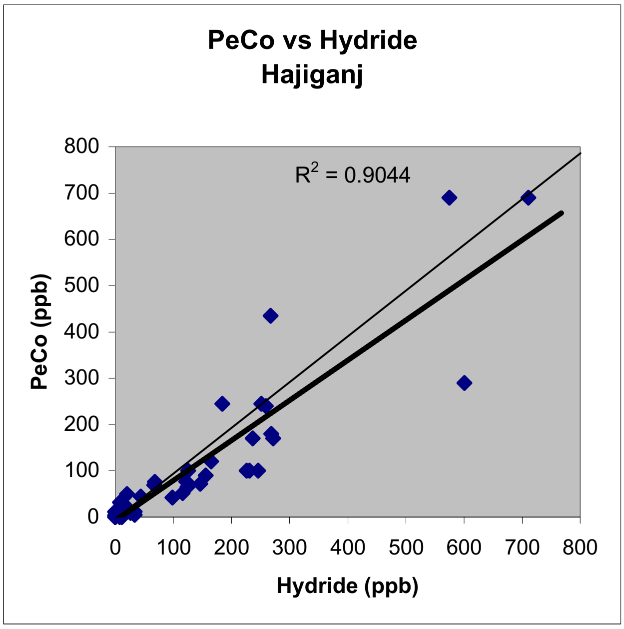


Figure 2: Comparison of PeCo 75 results with laboratory results for Iswardi

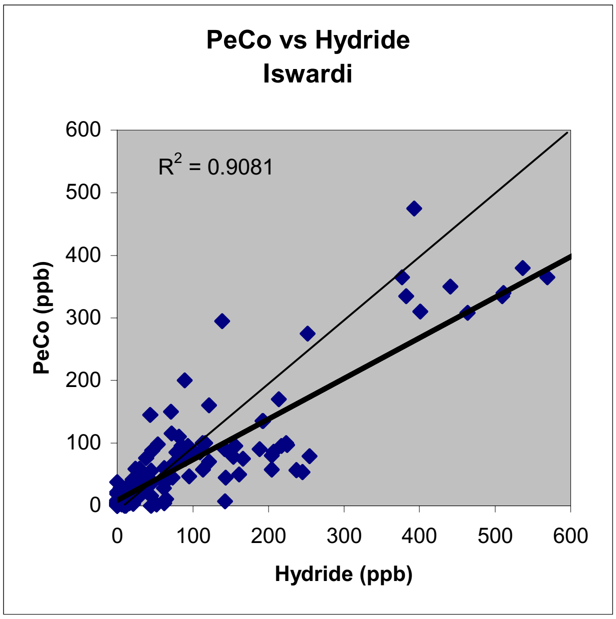
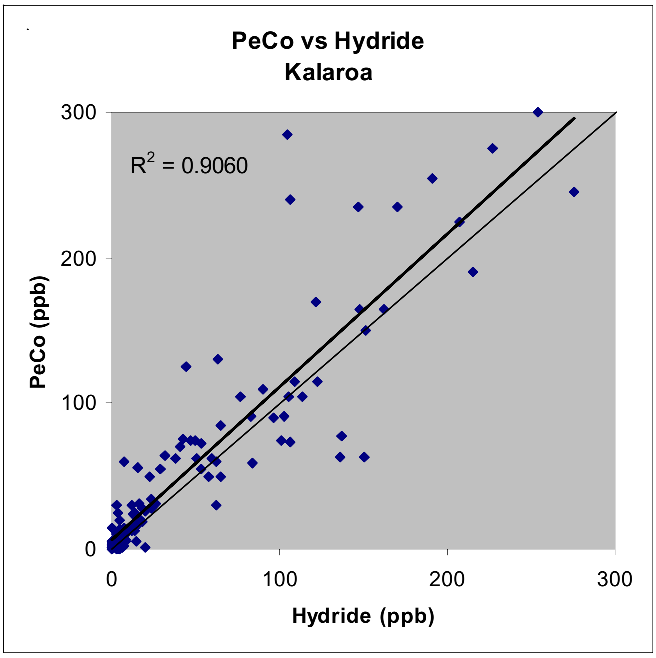


Figure 3: Comparison of PeCo 75 results with laboratory results for Kalaroa



55. The results for Sitakunda are not shown. The PeCo 75 was under-reading significantly until it was decided that 1 mL of nitric acid should be added to the samples (the sulphamic acid tablets were not reducing the pH sufficiently due to the relatively high alkalinity in the groundwater). After this the PeCo 75 performed adequately against ICP data for the wells.

56. In Hajiganj, Iswardi and Kalaroa, the correlation is about 0.9 and in Hajiganj and Iswardi,the PeCo 75 has a tendency to read a little bit low. This is particularly the case once arsenic concentrations get to more than 100ppb.

Arsenic removal by the technologies

57. The results are set out below on one page for each technology, with four tables (one for each area) showing average arsenic concentrations into and out of the technologies (raw and treated) on an average basis for each well. The results are set out for the technologies in alphabetical order.

58. The average treated water figure at each well is the mean of 12 treated waters for the technology at each well. This is made up of samples from four treated waters for each of the three replicates for each of the technologies.

59. For each technology the results are presented in tabular format and any comments relating to the results are listed below the tables

60. All of the other technologies were, on the whole successful. In particular, the Alcan enhanced activated alumina and BUET activated alumina filters, Sono 3-kolshi, and Stevens Institute performed consistently well in all locations. The GARNET was also consistent and, whilst not taking arsenic to the low levels of the others mentioned before, passed the 50ppb threshold on all but two occasions.

61. The Tetra Hedron also performed well on the whole with reductions well below 50ppb at 14 of the 20 wells. However, there were some wells, particularly in Hajiganj and Sitakunda, where performance was poor. There appears to be no immediately discernable reason why this should be. Performance appeared not to be linked to levels of arsenic in the groundwater or to individual non-arsenic parameters within the groundwater. This is perplexing and the manufacturers in the United States have been invited to comment. Raw data will be supplied if required.

NOTE:

The results are based on a data set, made up of laboratory results for Sitakunda and Hajiganj, and on PeCo 75 results for Iswardi and Kalaroa.

Out of the database, containing over 2200 data points for feed and treated arsenic concentrations, approximately 3% are anomalous data points. These anomalies are being tracked through the quality control procedures to see if they are genuine errors or outliers and reasons for the outliers will be researched and commented upon. None of the anomalous data significantly affects the overall results for each of the technologies.

Alcan Enhanced Activated Alumina

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	207	32	11	12	100%
2	423	33	1	2	100%
3	271	21	17	13	100%
4	172	35	6	6	100%
5	81	26	6	7	100%
Sitakunda	231	118	8	8	100%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	227	54	9	11	100%
2	621	76	16	18	92% *
3	263	45	11	9	100%
4	301	75	7	8	100%
5	603	37	5	7	100%
Hajiganj	403	181	10	6	98%

* 1 sample fractionally above 50ppb

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	174	67	4	4	100%
2	121	25	3	1	100%
3	71	26	1	2	100%
4	89	5	5	1	100%
5	402	65	2	2	100%
Iswardi	159	118	3	3	100%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	175	7	1	1	100%
2	295	32	2	3	100%
3	246	33	1	4	100%
4	159	26	5	3	100%
5	95	5	1	2	100%
Kalaroa	211	85	2	2	100%

- On average, the Alcan passed the 50ppb threshold comfortably at all wells in all areas.
- There were only two wells in Hajiganj and one in Sitakunda where mean treated water arsenic concentrations were above 10ppb.

Ardasha Filter

Sitakunda					
Well	Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
1	268	71	235	29	0%
2	464	95	332	36	0%
3	311	69	239	88	8%
4	141	57	130	54	9%
5	96	67	66	18	25
Sitakunda	256	146	199	198	8%

Hajiganj					
Well	Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
1	227	25	146	39	0%
2	585	44	376	109	0%
3	174	101	164	24	0%
4	270	39	193	87	17%
5	673	91	366	110	0%
Hajiganj	394	215	251	108	3%

Iswardi					
Well	Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples Passed
1	204	96	91	25	0%
2	133	47	51	19	42%
3	64	8	58	18	33%
4	101	24	56	15	25%
5	365		50	11	50%
Iswardi	173	115	61	61	30%

Kalaroa					
Well	Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples Passed
1	161	17	63	27	25%
2	258	47	121	31	0%
3	252	59	97	56	0%
4	183	28	53	15	25%
5	85	7	86	33	17%
Kalaroa	174	76	84	29	13%

- At no well did the Ardasha filtered, on average, take the arsenic concentrations below 50ppb.
- Where the raw water arsenic concentrations were less than 100ppb, such as in Iswardi, the Ardasha got close to the 50ppb threshold, on average.

BUET Activated Alumina

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	213	22	3	6	100%
2	455	94	4	6	100%
3	304	66	19	14	92%*
4	123	30	6	10	100%
5	107	73	4	6	100%
Sitakunda	240	141	7	7	98%

* 1 sample fractionally above 50ppb

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	253	35	7	12	100%
2	627	59	22	37	82% *
3	251	22	6	12	100%
4	274	44	2	4	100%
5	607	47	3	5	100%
Hajiganj	410	182	8	11	97%

* 3 Outliers at Well 2 yet to be explained

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	188	83	2	1	100%
2	126	50	3	1	100%
3	67	16	3	4	100%
4	100	44	4	2	100%
5	397	71	3	5	100%
Iswardi	164	120	3	3	100%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	171	19	2	2	100%
2	275	21	2	2	100%
3	227	28	2	4	100%
4	173	39	4	2	100%
5	90	16	2	1	100%
Kalaroa	188	65	2	1	100%

- On average, the BUET activated alumina filter passed the 50ppb threshold comfortably in all areas and at all wells.
- There were only two wells, one in Hajiganj and one in Sitakunda, where mean treated water arsenic concentrations were above 10ppb.

DPHE/Danida 2-bucket

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated Mean**	**Treated Std. Dev**	**% samples Passed**
1	265	77	227	46	0%
2	466	49	151	34	0%
3	266	101	41	24	50%
4	175	61	14	21	92%
5	73	37	20	21	91%
Sitakunda	249	144	92	90	46%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	206	39	105	37	8%
2	548	79	130	58	0%
3	224	68	100	37	8%
4	325	19	134	36	0%
5	620	61	210	61	0%
Hajiganj	385	178	136	60	3%

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	149	71	36	15	83%
2	119	23	44	12	75%
3	67	16	25	10	100%
4	100	44	12	7	100%
5	369	81	54	24	42%
Iswardi	161	118	34	20	80%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	186	37	85	28	8%
2	263	21	76	12	0%
3	235	39	163	27	0%
4	227	28	76	24	17%
5	90	16	75	19	0%
Kalaroa	178	63	95	41	5%

- The DPHE/Danida 2-bucket performed adequately in Iswardi and at three wells in Sitakunda. In other areas the performance was not as good.
- Early analysis has failed to identify why this should be, see Appendix 5 for correlation graphs. Further work will be carried out during Phase II to identify influences.
- It should be stated that DPHE/Danida requested that the water should be left to stand for four hours, not two hours as stated in the instruction booklet. This request was turned down as it was presented after mobilisation to the field. Technologies were tested on an ‘as delivered’ basis and this change would have required major changes to the field testing programme. The increased waiting time will be applied in Phase II.

GARNET Homemade Filter

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	268	71	174	62	0%
2	455	94	15	20	92%
3	311	69	68	98	67%
4	141	57	18	19	92%
5	96	67	7	6	100%
Sitakunda	254	144	54	56	71%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	227	25	66	40	33%
2	610	79	176	99	8%
3	196	75	27	20	83%
4	300	53	38	26	83%
5	646	93	22	24	83%
Hajiganj	410	201	66	61	58%

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	204	96	20	11	100%
2	130	47	22	11	100%
3	62	9	59	27	50%
4	101	24	23	5	100%
5	365		29	7	100%
Iswardi	172	116	30	30	90%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	161	17	28	7	100%
2	264	47	62	16	17%
3	235	39	16	12	100%
4	185	25	26	13	100%
5	92	19	30	12	92%
Kalaroa	192	70	32	18	81%

- On the whole, the GARNET performed steadily to bring arsenic concentrations down, on average, to below 50ppb for 75% of wells.
- There were just two wells, one in Sitakunda and one in Hajiganj where performance was particularly poor. Initial correlation analysis has not explained this (see Appendix 5).

Passive Sedimentation

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated Mean**	**Treated Std. Dev**	**% samples Passed**
1	282	59	295	112	0%
2	437	72	387	121	0%
3	292	46	314	60	0%
4	152	51	193	80	0%
5	84	45	90	36	0%
Sitakunda	249	133	259	135	0%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated Mean**	**Treated Std. Dev**	**% samples Passed**
1	282	59	295	112	0%
2	610	79	506	78	0%
3	226	91	209	97	0%
4	283	57	287	72	0%
5	622	79	594	92	0%
Hajiganj	396	187	367	177	0%

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated Mean**	**Treated Std. Dev**	**% samples Passed**
1	204	96	128	34	0%
2	133	47	119	25	0%
3	64	8	66	14	17%
4	94	28	109	44	0%
5	365		327	18	0%
Iswardi	172	117	150	97	3%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated Mean**	**Treated Std. Dev**	**% samples passed**
1	161	17	166	44	0%
2	258	47	231	50	0%
3	235	39	244	35	0%
4	185	25	160	51	0%
5	94	16	98	14	0%
Kalaroa	172	74	175	69	0%

- At none of the wells did passive sedimentation, on average, bring arsenic concentrations below 50ppb over a 12 hour period

Sono 3-kolshi

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated Mean**	**Treated Std. Dev**	**% samples Passed**
1	226	39	28	17	92%
2	463	47	11	10	100%
3	309	59	23	9	100%
4	204	39	10	7	100%
5	65	36	9	10	100%
Sitakunda	253	138	16	16	98%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	219	38	7	3	100%
2	287	201	17	17	92%
3	205	95	21	17	92%
4	312	46	7	10	100%
5	613	82	16	17	92%
Hajiganj	324	185	15	8	95%

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	148	69	4	4	100%
2	110	27	12	7	100%
3	72	26	11	4	100%
4	*	*	*	*	*
5	*	*	*	*	*
Iswardi	110	51	9	6	100%

* Kolshis damaged during transport from Hajiganj to Iswardi, only three wells used

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	186	37	7	3	100%
2	269	51	14	7	100%
3	220	47	16	2	100%
4	203	14	16	7	100%
5	91	14	13	6	100%
Kalaroa	199	64	13	5	100%

- The Sono 3-kolshi method performed consistently well throughout, on average, passing the 50ppb threshold at all wells where it was tested.

Stevens Institute Technology

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	265	77	26	28	75%
2	453	28	1	3	100%
3	314	52	13	11	100%
4	167	56	8	12	100%
5	78	22	3	6	100%
Sitakunda	255	137	10	17	95%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	225	34	37	18	67%
2	545	76	5	11	100%
3	216	120	23	35	92%
4	295	41	28	31	75%
5	629	72	2	4	100%
Hajiganj	391	184	19	26	87%

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	149	71	6	5	100%
2	116	24	3	1	100%
3	79	26	5	5	100%
4	93	6	8	12	100%
5	335		11	6	100%
Iswardi	154	99	6	5	100%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	184	37	10	4	100%
2	116	24	9	4	100%
3	285	77	16	7	100%
4	144	59	10	8	100%
5	85	9	3	3	100%
Kalaroa	171	81	9	7	100%

- The Stevens Institute Technology performed consistently well throughout, on average, reducing arsenic to below 50ppb at all wells tested.

Tetra Hedron

Sitakunda					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	259	72	55	54	58%
2	444	22	98	104	33%
3	311	53	18	15	92%
4	161	49	5	13	100%
5	62	18	61	118	83%
Sitakunda	**247**	138	47	47	73%

Hajiganj					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	243	45	72	55	42%
2	545	76	220	135	8%
3	247	22	10	6	100%
4	246	104	54	74	67%
5	664	82	63	71	67%
Hajiganj	**396**	194	84	79	57%

Iswardi					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples Passed**
1	173	68	7	4	100%
2	114	26	5	3	100%
3	79	26	3	3	100%
4	89	5	8	3	100%
5	405	81	15	12	100%
Iswardi	**172**	130	7	7	100%

Kalaroa					
Well	**Feed Mean**	**Feed Std. Dev**	**Treated mean**	**Treated Std. Dev**	**% samples passed**
1	166	19	9	6	100%
2	269	20	29	18	83%
3	283	79	5	5	100%
4	144	59	17	17	92%
5	85	9	16	11	100%
Kalaroa	**201**	83	16	11	95%

- The Tetra Hedron generally performed well, reducing arsenic concentrations to below 50ppb at 14 of the 20 wells and getting very close at another two.
- Performance at Sitakunda and Hajiganj was extremely variable, as demonstrated by the high standard deviations. It is not clear what is causing this volatility. The manufacturers have been contacted and dialogue is being held with them to try and ascertain the reasons for the volatile performance.

Aluminium and manganese in treated waters

62. Aluminium and manganese were tested for in the treated waters of the DPHE/Danida 2-bucket and BUET activated alumina technologies. Aluminium only was tested for in the Alcan enhanced activated alumina. The results are presented on an area by area basis below in Tables 3 to 6 below. More detailed discussion of these results is presented in Appendix 4c.

63. It is evident that at a number of wells in each of the four areas, an increase in the concentrations of aluminium or manganese or both occurs in the water which passes through the DPHE/Danida technology replicates. This increase occasionally results in an exceedence of the guideline maximum drinking water standards.

64. Mean aluminium and manganese concentrations in treated waters arising from the BUET and Alcan technologies exceed guideline concentrations on only one or two occasions. However the cause of exceedence is high concentrations in the feed water except on one occasion where Alcan appears to give rise to the exceedence (aluminium, Well 3, Kalaroa).

Table 3: Aluminium and manganese in treated waters - Sitakunda

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	0.37	0.03	0.08
	2	BDL	0.17	0.23	0.15
	3	BDL	0.18	0.13	0.12
	4	BDL	BDL	1.16	0.54
	5	BDL	BDL	0.27	0.12
BUET	1	BDL	0.06	0.03	0.01
	2	BDL	BDL	0.23	BDL
	3	BDL	BDL	0.13	0.01
	4	BDL	0.05	1.16	0.01
	5	BDL	0.10	0.27	0.03
ALCAN	1	BDL	BDL		
	2	BDL	BDL		
	3	BDL	BDL		
	4	BDL	BDL		
	5	BDL	BDL		

Table 4: Aluminium and manganese in treated waters - Hajiganj

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	0.17	0.09	0.32
	2	BDL	0.06	0.04	0.08
	3	BDL	0.28	0.13	1.02
	4	BDL	BDL	0.12	0.41
	5	BDL	0.38	0.03	0.19
BUET	1	BDL	BDL	0.09	0.06
	2	BDL	BDL	0.04	BDL
	3	BDL	BDL	0.13	0.04
	4	BDL	BDL	0.12	0.04
	5	BDL	BDL	0.03	BDL
ALCAN	1	BDL	BDL		
	2	BDL	BDL		
	3	BDL	BDL		
	4	BDL	BDL		
	5	BDL	0.12		

Table 5: Aluminium and manganese in treated waters - Iswardi

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	BDL	0.38	0.07
	2	BDL	0.13	1.04	1.35
	3	0.06	0.33	0.24	0.45
	4	BDL	BDL	0.91	0.78
	5	BDL	BDL	0.27	1.56
BUET	1	BDL	BDL	0.38	0.04
	2	BDL	BDL	1.04	0.43
	3	0.06	BDL	0.24	0.02
	4	BDL	BDL	0.91	0.03
	5	BDL	BDL	0.27	0.07
ALCAN	1	BDL	BDL		
	2	BDL	0.06		
	3	0.06	0.05		
	4	BDL	BDL		
	5	BDL	BDL		

Table 6: Aluminium and manganese in treated waters - Kalaroa

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	0.07	0.61	0.66
	2	BDL	0.11	0.13	0.62
	3	0.17	0.36	0.10	0.65
	4	BDL	BDL	0.12	0.81
	5	BDL	BDL	0.20	0.60
BUET	1	BDL	BDL	0.61	0.15
	2	BDL	BDL	0.13	0.02
	3	0.17	0.11	0.10	0.03
	4	BDL	BDL	0.12	0.03
	5	BDL	BDL	0.20	0.01
ALCAN	1	BDL	BDL		
	2	BDL	BDL		
	3	0.17	0.24		
	4	BDL	BDL		
	5	BDL	BDL		

CONCLUSIONS AND RECOMMENDATIONS

65. In most cases, the results from this study support the claims of the manufacturers in that they do indeed remove arsenic from groundwater such that treated water is below 50ppb. The only technologies which did not perform to a high standard were passive sedimentation and the Ardasha filter. It may be that in areas with very high iron concentrations and arsenic concentrations below 100ppb, they may still have a role to play. Active sedimentation, rather than passive sedimentation has also been put forward as a possible improvement to this cheap and easy approach.

66. There are some unusual results for some of the technologies, particularly the Tetra Hedron and the DPHE/Danida 2-bucket system. Early analysis has not, at this stage, managed to establish why these technologies should be performing differently at different wells. For these technologies, discussions will be held with the proponents, the raw data will be examined in more detail by the scientific supervisor and reviewer, and further tests will be carried out during Phase II. Another factor that has been suggested as a key influence on the performance of arsenic removing technologies is water hardness. This will be tested in Phase II and may help to explain some of these differences.

67. This project has demonstrated that it is possible to carry out a rapid technical appraisal in a very short period of time, so long as there is sufficient time to mobilise and prepare for the field, and that sufficient human and financial resources are available. The field work was completed in four areas of Bangladesh in a three week period. It is, however, a major logistical exercise that needs thorough preparation and training.

68. The arsenic field testing kits used in this project seems to be providing adequate results. It is the first time it has been used in the field and there were, and continue to be, some minor teething problems. However, correlation with laboratory analysis suggests that the field test kit performance is adequate for an exercise such as this. At least 10% of field samples will continue to be checked in the laboratory. This level of cross checking is seen as ideal for any field testing technology.

69. Based on the criterion that all three replicates of a technology at one well or more reduce arsenic to below 50ppb, it is proposed that only seven technologies should be taken forward to Phase II. These are:

- Alcan enhanced activated alumina filter
- BUET activated alumina filter
- DPHE/Danida two bucket system
- GARNET home-made filter
- Sono 3-kolshi method
- Stevens Institute technology
- Tetra Hedron ion exchange resin filter

FURTHER ISSUES FOR ASSESSMENT IN PHASE II

70. Phase I has concentrated very much upon the technical performance of the technologies in terms of whether they reduce contaminated groundwater to below the Bangladesh Guideline Standard of 50ppb. Phase II will consider outstanding issues in this area but will concentrate on following issues:

Technical aspects

- Technical performance of the technologies regarding arsenic removal and the water chemistry parameters listed above (both for feed, and where appropriate for treated waters).
- Quantity of water produced within a 12 hour time-span.
- Consequences of incorrect usage of technologies
- Maintenance frequency (including sludge disposal and backwash drainage)
- Operational safety
  - Physical (installation, operation, replacement)
  - Chemical (including robustness under misuse, sludge disposal, backwashing)
- Environmental and health issues relating to chemicals used in the technologies and the disposal of the same
- Comparative evaluation of field testing kits.

Social aspects

- Access to tubewell water, ownership of tubewells and access to other safe drinking water
- Convenience of the technology (time and effort, flow rates, frequency of maintenance)
- Acceptability on grounds of odour and taste of treated water
- Ease of adoption, application and maintenance
- Affordability
  - Costs (capital and recurrent)
  - Willingness and ability to pay for technologies
  - Organisation required to manage cost-recovery (if community system)
- Gender issues
  - share of workload in water collection and technology maintenance
  - ergonomic design

71. In addition, the following issues will be considered in consultation with the users, the proponents, and potential implementing agencies:

- Level of interest in arsenic removal and other mitigation technologies (other priorities for household?)
- Level of detail required for explanation of use (also refers to ease of adoption), communication materials and methods (household v. mass media)
- Infrastructure requirements in terms of logistical support for spare parts and reagents.

RAPID ASSESSMENT OF HOUSEHOLD LEVEL ARSENIC REMOVAL TECHNOLOGIES

Appendices of Phase I - Final Draft Report

January 2001

WS Atkins

DFID/BAMWSP/WaterAid Bangladesh

Appendix 1	**Technology Descriptions**
Appendix 2	**Field Testing Procedures**
Appendix 3	**Quality Control Measures**
Appendix 4	**Results**
Appendix 5	**Arsenic v Non-arsenic correlations**
Appendix 6	**Waste Disposal Issues – A Preliminary Review**

APPENDIX 1

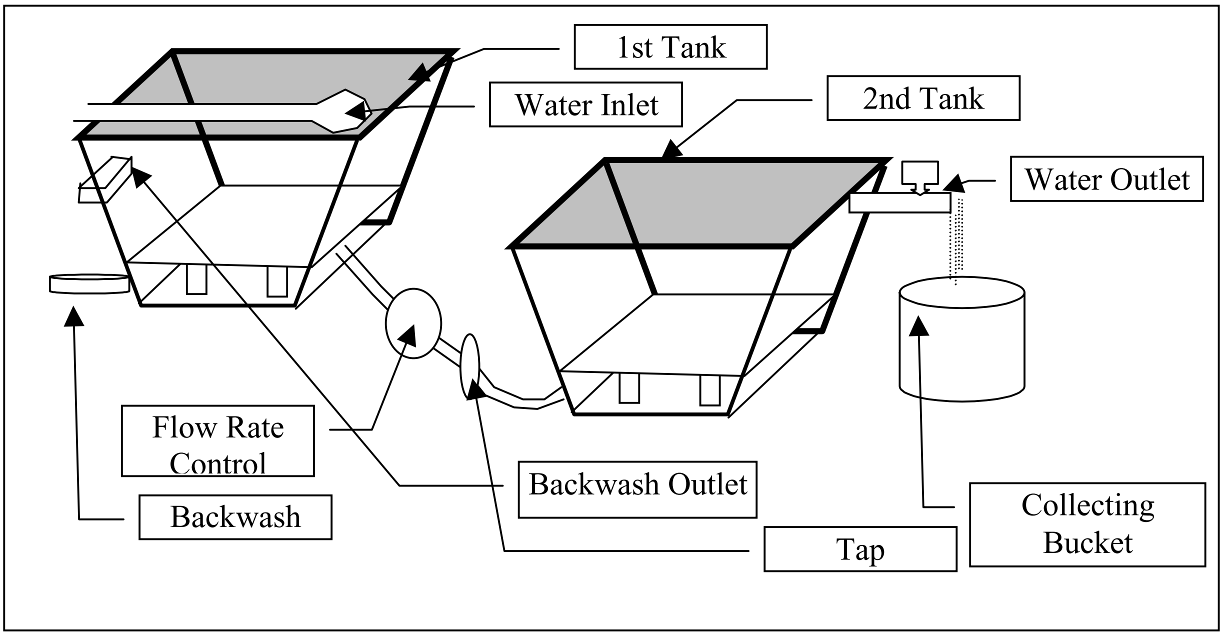
TECHNOLOGIES

ACKNOWLEDGEMENT

Thanks go to Ahammadul Kabir for the diagrams and the operating instructions.

ALCAN ENHANCED ACTIVATED ALUMINA FILTER

TECHNOLOGY	ALCAN ENHANCED ACTIVATED ALUMINA FILTER
Process	Sedimentation, filtration, actived alumina (AAFS-50)
Chemical controls	Semi-reversible adsorption to Al_2O_3 Arsenite removal occurs (through oxidative step- chlorine)
Physical controls	Formulae to calculate bed-volumes to exhaustion (for 0.1mg/l AsO_4, 15000 bed volumes) Potentially prone to clogging by FeOH
Operating procedure	Usually attached to well head and pump directly into the filter
Flow rate - low turbidity - high turbidity	>300 litres per hour >300 litres per hour
Time for 20 litres to pass	3-5 minutes
Litres in 12 hours	>3600 litres
Batches before deterioration - low turbidity - high turbidity	 No deterioration No deterioration
Claims on effectiveness (Results and references)	Studies by Department of Chemistry, Dhaka University, and BRAC (Sonargaon) show a removal rate of 100%.
Costs (capital and recurrent)	US$500 (US$200 for the unit and US$300 for the material (5 year warranty, expected life 10 years). Annual filter material costs US$300. Costs could fall if demand is high.
Contact details	M. Saber Afzal, MAGC Technologies Ltd, House 15, Road 5' Dhanmondi, Dhaka-1205. E-mail: mendota@bdmail.net



1. SETUP
Set up the unit according to the flow diagram.

2. FILLING AND OPERATION
Pour tubewell water into the water inlet hole in the first tank. Open the Tap in the middle of two tanks. Open the tap in the water outlet. Collect water.

3. PROBLEMS AND ANSWER
During flow rate testing it is observed that water leaks from all of the joints, if it happens tight all the joints properly

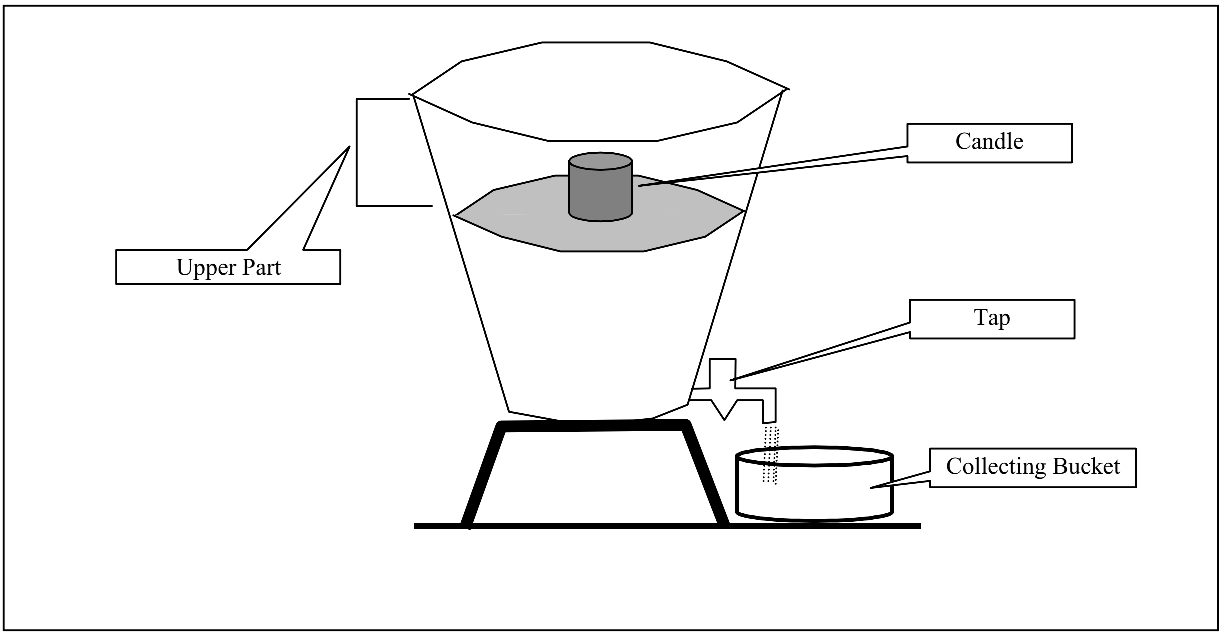
4. MAINTENANCE
There is no indication of time of backwash. But it is well to backwash every five days.

5. DECONSTRUCTION
Open all the joints and pipes.

6. CAUTION
Avoid contamination of the filtered water from leakage.

ARDASHA


TECHNOLOGY	**Ardasha**
Process	Filtration
Chemical controls	Unkown
Physical controls	Character and flow rate through filter
Operating procedure	Pour water into tray within bucket. Use tap to get treated water from bottom of bucket.
Flow rate - low turbidity - high turbidity	1.1 litres per hour 1.1 litres per hour
Time for 20 litres to pass	19 hours
Litres in 12 hours	13 litres
Batches before deterioration - low turbidity - high turbidity	 No deterioration in 15 batches No deterioration in 15 batches
Claims on effectiveness (Results and references)	DPHE R& D have done some assessment and think it reduces As below 50ppb. They are not sure why.
Costs (capital and recurrent)	Tk. 550
Contact details	Mr. Sounir Mojumdar, CRS-Ardasha Filter Industries, Chagalnaya Bazar, Chagalnaya, Feni



1. SETUP
Place the Filter in appropriate position (some height from the ground so that the tap should not be disturbed)

2. FILLING AND OPERATION
Pour tubewell water at the upper part of the filter (approx. 10lit). Open the tap and collect water. Maintain the level of water in the upper part of the top of the filter

3. PROBLEMS AND ANSWER
No problem was found during flow rate testing.

4. MAINTENANCE
Clean the candle of the filter every seven days by rubbing with hand and the unclean water should be thrown in a cowdung pit.

5. DECONSTRUCTION
Nothing to be deconstructed.

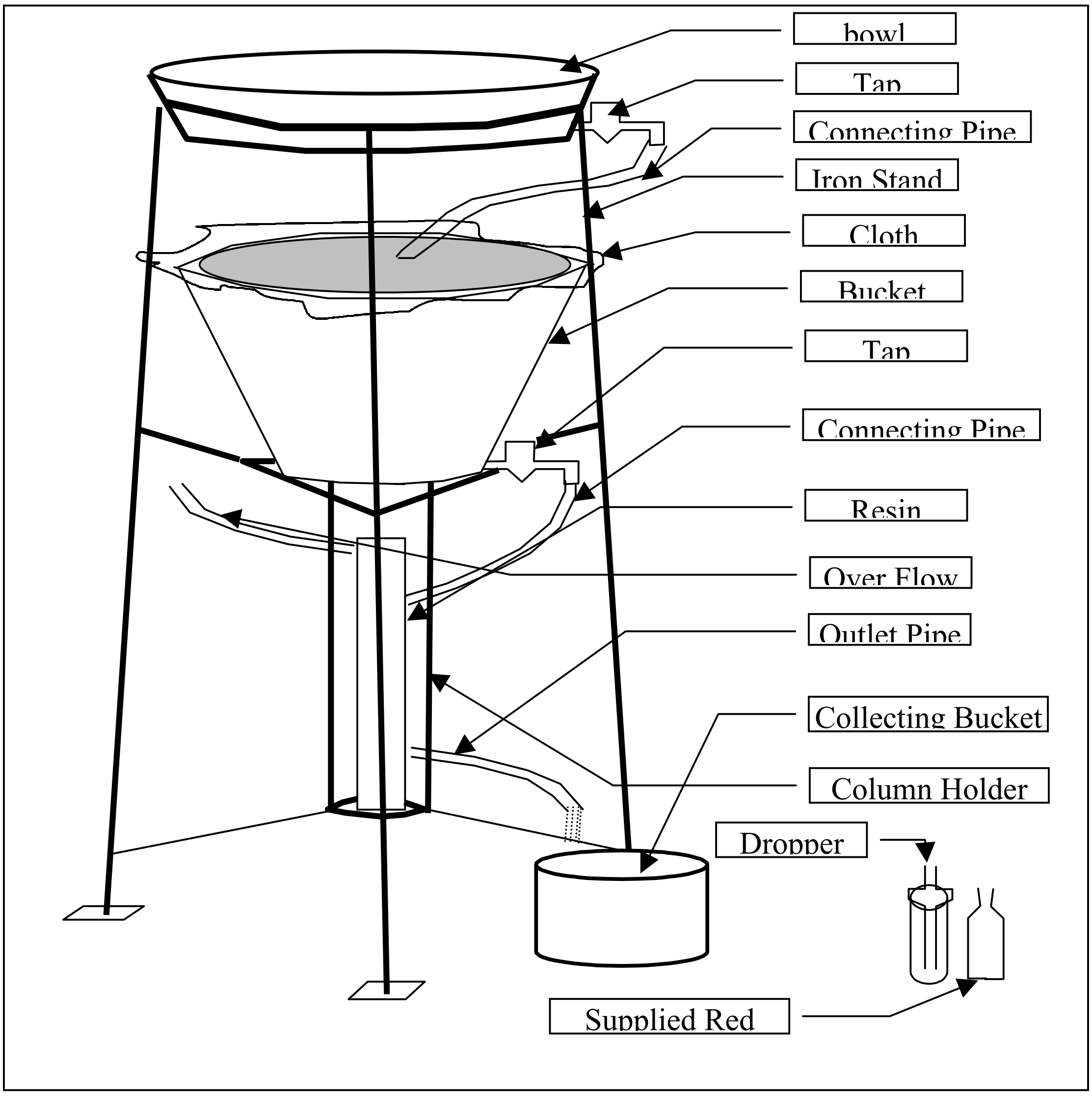
6. CAUTION
Handle carefully, so that the tap and the candle is not disturbed.

BUET ACTIVATED ALUMINA FILTER

TECHNOLOGY	**BUET ACTIVATED ALUMINA**
Process	Oxidation, sedimentation, filtration, actived alumina
Chemical controls	Semi-reversible adsorption to Al_2O_3 Arsenite removal occurs (through oxidative step)
Physical controls	Formulae to calculate bed-volumes to exhaustion (for 0.1mg/l AsO_4, 15000 bed volumes) Potentially prone to clogging by FeOH
Operating procedure	Fill top bucket and add chemicals as directed. Stir vigorously and leave for one hour. Turn tap to allow water into the activated alumina column. Retrieve water from bottom of column.
Flow rate - low turbidity - high turbidity	Approx. 8 litres per hour Approx. 8 litres per hour
Time for 20 litres to pass	Approx. 2.5 hours
Litres in 12 hours	Approx. 96 litres
Batches before deterioration - low turbidity - high turbidity	 Steady gentle deterioration (<10% over 15 batches) Steady gentle deterioration (<10% over 15 batches)
Claims on effectiveness (Results and references)	
Costs (capital and recurrent)	Tk. 1000/-
Contact details	Dr. M.A. Jalil, Department of Civil Engineering, BUET, E:mail: majalil@buet.edu

1. SETUP

Place the stand in the appropriate position. Insert the column to the column holder very carefully without disturbing the pipes. Place the bucket containing the coarse sand in the middle of the stand. Join the connecting pipe to the tap of the bucket. Place the cloth over the bucket and put the lid on top. With the help of another connecting pipe join the bowl tap to the top of the bucket cover hole. Tie the overflow pipe to the stand with a rope.



2. FILLING AND OPERATION

Pour 16lit of tubewell water to the bowl (If there is a red mark then pour water according to that level). Add 1ml of the supplied red solution with the help of the graduated dropper (supplied). Stir and mix. (approx. 30-40 times) Wait for 1 hour.

After 1 hour open the tap fitted in the bowl then the tap in the bucket and collect water in collecting bucket through the outlet pipe. All the taps should be opened very carefully and slowly so that no water can come out from the overflow pipe. When water stops in the outlet pipe close all the two taps. Everyday clean the cloth and dry.

3. PROBLEMS AND ANSWER

No problem was found during flow rate testing.

4. MAINTENANCE

Clean the cloth and the bowl everyday with tubewell water.

5. DECONSTRUCTION

Remove the bowl first and keep in the appropriate position so that the tap is not disturbed. Next, remove the bucket from stand very carefully without disturbing the tap. and finally remove the resin column without disturbing the pipe and keep it in the safe position.

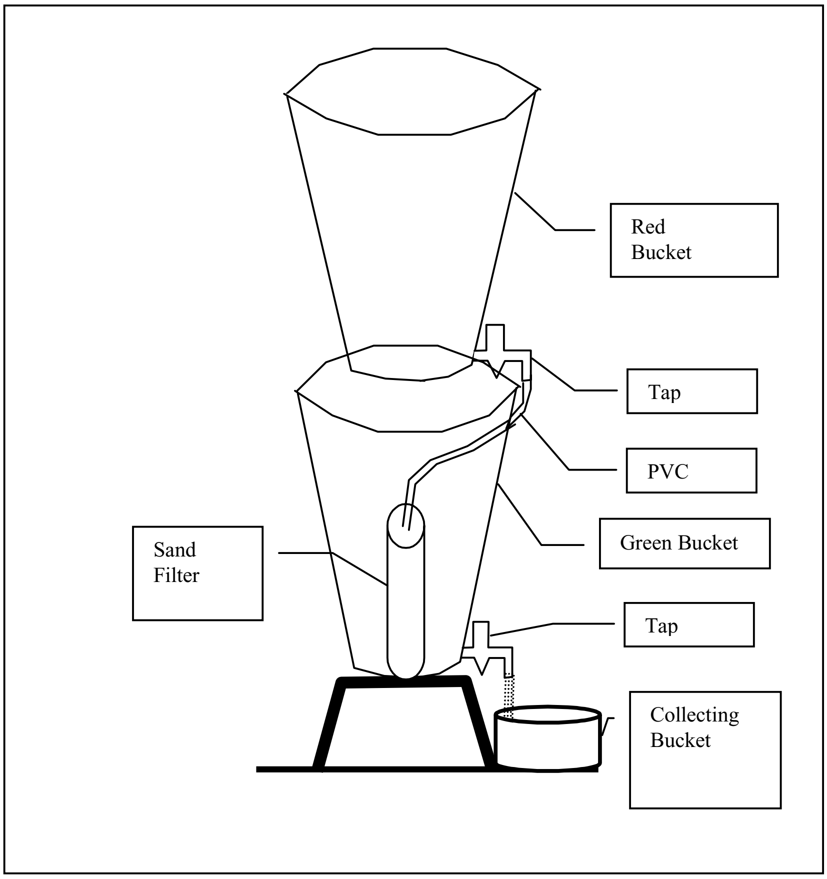
6. CAUTION

Do not create pressure on the taps during opening and closing. Handle carefully the resin column so that the pipes are not disturbed.

DPHE/DANIDA BUCKET TREATMENT UNIT

TECHNOLOGY	**DPHE/Danida Bucket Treatment Unit**
Process	Oxidation/coagulation/flocculation/filtration
Chemical controls	Relies on enhanced coagulation Less dependent upon groundwater Fe Chemical oxidant enhances arsenite removal PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact Ideal pH 6.5 to 8 for optima functioning of alum Possible residual Mn
Physical controls	Agitation and duration of coagulation Sand packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Pour water into the top bucket. Add mixture of aluminium sulphate and potassium permanganate and stir vigorously 20 times. Leave to settle for 2 hours. Turn tap to send water to lower bucket where it passes through a sand filter. Turn tap in bottom bucket to get drinking water.
Flow rate - low turbidity - high turbidity	70 litres per hour (but 23 l/hr including 2 hours preparation) 50 litres per hour (but 17 l/hr including 2 hours preparation)
Time for 20 litres to pass	Approx. 3 hours (1 hour settling + 1 hour filtration)
Litres in 12 hours	Approx. 240 litres
Batches before deterioration	- low turbidity 17 batches – no deterioration - high turbidity 40% fall in flow after 6 batches, then constant to 15 batches

Examples of claims on effectiveness (Results and references)	Noakhali – 100% As below 50ppb after treatment (initial levels 120-1000ppb.) DPHE/Danida Arsenic Mitigation Pilot Project Information leaflet 'Arsenic Removal at Household Level' Sitakunda and Gomastapur – 100% As below 50ppb after treatment (initial levels 116-201 ppb) Water Aid, March 2000. Household Level Arsenic Removal Methodologies, Preliminary Research Report.
Costs (capital and recurrent)	Tk. 300-350 depending on the production cost of the flat cover for the lower bucket.
Contact details	DPHE-Danida Water Supply and Sanitation Components, Arsenic Mitigation Component, 2888, Central Road, Harinarayanpur, Maijdee Court, Noakhali. Ph. 0321 5582



1. SETUP

Fix the taps at the bottom hole of both of the buckets using washer and F-socket. Test both of the buckets for leakages by filling them with water. Place the sand filter column inside the green bucket. Connect the sand filter column with flexible pipe through the top hole of the green bucket to the outlet tap of the red bucket.

2. FILLING AND OPERATION

Follow the following procedure :

1. Fill the red bucket with the tubewell water up to 1" from the top
2. Add one level spoon of the supplied chemicals to the tubewell water in the red bucket.
3. Stir the water with supplied wooden stirrer for 30 strong circular rotation. (30 seconds)
4. Leave the water undisturbed for 2 hours.

5. Open the tap of the red bucket and allow water to flow to the green bucket. through the filter column.
6. Collect water by opening the tap of the green bucket for testing.

3. PROBLEMS AND ANSWER

The pipe which connects the tap of the red bucket to the sand filter placed in the green bucket, tie both ends of the pipe to the tap to avoid leakage.

4. MAINTENANCE

Empty Sludge from the red bucket will be disposed into a latrine or any cowdung pit.
The red bucket should be cleaned with tubewell water.
Gently open and close the Tap for avoiding linkage
When sludge observed in the green bucket remove and open the filter column and wash with tubewell water.

5. DECONSTRUCTION

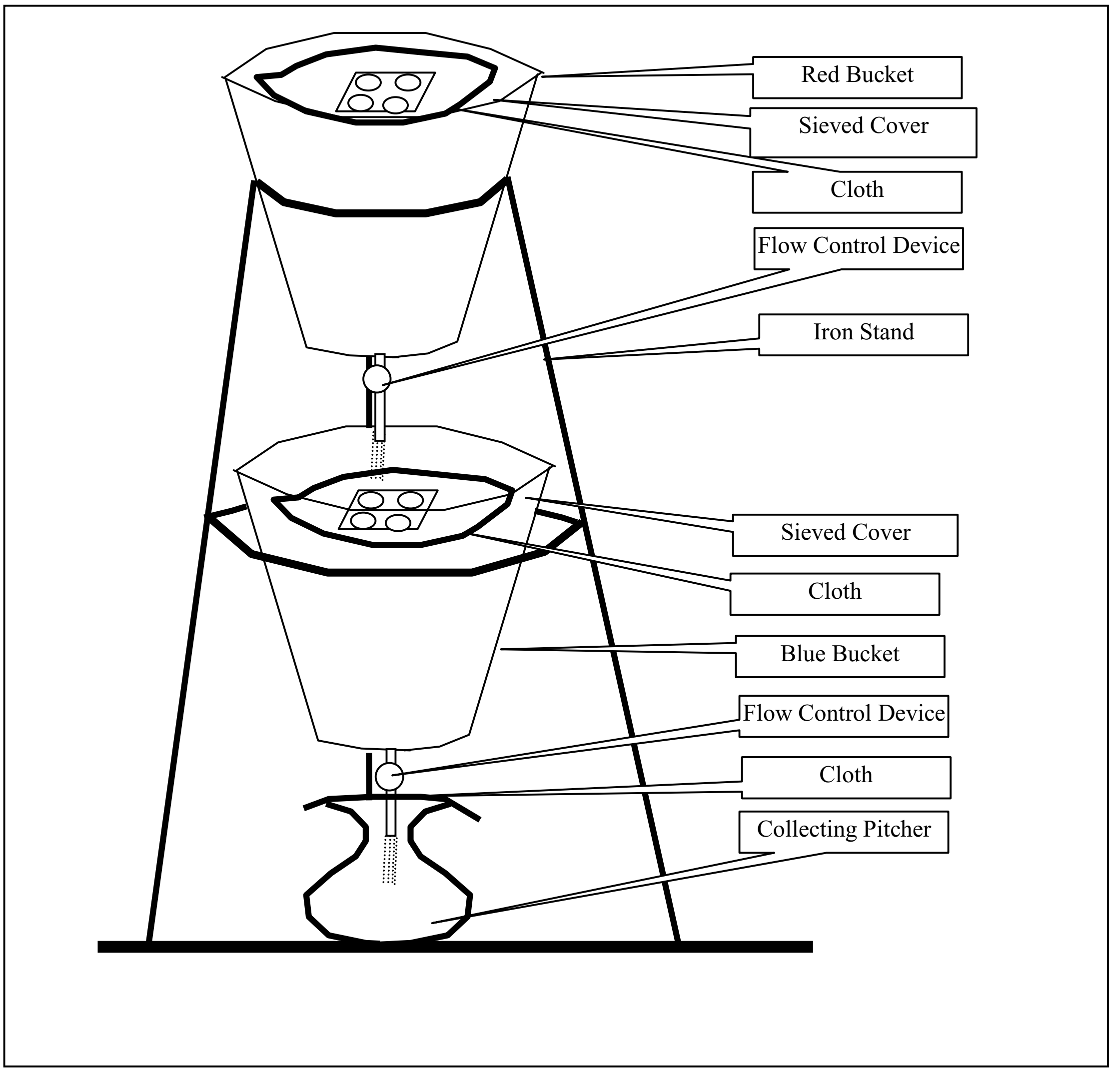
Remove the PVC pipe from the filter and the tap of the red bucket.

6. CAUTION

Handle carefully, so that the tap is not disturbed.

GARNET FILTER

TECHNOLOGY	GARNET FILTER
Process	Coagulation, adsorption and filtration
Chemical controls	Relies on passive coagulation with Fe and/or adsorption to sand matrix PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Sand packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Water frequently topped up in top bucket. Flow regulated to second bucket – regular checking required.
Flow rate - low turbidity - high turbidity	0.7 litres per hour 0.4 litres per hour
Time for 20 litres to pass	Approx. 30 hours
Litres in 12 hours	Approx. 7 litres
Batches before deterioration - low turbidity - high turbidity	 50% initial flow after 7 batches 30% initial flow after 5 batches
Claims on effectiveness (Results and references)	Removal efficiencies of 70-100% cited in GARNET's own literature, depending on the presence of As and Fe in the feed water.
Costs (capital and recurrent)	Tk.250-600 based on material for stand and containers
Contact details	Shah Monirul Kabir, Programme Officer/GARNET Secretary, GARNET-SA, 1/7, Block-E, Lalmatia, Dhaka-1207, Tel: 9117421



1. SETUP

Assemble the filter according to the above figure. Place the Blue bucket first then the red bucket. Adjust the flow rate with the help of the flow control device to approximately 200 drops per minute.

2. FILLING AND OPERATION

Pour tubewell water slowly into the sieved cover. Let the water pass through the red and blue buckets and collect water from the collecting pitcher.

3. PROBLEMS AND ANSWER

Some problems were found during flow rate testing.

1. Always keep the cloths of both of the buckets inside otherwise water can drop down to the filtered water in the collecting pitcher and presumably contamination of filtered water can occur.
2. Sometimes it is observed in the laboratory that flow control device does not work properly due to blockage. (If you open the flow control device completely then water will not come out) Then push upward very carefully with the help of a thin stick or anything like that. (with out squeezing the outlet pipe).

4. MAINTENANCE

1. Pass dilute bleaching powder solution through the system once in a week. (1 teaspoon/20 litres)
2. Mix brick chip and sands (upside down) about once in two or three days.

5. DECONSTRUCTION

Remove the red bucket first. then the blue bucket from the stand.

Do not keep the buckets to the plane ground otherwise the flow control device can the broken. Always keep it in safe position

6. CAUTION

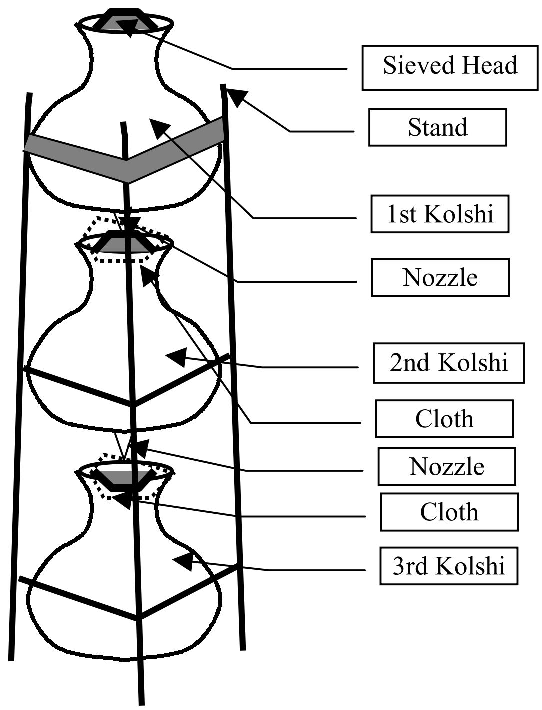
Handle carefully, so that the flow control device is not be disturbed.

PASSIVE SEDIMENTATION

TECHNOLOGY	**PASSIVE SEDIMENTATION**
Process	Sedimentation – co-precipitation with iron upon oxidation
Chemical controls	Relies on passive coagulation with iron Main control is iron in the water PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Duration of settling Final water could be contaminated by stirring Bacteriological contamination could be an issue
Operating procedure	Fill kolshi and leave to settle for over 12 hours. Pour top 2/3^{rds} for use and discard lower 1/3rd.
Flow rate - low turbidity - high turbidity	N/A N/A
Time for 20 litres to pass	12 hours (depends on size of kolshi – 12 hrs = 30l kolshi)
Litres in 12 hours	20 litres (depends on size of kolshi – 20 litres = 30l kolshi)
Batches before deterioration - low turbidity - high turbidity	 N/A N/A
Claims on effectiveness (Results and references)	2 out of 17 wells tested took As below 50ppb. Greatest influence seen was negative correlation between As removal and Electrical Conductivity. Water Aid, March 2000. Household Level Arsenic Removal Methodologies, Preliminary Research Report.
Costs (capital and recurrent)	20 litre aluminium kolhsi – approx. Tk. 200/-
Contact details	-

SONO 3-KOLSHI FILTER

TECHNOLOGY	SONO 3-KOLSHI FILTER
Process	Coagulation, adsorption, filtration
Chemical controls	Relies on passive coagulation with Fe and/or adsorption to sand matrix PO_4 > ASO_4 >> SiO_4 >F High HCO_3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Sand/iron filings/charcoal packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Pour water into top kolshi. Use water from the bottom kolshi.
Flow rate - low turbidity - high turbidity	Approx. 5 litres per hour Approx. 5 litres per hour
Time for 20 litres to pass	Approx. 4 hours
Litres in 12 hours	Approx. 60 litres
Batches before deterioration - low turbidity - high turbidity	 15 batches with no major deterioration 15 batches with no major deterioration
Claims on effectiveness (Results and references)	As (III) from 800ppb to less than 50ppb (2ppb) As (total) from 1100ppb to less than 50ppb (10ppb) A.H.Khan et al, 'Appraisal of a Simple Arsenic Removal Method for Groundwater of Bangladesh', Journal of Environmental Science and Health, A35(7), 1021-1041 (2000)
Costs (capital and recurrent)	Tk. 325/-
Contact details	Professor A.H. Khan, Department of Chemistry, University of Dhaka, Dhaka-1000, E-mail: ahkhan@du.bangla.net Dr. A.K.M. Munir, Director, SDC-Environment Initiative, College More, Courtpara, Kushtia 7000



1. SETUP

Install the system according to the figure. Place the second kolshi first (ingredients of this kolshi are fine sand and charcoal). Then place the second kolshi (ingredients of this kolshi are iron filing and coarse sand). Place the 3rd kolshi. The 3rd kolshi is the collecting vessel of the filtered water. There are three heads. Put the sieved head on the 1st kolshi, another to the second kolshi covering with the supplied polyester cloth and in the same way of the second to the third kolshi.

2. FILLING AND OPERATION

Pour water on the top kolshi and let it percolate through. Collect water from the 3rd kolshi. Do not use the first two batch of water after installation. The water in the bottom kolshi should be crystal clear.

3. PROBLEMS AND ANSWER

Some times it is observed that the nozzle on the first kolshi and the second are blocked by particle and consequently the flow rate is decreased. If it happens clear it by pushing upward with a thin stick (e.g., pin, needle etc.) If it does not work then cut a very small amount with a sharp knife.

4. MAINTENANCE

Clean the heads and all of the cloths every five days. If any leakages are found on the kolshi then stop it by calcium, wax or cement. Clean the nozzles (which is called free flow junction) every five days. If the water of the bottom kolshi (filtered water collecting kolshi) is cloudy then the sand layer shall have to be replaced.

5. DECONSTRUCTION

Remove all the heads and the cloths from all of the kolshis. Then 1st kolshi and second kolshi from the stand. Do not keep 1st and 2nd kolshis on a plane ground because there is a nozzle at the bottom of these kolshis. Place the kolshis appropriate position so that the nozzle is not disturbed.

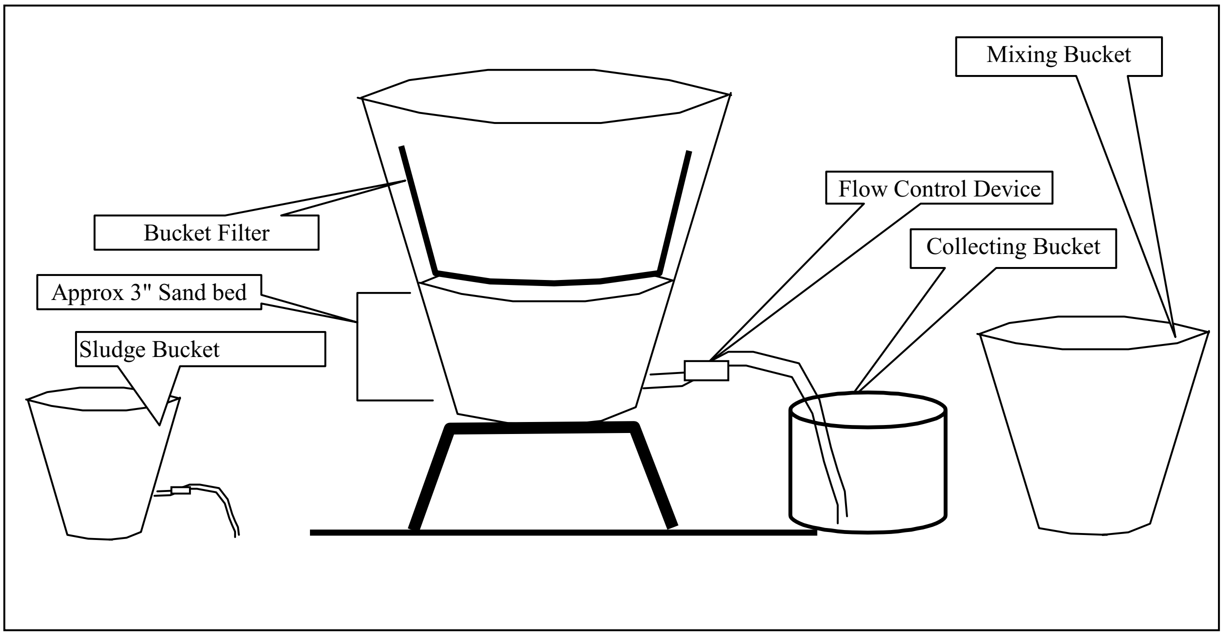
6. CAUTION

Handle carefully, all of the parts of this filtration system is earthen.

STEVEN'S INSTITUTE TECHNOLOGY

TECHNOLOGY	STEVENS INSTITUTE TECHNOLOGY
Process	Coagulation/filtration
Chemical controls	Relies on enhanced coagulation and co-precipitation (ferrous suphate) Less dependent upon groundwater Fe Chemical coagulant (ferric chloride) enhances arsenite removal PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Sand cleaning and packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Collect 20 l in a bucket, add chemicals and stir rapidly for a minute. Pour into filter (bucket with holes on top of sand in larger bucket) and wait for water.
Flow rate - low turbidity - high turbidity	18 litres per hour 18 litres per hour
Time for 20 litres to pass	Just over one hour
Litres in 12 hours	Approx. 240 litres
Batches before deterioration - low turbidity - high turbidity	 Steady decline to 50% initial flow after 10 batches Steady decline to 50% initial flow after 10 batches
Claims on effectiveness (Results and references)	Kachua - less than 50ppb As in treated water (max. 25ppb) from initial As concentrations of 300-800ppb). BAMWSP testing programme

	Kishoreganj and Munshiganj – max. As was 19ppb from initial untreated concentrations of 280-468ppb. Xiaoguang Meang and George P. Korfiatis, 'Removal of Arsenic from Bangladesh Well Water by the Stevens Technology for Arsenic Removal (STAR)'. Occasional Paper.
Costs (capital and recurrent)	Tk 500/-
Contact details	Professor Meng, Center for Environmental Engineering, Stevens Institute of Technology, Hoboken, NJ 07030. E-mail: xmeng@stevens-tech.edu Md. Suruzzaman, Earth Identity Project, House 13A, Road 35, Gulshan, Dhaka-1212. Tel: 8812049



1. SETUP

Place the filter unit in appropriate position (some height from the ground). Put bucket filter on the top of the sand bed.

2. FILLING AND OPERATION

Take 20lit of tubewell water in the mixing bucket. Add one bag supplied material to the mixing bucket. Stir for one minute for mixing with help of the supplied plastic rod. After mixing take water form the mixing bucket with the help of a mug and pour into the bucket filter. Open the flow control device and collect water in the collecting bucket. After collection transfer the waste water of the bucket filter to the sludge bucket.

3. PROBLEMS AND ANSWER

No problem was found during flow rate testing.

4. MAINTENANCE

After every 5th batch, the sand should be cleaned according to the following procedure.

Transfer the sand into the bucket. Add some amount of the ground water to the bucket. Add one spoon cleaning reagent. Stir and mix. Decant the water from the bucket. Follow the same procedure for four times with the ground water. Place all the sand again to the filter unit and then the bucket filter. Now the system is ready for filtration.

When the sludge water settles down in sludge bucket, open the tap and decant the water from the top with the help of the tap. Keep the sludge there. The people of Steven's will collect the sludge.

5. DECONSTRUCTION

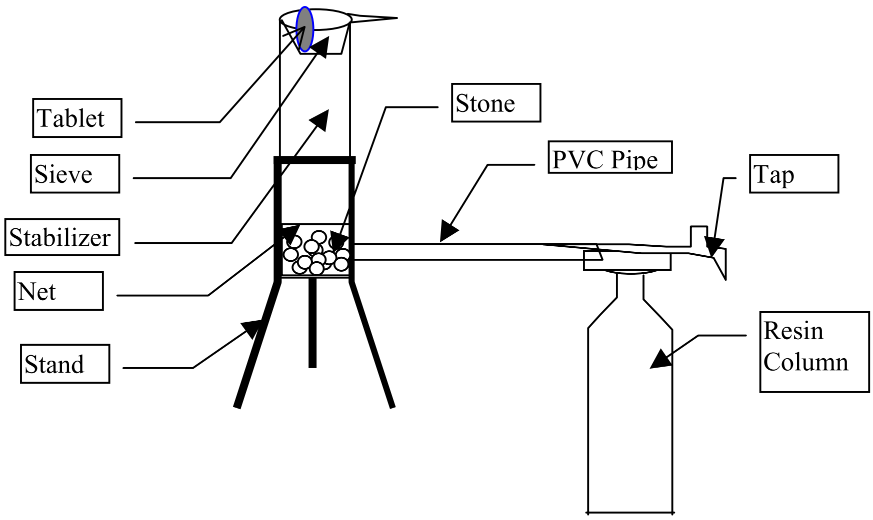
Nothing to be deconstructed.

6. CAUTION

Handle the supplied chemicals carefully, avoid contact with eyes or skin. This can harm your eyes and the skin. If it contacts with eyes or skin, clean with ground water.

TETRAHEDRON

TECHNOLOGY	**TETRA HEDRON**
Process	Ion exchange resin
Chemical controls	Reversible exchange of anions with chlorine Relatively independent of feed As and Fe Potentially affected by competing SO_4 and NO_3 Affinities for ion exchange SO_4>NO_3>ASO_4>Cl-PO_4 not known
Physical controls	Formulae to calculate bed-volumes to exhaustion (for 1mg/l SO_4, 1000 bed volumes) Potentially prone to clogging by FeOH
Operating procedure	Fill first container with feed water (over chlorine tablet), water enters second container and turning the tap at the second container releases the water for. Water supply is almost instant.
Flow rate - low turbidity - high turbidity	90 litres per hour 85 litres per hour
Time for 20 litres to pass	15 minutes
Litres in 12 hours	1080 litres
Batches before deterioration - low turbidity - high turbidity	 No deterioration No deterioration
Claims on effectiveness (Results and references)	Pre-testing through BAMWSP for 50 units installed in Singair, Hajiganj, Urzipur, Gopalganj (50 units in all) suggest complete removal of As from initial concentration of 100-1700ppb.
Costs (capital and recurrent)	Tk. 12000/- plus annual costs of Tk. 6000/- (ion resin column lasts on average for six months)
Contact details	US: Waqi Alam, TETRAHEDRON@prodigy.net Bangladesh: Mr. Wazir Alam or Mr. Altaf, Dhaka Tel: 9882770



1. SETUP

Wrap the stones and place in the bottom of the stabilizer. Put the stabilizer in the supplied stand and attach the PVC pipe to the stabilizer. Fix the other end of the PVC pipe to the tap. Put the sieve on the top of the stabilizer. Pass tubewell water through the system until water comes out from the other end of the resin column. Now remove the PVC piper from the tap and fix it to the other end. Place the tablet against one side of the sieve.

2. FILLING AND OPERATION

Pour tubewell water touching the tablet. After some time water will come out from the tap of the resin column. Close the tap after use keeping the stabilizer half filled.

3. PROBLEMS AND ANSWER

No problem was found during flow rate testing.

4. MAINTENANCE

Everyday after use of the system should be back washed. Remove the PVC pipe from the resin column and fix it to the tap again pass tubewell water through the system for some times (time is not mentioned in the supplied material but approx. 3-5 minutes) Then remove the pipe from the tap and fix it to the other end.

5. CAUTION

Always keep some amount of water (half of the stabilizer) in the stabilizer.

APPENDIX 2

FIELD TESTING PROCEDURES

ARSENIC TESTING INSTRUCTIONS

MORNING FEED WATERS

1. Check required feed sample volume / dilution with team leader

Arsenic concentration	Sample volume	Dilution volume
< 100 ug/l	50 ml into measuring cylinder	0
100-500 ug/l	10 ml by syringe	40 ml
500-1000 ug/l	5 ml by syringe	45 ml

2. FIRST THREE SAMPLES

Sample 1		Sample 2		Sample 3	
Unpumped unfiltered		Pumped filtered		Pumped feed 1	
1	Pump well 5 times (producing water)	1	During fill of technologies 1-3	1	During fill of technologies 1-3
2	Take 2 litre sample from well	2	Take 2 litre sample from well	2	Take 2 litre sample from well
3	Analyse using PeCo test kit	3	Filter	3	Analyse using PeCo test kit
		4	Analyse using PeCo test kit		

Record results. Rinse in well water and clean with DISTILLED WATER

3. SECOND THREE SAMPLES

Sample 1		Sample 2		Sample 3	
Pumped feed 2		Pumped feed 3		Standard	
1	During fill of technologies 4-6	1	During fill of technologies 7-9	1	After previous sample
2	Take 2 litre sample from well	2	Take 2 litre sample from well	2	Pour 50 ml STANDARD into measuring cylinder then flask
3	Analyse using PeCo test kit	3	Analyse using PeCo test kit	3	Analyse using PeCo test kit

Record results. Rinse in well water and clean with DISTILLED WATER

TREATED WATERS

Treated waters will be brought in sets of 3, one for each technology replicate.

1. Ensure that samples are clearly labelled and correctly located on the sampling table.

2. Check with team leader what sample volume / dilution is required.

3. Analyse set of 3 using standard PeCo method.

4. Record results. Rinse in treated water and clean with DISTILLED WATER.

ARSENIC TEST KIT "PeCo75" INSTRUCTIONS

1. **Check kit has been rinsed in distilled water and shaken dry**

2. **Place correct sample volume into flask using**
   - **50ml cylinder, 10 ml syringe or 5 ml syringe**

3. **Prepare filter holder (cotton wool, filter B-bottom and filter A) using fine tweezers**

4. **Add 3 pieces of TABLET 1**

5. **Put 2 pieces of TABLET 2 on lid, add to flask and immediately insert filter. WRITE DOWN TIME**

6. **Keep swirling gently for 15 minutes, or a until large fizzing tablets all dissolved**

7. **START NEXT 1 OR 2 PeCo TESTS IF SAMPLES ARE READY**

8. **Towards end of Stage 6 (reaction) prepare Photometer as below**

ON	
SELECT X 1	**"CALIBRATION"** **Insert filter**
MEASURE	**IF "Done" "Error O5" "As 0 ug/l"** **the Photometer is calibrated and ready to read** **IF "Defect filter" press SELECT x 1, MEASURE** **"Error O5" "As 0 ug/l"** **the Photometer is calibrated and ready to read** **IF Problems persist, calibrate with new filter**

9. **If the Photometer switches off, repeat the steps above**

10. **When reaction complete (always leave 15 minutes), place result filter into Photometer**

SELECT X 1	**Select correct sample volume using up and down arrows**
MEASURE	**RECORD RESULT IN RECORD SHEET**
	Remove filter and throw in waste, insert next result filter in Photometer then press
MEASURE	**RECORD RESULT IN RECORD SHEET**
	Remove filter and throw in waste, insert next result filter in Photometer then press

INSTRUCTIONS FOR HACH TESTING OF FEED WATER

1. Purge tubewell after unpurged arsenic sample has been taken i.e. pump 3 times the well volume to waste.
   (NB: 1 ft = approximately 1 litre). Allow 10 mins for this step.

2. Take sample from well in 1 litre bottle and also fill a bucket for the probes

3. Make sure the pH/mV, Conductivity and Dissolved Oxygen probe units are switched on and put the probes into the bucket.

4. Make sure there is distilled/deionized water available

5. Take the required volume of sample from the 1 litre bottle and undertake the following tests in the same order shown here: -

Ferrous Iron First check if there is a dilution required for the well area i.e. if historical ferrous iron concentration is > 3 mg/l. If a dilution factor is given, dilute the sample by the dilution factor. Follow the instructions in the Hach manual for Ferrous Iron. Record the result in the relevant box on the proforma sheet.

pH, mV, Conductivity, DO, Temperature Record the readings given by the probes in the relevant boxes on the proforma sheet.

Total Iron First check if there is a dilution required for the well area i.e. if historical total iron concentration is > 3 mg/l. If a dilution factor is given, dilute the sample by the dilution factor. Follow the instructions in the Hach manual for Total Iron. Record the result in the relevant box on the proforma sheet.

Turbidity Follow the instructions in the Hach manual for Turbidity.

Sulphide Put on new pair of rubber gloves. Follow the instructions in the Hach manual for Sulfide (0 to 0.6 mg/l). Record the result in the relevant box on the proforma sheet.

Alkalinity Keep rubber gloves on after rinsing under well. First check if there is a dilution required for the well area i.e.

if historical total iron concentration is > 3 mg/l. If a dilution factor is given, dilute the sample by the dilution factor. Follow the instructions in the Hach manual for Alkalinity. Record the result in the relevant box on the proforma sheet.

Manganese Keep rubber gloves on after rinsing under well. Use the Managanese LR test. from the historical ICP data for the well. First check if there is a dilution required for the well area i.e. if historical total manganese concentration is > 0.7 mg/l. If a dilution factor is given, dilute the sample by the dilution factor. Follow the instructions in the Hach manual for Manganese LR. Note that if Alkalinity is >300 mg/l $CaCO_3$, Rochelle Salt Solution is required in Step 6. Record the result in the relevant box on the proforma sheet.

Phosphate Keep rubber gloves on after rinsing under well. Use the Phosphorus Reactive test. Follow the instructions in the Hach manual for Phosphorus Reactive (0 to 30.00mg/l). Record the result in the relevant box on the proforma sheet.

Fluoride Keep rubber gloves on after rinsing under well. Follow the instructions in the Hach manual for Fluoride (0 to 2.00 mg/l). Record the result in the relevant box on the proforma sheet.

Chloride Keep rubber gloves on after rinsing under well. First check if there is a dilution required for the well area. If a dilution factor is given, dilute the sample by the dilution factor. Follow the instructions in the Hach manual for Chloride. Record the result in the relevant box on the proforma sheet.

Aluminium Use the Aluminium (0 – 0.220 mg/l) test. Follow the instructions in the Hach manual for Aluminium Eriochrome Cyanine R Method. Record the result in the relevant box on the proforma sheet.

Nitrate Check with Team Leader which Nitrate test to use. Follow the instructions in the Hach manual for Nitrate. Record the result in the relevant box on the proforma sheet.

Sulphate Follow the instructions in the Hach manual for Sulfate (0 to 70 mg/l). Record the result in the relevant box on the proforma sheet.

INSTRUCTIONS FOR TECHNOLOGY FILLING AND SAMPLE COLLECTION AT EACH WELL

SETUP DAY

1. Set up all technologies at well
2. Fill all technologies to flush through overnight.

DAY 1

1. Deliver unpumped, unfilterd sample to Arsenic Tester. Pump the well 5 strokes, then fill a 2 litre sample bottle and deliver to Arsenic Tester.
2. Pump the well one litre for every ft of well depth (check depth with Team Leader). Fill 2 large sample bottles and a bucket (this is FEED 1). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.
3. Fill all replicates of the Garnet, Ardasha and BUET technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".
4. Fill a large sample bottle from the well (this is FEED 2). Deliver to the Arsenic Tester.
5. Fill all replicates of DPHE/DANIDA, Steven's Institute, Sono-3-kolshi and Tetrahedron technologies. Record the time of filling on the "TECHNOLOGY RECORD SHEET".
6. Flush through all replicates of ALCAN with 140 litres well water.
7. Fill a large sample bottle from the well (this is FEED 3). Deliver to the Arsenic Tester.
8. Fill all replicates of ALCAN. Record the time of filling on the "TECHNOLOGY RECORD SHEET".
9. Take a sample from each of the Tetrehedron replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is

Tetrahedron - Batch 1). Leave the tap open on the technologies to drain the remainder of Batch 1.

10. Take TWO samples from each of the ALCAN replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is ALCAN - Batch 1).

11. Take a sample from each of the Steven’s Institute replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver to the Arsenic Tester (This water is Steven’s Institute - Batch 1). Leave the tap open on the technologies to drain the remainder of Batch 1 and discard of the coagulated material in the top bucket.

12. Take TWO samples from each of the DPHE/DANIDA replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is DPHE/DANIDA - Batch 1). Leave the tap open on the technologies to drain the remainder of Batch 1.

13. Fill 2 large sample bottles and a bucket (this is FEED 4). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

14. Fill all replicates of DPHE/DANIDA, Steven’s Institute, Sono-3-kolshi technologies. Record the time of filling on the “TECHNOLOGY RECORD SHEET”.

15. Fill a large sample bottle from the well (this is FEED 5). Deliver to the Arsenic Tester.

16. Fill all replicates of Tetrahedron technologies. Record the time of filling on the “TECHNOLOGY RECORD SHEET”.

17. Take TWO samples from each of the BUET replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is BUET - Batch 1).). Leave the tap open on the technologies to drain the remainder of Batch 1 and discard any water left in the top bucket.

18. Take a sample from each of the Tetrahedron replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver to the Arsenic Tester (This water is Tetrahedron - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 2.

19. CHECK WITH TEAM LEADER WHETHER YOU CAN TAKE A BREAK FOR LUNCH.

20. Take a sample from each of the Steven's Institute replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Steven's Institute - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 2 and discard of the water and the coagulated material in the top bucket.

21. Take a sample from each of the DPHE/DANIDA replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester. (This water is DPHE/DANIDA - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 2 and discard of the water in the top bucket.

22. Take a sample from each of the Ardasha replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Ardasha - Batch 1). Leave the tap open on the technologies to drain the remainder of Batch 1 and discard of the water in the top bucket.

23. Take a sample from each of the Garnet replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Garnet - Batch 1). Leave the tap open on the technologies to drain the remainder of Batch 1.

24. Fill 2 large sample bottles and a bucket (this is FEED 6). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

25. Fill all replicates of Garnet, Passive Sedimentation and BUET technologies. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

26. Flush through all replicates of ALCAN with 140 litres well water.

27. Fill a large sample bottle from the well (this is FEED 7). Deliver to the Arsenic Tester.

28. Fill all replicates of ALCAN technologies. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

29. Take a sample from each of the ALCAN replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is ALCAN - Batch 2).

DAY 2

1. Take a sample from each of the Garnet replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Garnet - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 1.

2. Take a sample from each of the Passive Sedimentation replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Passive Sedimentation - Batch 1). Discard of the remaining water in the bucket and rinse out.

3. Take a sample from each of the BUET replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester. (This water is BUET - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 1 and discard any water left in the top bucket.

4. Deliver unpumped, unfilterd sample to Arsenic Tester. Pump the well 5 strokes, then fill a 2 litre sample bottle and deliver to Arsenic Tester.

5. Pump the well one litre for every ft of well depth (check depth with Team Leader). Fill 2 large sample bottles and a bucket (this is FEED 8). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

6. Fill all replicates of the Garnet, Passive Sedimentation, Ardasha and BUET technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

7. Fill a large sample bottle from the well (this is FEED 9). Deliver to the Arsenic Tester.

8. Fill all replicates of the DPHE/DANIDA, Steven's Institute, Sono-3-kolshi technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

9. Fill a large sample bottle from the well (this is FEED 10). Deliver to the Arsenic Tester.

10. Fill all replicates of the Tetrahedron technology following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

11. Take a sample from each of the Steven's Institute replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Steven's Institute - Batch 3). Leave the tap open on the technologies to drain the remainder of Batch 1 and discard of the coagulated material in the top bucket.

12. Take a sample from each of the Tetrahedron replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Steven's Institute - Batch 3). Leave the tap open on the technologies to drain the remainder of Batch 3.

13. Take a sample from each of the Sono-3-kolshi replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Sono-3-kolshi - Batch 1). Leave the tap open on the technologies to drain the remainder of Batch 1.

14. Take TWO samples from each of the DPHE/DANIDA replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is DPHE/DANIDA - Batch 3). Leave the tap open on the technologies to drain the remainder of Batch 3 and discard of any water left in top bucket.

15. Fill 2 large sample bottles and a bucket (this is FEED 11). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

16. Fill all replicates of the Sono-3-kolshi and Tetrahedron technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

17. CHECK WITH TEAM LEADER WHETHER YOU CAN TAKE A BREAK FOR LUNCH.

18. Take a sample from each of the Tetrehedron replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Tetrahedron - Batch 4). Leave the tap open on the technologies to drain the remainder of Batch 4.

19. Take a sample from each of the Sono-3-kolshi replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Sono-

3-kolshi - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 2.

20. Take TWO samples from each of the BUET replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is BUET - Batch 3).). Leave the tap open on the technologies to drain the remainder of Batch 3 and discard any water left in the top bucket.

21. Take a sample from each of the Ardasha replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver to the Arsenic Tester (This water is Ardasha - Batch 2). Leave the tap open on the technologies to drain the remainder of Batch 2 and discard of the water in the top bucket.

22. Take a sample from each of the Passive Sedimentation replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver to the Arsenic Tester (This water is Passive Sedimentation - Batch 2). Discard of the remaining water in the bucket and rinse out.

23. Take a sample from each of the Garnet replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked “A” with treated water from “Replicate A” and so on). Deliver to the Arsenic Tester (This water is Garnet - Batch 3). Leave the tap open on the technologies to drain the remainder of Batch 3.

24. Fill 2 large sample bottles and a bucket (this is FEED 12). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

25. Fill all replicates of the Garnet, Passive Sedimentation and Ardasha technologies following the instructions given on a separate sheet. Record the time of filling on the “TECHNOLOGY RECORD SHEET”.

26. Fill a large sample bottle from the well (this is FEED 13). Deliver to the Arsenic Tester.

27. Fill all replicates of the BUET technology following the instructions given on a separate sheet. Record the time of filling on the “TECHNOLOGY RECORD SHEET”.

DAY 3

1. Take a sample from each of the Passive Sedimentation replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Passive Sedimentation - Batch 3). Discard of the remaining water in the bucket and rinse out.

2. Take a sample from each of the Ardasha replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Ardasha - Batch 3). Leave the tap open on the technologies to drain the remainder of Batch 3.

3. Take TWO samples from each of the BUET replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is BUET - Batch 4).). Leave the tap open on the technologies to drain the remainder of Batch 4 and discard any water left in the top bucket.

4. Deliver unpumped, unfilterd sample to Arsenic Tester. Pump the well 5 strokes, then fill a 2 litre sample bottle and deliver to Arsenic Tester.

5. Pump the well one litre for every ft of well depth (check depth with Team Leader). Fill 2 large sample bottles and a bucket (this is FEED 14). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

6. Fill all replicates of the Passive Sedimentation and Ardasha technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

7. Fill a large sample bottle from the well (this is FEED 15). Deliver to the Arsenic Tester.

8. Fill all replicates of the DPHE/DANIDA, Steven's Institute, Sono-3-kolshi technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

9. Flush through all replicates of ALCAN with 140 litres well water.

10. Fill a large sample bottle from the well (this is FEED 16). Deliver to the Arsenic Tester.

11. Fill all replicates of ALCAN technologies. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

12. Take TWO samples from each of the ALCAN replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is ALCAN - Batch 3).

13. Take a sample from each of the Sono-3-kolshi replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Sono-3-kolshi - Batch 3). Leave the tap open on the technologies to drain the remainder of Batch 3.

14. Take a sample from each of the Garnet replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Garnet - Batch 4). Leave the tap open on the technologies to drain the remainder of Batch 4.

15. Take a sample from each of the Steven's Institute replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Steven's Institute - Batch 4). Leave the tap open on the technologies to drain the remainder of Batch 4 and discard of the coagulated material in the top bucket.

16. Take TWO samples from each of the DPHE/DANIDA replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is DPHE/DANIDA - Batch 4) Leave the tap open on the technologies to drain the remainder of Batch 4.

17. Flush through all replicates of ALCAN with 140 litres well water.

18. Fill 2 large sample bottles and a bucket (this is FEED 17). Deliver one sample bottle to the arsenic tester. Deliver the other sample bottle and the bucket to the HACH tester.

19. Fill all replicates of the Sono-3-kolshi and ALCAN technologies following the instructions given on a separate sheet. Record the time of filling on the "TECHNOLOGY RECORD SHEET".

20. CHECK WITH TEAM LEADER WHETHER YOU CAN TAKE A BREAK FOR LUNCH.

21. Take TWO samples from each of the ALCAN replicates (i.e. 6 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water

from "Replicate A" and so on). Deliver one set to the Arsenic Tester and one set to the HACH Tester. (This water is ALCAN - Batch 4).

22. Take a sample from each of the Sono-3-kolshi replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Sono-3-kolshi - Batch 4). Leave the tap open on the technologies to drain the remainder of Batch 4.

23. Take a sample from each of the Ardasha replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Ardasha - Batch 4). Leave the tap open on the technologies to drain the remainder of Batch 4.

24. Take a sample from each of the Passive Sedimentation replicates (i.e. 3 samples) in the marked 1 litre sample bottles (fill sample bottled marked "A" with treated water from "Replicate A" and so on). Deliver to the Arsenic Tester (This water is Passive Sedimentation - Batch 4). Discard of the remaining water in the bucket and rinse out.

25. CHECK WITH YOUR TEAM LEADER TO SEE WHERE ASSISTANCE IS REQUIRED.

TECHNOLOGY RECORD SHEET							
"TECHNOLOGY NAME"							
"AREA NAME"	Well No		Mouza		Owner		
BATCH 1	Fill date		Fill time		Sample time		
COMMENTS							
Replicate A							
Replicate B							
Replicate C							
BATCH 2	Fill date		Fill time		Sample time		
COMMENTS							
Replicate A							
Replicate B							
Replicate C							
BATCH 3	Fill date		Fill time		Sample time		
COMMENTS							
Replicate A							
Replicate B							
Replicate C							
BATCH 4	Fill date		Fill time		Sample time		
COMMENTS							
Replicate A							
Replicate B							
Replicate C							
Additional Notes							

FEED WATERS

ARSENIC ANALYSIS (*Area*)

TEAM No:
Method: PeCo75 Arsenic test kit

Area: **Well No:** **Mouza:** **Owner:**
ICP As: **Sample volume for PeCo test:**

Feed No	Date	Time	Technologies filled	Readers name	Unpumped (UP)	Pumped filtered (PF)	Pumped unfiltered (PU)	Standard
Feed 1								
Feed 2								
Feed 3								
Feed 4								
Feed 5								
Feed 6								
Feed 7								
Feed 8								
Feed 9								
Feed 10								
Feed 11								
Feed 12								
Feed 13								
Feed 14								
Feed 15								
Feed 16								
Feed 17								

Lab Sample Lables: "*Area Code (SI, HA, IS or KA)*" - "*Well No*" - FEED "*Number*" - "*Water type (UP, PF or PU)*"
e.g.: SI-1-FEED01-PU

Notes

FEED WATERS
WATER QUALITY PARAMETERS (Hach and probes)

Method: **Hach field laboratory and DU Instruments' probes**

Team No:

Area: **Well No:** **Mouza:** **Owner:**

Parameter	Dilution Factor	FEED NUMBER								Standards
Ferrous Iron (mg/l)										
pH										
Eh (mV)										
Conductivity (mS/cm)										
Temperature (deg C)										
Dissolved Oxygen (mg/l)										
Total Iron (mg/l)										
Turbidity (NTU)										
Sulphide (mg/l)										
Alkalinity (mg/l $CaCO_3$)										
Manganese (mg/l)										
Phosphate (mg/l)										
Chloride (mg/l)										
Fluoride (mg/l)										
Aluminium (mg/l)										
Nitrate (mg/l)										
Sulphate (mg/l)										
Sand/silt production										
Smells eg H_2S										
Other comments										
Tester's name										

"TECHNOLOGY"

ARSENIC ANALYSIS OF TREATED WATERS

TEAM No: PeCo sample
Method: PeCo75 Arsenic test kit

			Batch 1	Batch 2	Batch 3	Batch 4
Area	**Sitakunda**					
Well No		Date				
Mouza		Time				
Owner		**Lab sample lables**				
Sample Volume		Replicate A	SI- -GA-A1	SI- -GA-A2	SI- -GA-A3	SI- -GA-A4
		Replicate B	SI- -GA-B1	SI- -GA-B2	SI- -GA-B3	SI- -GA-B4
		Replicate C	SI- -GA-C1	SI- -GA-C2	SI- -GA-C3	SI- -GA-C4
Readers name						
PeCo75 sample result						
Notes						

			Batch 1	Batch 2	Batch 3	Batch 4
Area	**Hajiganj**					
Well No		Date				
Mouza		Time				
Owner		**PeCo75 Results**				
Sample Volume		Replicate A				
		Replicate B				
		Replicate C				
Readers name						
Lab sample lable: (Area-"Well No"-Technology-Replicate-Batch)					HA- -GA-B3	
Notes						

			Batch 1	Batch 2	Batch 3	Batch 4
Area	**Ishwardi**					
Well No		Date				
Mouza		Time				
Owner		**PeCo75 Results**				
Sample Volume		Replicate A				
		Replicate B				
		Replicate C				
Readers name						
Lab sample lable: (Area-"Well No"-Technology-Replicate-Batch)					IS- -GA-C3	
Notes						

			Batch 1	Batch 2	Batch 3	Batch 4
Area	**Kalaroa**					
Well No		Date				
Mouza		Time				
Owner		**PeCo75 Results**				
Sample Volume		Replicate A				
		Replicate B				
		Replicate C				
Readers name						
Lab sample lable: (Area-"Well No"-Technology-Replicate-Batch)					KA- -GA-A3	
Notes						

TREATED WATERS
HACH TESTING RECORD SHEET

Team No: ______ Well No: ______ Well Owner: ______

Area: ______ Mouza: ______ ______

Technology	Replicate	Concentration of parameter in treated waters (mg/l)							
		Batch 1		Batch 2		Batch 3		Batch 4	
		Aluminium*	Manganese	Aluminium*	Manganese	Aluminium*	Manganese	Aluminium*	Manganese
DPHE/DANIDA	A								
	B								
	C								
BUET	A								
	B								
	C								
ALCAN	A								
	B								
	C								

*Use the Aluminium High Range Test (Aluminon Method using AluVer3 reagent)

APPENDIX THREE

QUALITY CONTROL MEASURES

Equipment

A3.1 Each of the five field teams possessed their own set of equipment which was clearly numbered and comprised: a Hach spectrophotometer, Hach Turbidity and Alkalinity test kits, a PeCo 75 arsenic field testing kit and pH, conductivity and dissolved oxygen meters. All associated chemicals, spares and associated analytical items used for the work were kept in labelled plastic boxes. The kits were routinely restocked for chemicals, syringes, de-ionised water etc.

Sample numbering system

A3.2 The numbering system chosen for water samples collected for laboratory analysis is detailed in Table A3.1.

Table A3.1: Sample numbering system used in the study

Locality (x4)	Team/Well Number (x5)	Technology (x9)	Replicate (x3)	Treated Water Batch (x4)
SI	1	GA	A	1
HA	2	PS	B	2
IS	3	AD	C	3
KA	4	BU		4
	5	SO		
		DP		
		ST		
		TE		
		AL		
For example, sample SI-2-PS-A2 represents a treated water sample originating from - Sitakunda, team 2 (tube well 2), using passive sedimentation, replicate A, treated water batch 2.				

(Note: Five teams and five wells in each area. Team no. = Well no.)

A3.3 All samples taken for laboratory analysis were stabilised and the remaining porion of the sample required for AAS analysis was kept as a back up in case of any problems. All samples taken in the field (50mL) for hydride generation were acidified (1mL) with a 1:1 nitric acid solution (50:50 concentrated acid:deionised water mixture). The samples were stored in plastic boxes and were usually analysed within ten days of sampling.

Standard operating procedures

A3.4 Manuals of operating procedures for the Hach spectrophotometer (Hach file) and the PeCo 75 (Arsenic file) were prepared prior to field work so as to simplify the analytical procedures for the individual water and probe tests. The individual handbooks on Hach and PeCo techniques were supplemented by intense training for field assistants by team leaders and trained Hach representatives in Dhaka. This allowed a time in motion study to be completed for time field programme planning es. The manuals contained standard pro forma data sheets for analytical and sample data input. A manual on the preparation, operation and sampling procedures on the individual technologies was also prepared (Technology file). These Standard Operating Procedures are presented as Appendix 2.

A3.5 The recording sheets contained clear guidance on sampling methodology and gave an indication on when samples needed to be collected and when analytical arsenic standards were required to be analysed. The solution samples sent for laboratory analysis in Dhaka will be kept at the BETS centre for any future analysis. The proportion of samples that were analysed in the field and the laboratory varied from area to area. One hundred percent laboratory analyses were carried out in the first two areas as the field performance of the PeCo test kit was unproven at that stage. During the course of the arsenic analytical work in the field and in the laboratory at least 10% of the samples were analytical standards (50ppb) to assess the performance of the equipment, help monitor errors and assess the need for equipment recalibration. The proportion of laboratory and field samples and analyses for each area are summarised in Table A3.2.

Table A3.2: Summary of proportion of laboratory and field samples and analyses for arsenic in each area

Area	Laboratory samples taken %	Laboratory samples analysed %	PeCo 75 field analyses %	PeCo 75 field standards (as % of PeCo75 samples)
Sitakunda	100%	100%	10%	>10%
Hajiganj	100%	100%	10%	>10%
Ishwardi	>30%	>30%	100%	>10%
Kalaroa	100%	>30%	95%	>10%

Notes:
1) Percentages are indicative
2) 100% laboratory samples taken in Sitakunda and Hajiganj as the PeCo test kit was at that stage considered unproven in the field.
3) Reduction to 30% laboratory samples in Ishwardi was made in response to encouraging laboratory/PeCo 75 correlation from Hajigang.
4) Return to 100% laboratory sampling (with 30% analysis) for Kalaroa was made in response to uncertainties concerning PeCo 75 results from Ishwardi.
5) ~95% PeCo analyses in Kalaroa due to shortage of reagents on the last day of the field programme.

A3.6 Individual data recording sheets from the 5 teams were regularly reviewed by team leaders and relevant sheets were removed or photocopied from the folders following every second tube well evaluation. Data were entered into EXCEL for analysis.

A3.7 All PeCo samples were analysed as soon as possible. This was generally within 30 minutes of sampling. Samples with arsenic concentrations below 100ppb require no dilution while samples in the range 100 – 500ppb required a 5x dilution, samples with concentrations greater than 500ppb required a 10x dilution. Following an initial period of evaluation at each tube well site it was possible to predict which dilution was required for treated waters from each technology. Those technologies which were performing well required no dilution as concentrations were well below 100ppb.

A3.8 The multi-element ICP data from the initial water samples taken in the reconnaissance survey provided a good estimate on initial elemental concentrations in the tube well waters and helped identify the dilutions that were required for arsenic. This was also used for other elemental concentrations and dilution for the Hach spectrophotometer methods could be predicted prior to field analysis. The ICP analytical data were based on unfiltered water whereas the Hach methods were being carried out on filtered water (0.2µm). Filtering was carried out on Hach samples in order to avoid unquantifiable interference of water colour/turbidity with the spectrophotometric analysis.

Probe techniques

A3.9 Conductivity, pH/Eh and Dissolved oxygen/temperature probes manufactured by Lutron and purchased in Dhaka were used for the fieldwork. Prior to fieldwork the probes were all calibrated and separate units compared on test solutions. Readings on the test solutions from separate units were found to agree to within 1% for conductivity and pH and to within 5% for dissolved oxygen.

A3.10 In the field, water quality probes were calibrated by team leaders at the end of testing at each of the four areas. In the calibration of the pH probe a two standard method (pH 7 and 4) was used. The calibration of the conductivity probe used a 1413µS/cm standard and for the calibration of the dissolved oxygen probe an air saturation standardisation technique was used. Data on calibration was recorded on the analytical data sheets. The procedures for operating and calibrating the probes were incorporated into the manual on analytical techniques and used by the field operatives as a reference (Hach file).

Chemical analysis in the field

A3.11 Elemental solution standards were made up using Merck 1000mg/L Atomic Absorption standards this allowed standards to be made with distilled water for calibration and standardisation purposes. Known arsenic standards (25, 50, 75, 200 and 400 ppb) were made up and analysed by the hydride generation and PeCo 75 field kit methods. The results by the two methods agreed very closely to the predicted values and are given in Table A3.3. The repeatability of the PeCo 75 was assessed using 5 photometers (Table A3.4). The short study involved using a 50ppb prepared standard which was also analysed in the laboratory. Accuracy and repeatability of results are very good due largely to the digital/photometric measuring technique used in the PeCo test kit. This feature removes the component of human judgement in taking readings thereby improving the objectivity and repeatability of results.

Table A3.3: Comparative analytical results on standards using AAS-HG and the PeCo 75

Standard (µg/l)	Sample 1				
	Reading 1	Reading 2	Reading 3	St.dev	% mean out
25	28	29	32	2.1	19%
50	51	52	54	1.5	5%
250	260	260	260	0.0	4%
500	510	510	520	5.8	3%
Standard (µg/l)	**Sample 2**				
	Reading 1	Reading 2	Reading 3	St.dev	% mean out
25	26	27	27	0.6	7%
50	50	50	50	0.0	0%
250	275	275	280	2.9	11%
500	450	510	520	37.9	-1%

Table A3.4. Repeatability assessment of PeCo 75 measurement

Result filter paper	PeCo Kit Number				
	1	2	3	4	5
1	48	45	45	49	47
2	48	44	45	50	48
3	48	45	44	49	48
4	48	46	45	50	46
5	48	43	44	50	47
Mean	48	44.6	44.6	49.6	47.2
St. Dev.	0.00	1.14	0.55	0.55	0.84
Diff. from standard	-0.4	-3.8	-3.8	1.2	-1.2
% different	-0.8%	-7.9%	-7.9%	2.5%	-2.5%

A3.12 For field work 10 litres of synthetic arsenic standard was made up and distributed in 2 liter bottles to the 5 teams for use in quality control.

A3.13 The Hach portable laboratory system is the most widely used comprehensive water quality testing kit in the world and has a well-established track record. Nonetheless, as a further quality control measure, 10 litres of a multi-element standard was prepared using AA chemical solution standards for use in a Hach standard run that was carried out at each of the 20 wells. The synthetic solution contained Fe, Mn, Al, PO4, F, Cl and SO4 in the concentrations given in Table A3.5. The elemental concentrations in the solution were chosen so that they were within the analytical range of the Hach Spectrophotometer and within the range of typical Bangladesh tube well waters.

Table A3.5: Hach multi-element standard results

Element	Hach Spectrophotometer range (mg/L)	Target concentration (mg/L)	Field standard result Mean	Field standard result Standard Deviation
Fe	0 - 3	1.0	0.96	0.08
Mn	0 – 0.7	0.5	0.46	0.02
Al	0 – 0.8	0.5	0.12	0.02
PO4	0 – 30	5.0	5.82	1.96
F	0 – 2	1.0	0.75	0.29
Cl	0 – 20	5.0	4.40	1.53
SO4	0 - 70	5.0	8.00	1.63

A3.14 The detection limits and precision of the Hach spectrophotometer are, for most tests, stated in the Hack manual. For those tests where no detection limit was specified, detection limits were estimated in a one-off study during the field programme following the dilution method specified in the Hach manual. Working ranges, detection limits and precisions of the Hach tests that were used are summarised in Table A3.6.

Table A3.6: Hach Method detection limits and precisions

Element	Hach Method	Working Range	Method Detection Limit	Precision
Iron (Ferrous)	8146	**0 – 3**	0.01	**± 0.006**
Iron (Total)	8008	**0 - 3**	**0.02**	**± 0.006**
Manganese	8149	**0 – 0.7**	0.005	**± 0.0049**
Aluminium	High Range 8012	**0 – 0.8**	0.05	**± 0.016**
	Low Range 8326	**0 – 0.22**	0.02	**± 0.004**
Phosphate	8178	**0 - 30**	0.03	**± 0.02**
Nitrate	8171	**0 – 0.4**	0.03	**± 0.01**
Chloride	8113	**0 - 20**	0.4	**± 0.3**
Fluoride	8029	**0 – 2**	**0.02**	**± 0.02**
Sulphide	8131	**0 – 0.6**	**0.01**	**± 0.003**
Sulphate	8051	**0 - 70**	**7**	**± 0.9**

Notes:
1) Values in bold type are quoted from the Hach manual. Detection limits in normal type were measured according to dilution methods specified in the Hach manual.

Chemical analysis in the laboratory

A3.15 In the Intronics Technology Centre, Dhaka a Hydride generation technique was used for the determination of arsenic concentrations in water samples. The equipment used was a Buck Scientific Model 210VGP atomic absorption spectrophotometer attached to a Model 420 Hydride generator.

A3.16 Arsenic standards (5, 10, 25 and 30 ppb) were prepared in 1M HCl (5mL conc. HCl in 1L water), these concentration represent the working linear range of the technique used in the laboratory and were used throughout for instrument calibration purposes. Water samples were initially treated with an ascorbic acid /KI solution (50g/L of both ascorbic acid and KI) to reduce As(V) to As(III). The recipe for the individual solutions are detailed in Table A3.7.

Table A3.7. Solution used in hydride generation technique

Dilution (As concentration range)	Volume of sample mL	Volume of HCl mL	Volume(Asc+ KI) mL	Volume water mL
5x (<150ppb)	1	1	1	2
10x (150-300ppb)	1	1	1	7
20x (300-600ppb)	1	1	1	17
Blank	0	1	1	8

A3.17 After leaving the samples for 45 minutes the samples were processed by AAS-HG. The machine was allowed to warm up for 30 minutes and the standards were analysed using argon as the carrier gas, a 1.5% NaBH4 solution (made in a 0.5% NaOH solution) and an acidic solution of hydroxylamine + sulphuric acid and hydrochloric acid. On sampling the read out data from the instrument the data was taken when the read out remained constant and arsenic concentrations were taken down in a notebook. The data from the machine represents the concentration of arsenic in the water sample. This must be multiplied by the initial dilution factor to get the actual water sample concentration.

A3.18 On treating large quantities of samples a quality control procedure was established in order to reduce sample error and to speed up reporting. In the samples that were analysed standards were routinely analysed after every 5 samples to establish the consistency of the readings. Samples were put through the AAS-HG in a random manner and recorded in an EXCEL spreadsheet. The data was later sorted in serial number and reported (hard copy, floppy disk and by e-mail).

A3.19 Solution standards used at the Intronics laboratory were cross checked with standard reference solutions and also with freshly made standards all of which correlated very closely.

Health and Safety

A3.20 A hazard assessment was carried out for all the tests that were to be carried out in the field. This is shown below. Arrangements were made with the British High Commission doctor for emergency call if required. The nature of the survey was passed on, mobile phone numbers and contact details were made available in case the need for urgent attention.

A3.21 All field staff were told of the hazards, trained in emergency action and given a copy of the Hach hazard assessment shown below.

A3.22 All liquid and solid waste from the field testing was stored in sealed containers and disposed of off site.

HACH TESTING
HAZARD ASSESSMENT
AND HEALTH AND SAFETY INSTRUCTIONS

Test	Reagent	Components	Hazard	Potential Health Effects	Precautions	First Aid	Disposal
Ferrous Iron	Ferrous Iron Reagent Powder Pillows	1, 10-Phenanthroline Sodium Bicarbondate	Low	Eye, skin, respiratory tract irritation.	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. Induce vomiting if swallowed by sticking finger down throat. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
Total Iron	FerroVer Iron Reagent Powder Pillows	Sodium Thiosulfate; 1,10-Phenanthroline-p-toluenesulfonic Acid Salt; Sodium Hydrosulfite; Sodium Citrate; Sodium Metabisulfite	Low	Eye and respiratory tract irritation Allergic respiratory tract reation if inhaled or swallowed	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
Alkalinity	Sulphuric Acid 0.035 N standard solution	Sulphuric Acid; Isopropanol; Sulphuric Acid (<0.1%)	Low	Eye, skin, respiratory tract irritation	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
	Phenolphthalein Indicator Powder Pillows	Phenolphthalein; Sodium Chloride	Low	Eye and skin irritation Ingestion – dehydration, vomiting, blood pressure change, muscular twitching, rigidity	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
	Bromcresol Green-Methyl Red Indicator Powder Pillows	Potassium Chloride	Low	Eye and respiratory tract irritation Ingestion – gastrointestinal disturbance, blood pressure change, cardiac depression, gastroenteritis	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
Sulphate	SulfaVer 4 Reagent Powder Pillows	Barium Chloride Citric Acid	Low	Eye, skin, respiratory tract irritation	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. Induce vomiting if swallowed by sticking finger down throat. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container

Test	Reagent	Components	Hazard	Potential Health Effects	Precautions	First Aid	Disposal
Nitrate (medium range)	NitraVer 5 Nitrate Reagent Powder Pillows	Potassium Phosphate, monobasic; Magnesium Sulphate; Cadmium; Gentisic Acid; Sulfanilic Acid	Medium	Eye, skin, respiratory tract irritation Cadmium is a carcinogen	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. Induce vomiting if swallowed by sticking finger down throat. Drink milk or egg whites at frequent intervals. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
Nitrate (low range)	NitriVer 3 Nitrite Reagent Powder Pillows	1,2-Cyclohexanediaminetetraacetic Acid Trisodium Salt; Chromotropic Acid, Disodium Salt; Potassium Phosphate, Monobasic; Potassium Pyrosulfate; Sodium Sulfanilate	Medium	Eye burns, skin and respiratory tract irritation	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
	NitraVer 6 Nitrate Reagent Powder Pillows	Sodium Tartrate; 1,2-Cyclohexanediaminetetraacetic Acid Trisodium Salt; Cadmium; Sodium Sulfate; Tartaric Acid; Magnesium Sulfate	Medium	Eye, skin, respiratory tract irritation. Cadmium is a carcinogen	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. Induce vomiting if swallowed by sticking finger down throat. Drink milk or egg whites at frequent intervals. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
Aluminium (high range)	AluVer 3 Aluminium Reagent Powder Pillows	Aurintricarboxylic Acid, Calcium Salt; Disodium Succinate; Succinic Acid	Low	Eye, skin, respiratory tract irritation.	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
	Bleaching 3 Reagent Powder Pillows	Sodium Pyrophosphate; Potassium Pyrosulfate; Magnesium Sulfate	Medium	Eye burns, skin and respiratory tract irritation	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
	Ascorbic Acid Powder Pillows	Ascorbic Acid	Low	Possible irritation	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container

Test	Reagent	Components	Hazard	Potential Health Effects	Precautions	First Aid	Disposal
Sulphide	Sulfide 1 Reagent	Sulphuric Acid (55 – 65%); demineralized water	High	Severe eye and skin burns. Ingestion – severe internal burns; nausea; vomiting; death; circulatory disturbance; rapid pulse and breathing; diarrhoea	USE RUBBER GLOVES (rinse gloves at well before removing) Close container when not in use. Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
	Sulfide 2 Reagent	Potassium Dichromate (<1%); Demineralised Water	High	Eye, skin, respiratory tract irritation and allergic reaction. Ingestion – abdominal pain, vomiting, dizziness, thirst, fever, coma, liver damage. Chromium is a carcinogen	USE RUBBER GLOVES (rinse gloves at well before removing) Close container when not in use. Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water and induce vomiting by sticking finger down throat. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container
Phosphate	Amino Acid Reagent for Phosphate and Silica	N,N-Dimethylformamide; Demineralized water; Sodium Metabisulfite; Sodium Sulfite	High	Severe eye, skin and respiratory tract irritation. Harmful to kidneys and liver if inhaled or absorbed through skin. N,N-Dimethylformamide is a carcinogen	USE RUBBER GLOVES (rinse gloves at well before removing) Close container when not in use. Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water and induce vomiting by sticking finger down throat. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container Incompatible with: - Oxidizers; Alkali metals; Nitric acid; metal nitrates; chlorine; bromine
	Molybdate Reagent	Ammonium Molybdate; Demineralised Water; Sulphuric Acid	High	Severe eye burns, skin irritation, internal burns	USE RUBBER GLOVES (rinse gloves at well before removing) Close container when not in use. Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader.

Test	Reagent	Components	Hazard	Potential Health Effects	Precautions	First Aid	Disposal
Manganese (high range)	Buffer Powder Pillows Citrate Type	Citric Acid; Sodium Phosphate, Dibasic; Sodium Sulfate	Low	Eye, skin, respiratory tract irritation.	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container Incompatible with metal nitrates and aluminium
	Sodium Periodate Powder Pillows	Sodium m-Periodate (strong oxidizer)	Medium	Severe eye, moderate skin irritation.	Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. Dispose of empty sachets into solids waste container May react violently with reducers and organic materials

Manganese (low range)	Alkaline Cyanide Reagent	Sodium Hydroxide (1 – 5%); Sodium Cyanide (5 – 15%); Demineralized water	Very High	FAST ACTING POISON Burns to eyes and skin. Ingestion and inhalation – toxic and may be fatal. Causes cyanosis, internal burns, anxiety, headache.	USE RUBBER GLOVES (rinse gloves at well before removing) BE EXTREMELY CAREFUL. DO NOT BREATHE IN FUMES. Close container when not in use. Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, INFORM TEAM LEADER IMMEDIATELY. HOSPITAL TREATMENT REQUIRED	Contact with acid forms highly toxic fumes (cyanide gas) *Pour liquid reaction products into separate sealed container labelled "Alkaline Cyanide Liquid Waste"
	PAN indicator Solution 0.1%	Ammonium Acetate; N,N-Dimethylformamide; Octylphenoxypolyethoxyethanol; Demineralised water	High	Severe eye, skin and respiratory tract irritation. Harmful to kidneys and liver if inhaled or absorbed through skin. N,N-Dimethylformamide is a carcinogen	USE RUBBER GLOVES (rinse gloves at well before removing) BE EXTREMELY CAREFUL. DO NOT BREATHE IN FUMES. Close container when not in use. Avoid ingestion, inhalation and contact with skin.	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water and induce vomiting by sticking finger down throat. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Incompatible with nitric acid, metal nitrates, halogens alkali metals, oxidizers

Test	Reagent	Components	Hazard	Potential Health Effects	Precautions	First Aid	Disposal
Chloride	Mercuric Thiocyanate Solution	Mercuric Thiocyanate (<0.5%); Methyl Alcohol	High	Eye & skin contact – moderate irritation. May be fatal or cause blindness if swallowed.	USE RUBBER GLOVES (rinse gloves at well before removing) Avoid ingestion, inhalation and contact with skin	Rinse affected area with large volumes of water. If swallowed, drink large quantities of water and induce vomiting by sticking finger down throat. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Incompatible with oxidizers
	Ferric Ion Solution	Ferric Perchlorate; Demineralised water; Perchloric Acid	Medium	Causes burns through contact, inhalation and ingestion	USE RUBBER GLOVES (rinse gloves at well before removing) Avoid ingestion, inhalation and contact with skin	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	Pour into liquid waste container for later disposal by Team Leader. May react violently in contact with alkalies, reducers, organics, combustibles
Fluoride	SPADNS Reagent for Fluoride	Hydrochloric Acid; Sodium Arsenite; Demineralised Water	Medium	Causes burns through contact, inhalation and ingestion Contains Arsenic which is toxic.	USE RUBBER GLOVES (rinse gloves at well before removing) Avoid ingestion, inhalation and contact with skin	Rinse affected area with large volumes of water. DO NOT induce vomiting if swallowed. Drink 2 glasses of water. INFORM TEAM LEADER	* Pour into liquid waste container for later disposal by Team Leader. Incompatible with oxidizers

*HACH guidelines are to dispose of these reagents under the prevailing Hazardous Waste Regulations of the relevant country.

APPENDIX 4a

WATER CHEMISTRY DATA FOR EACH AREA

SITAKUNDA – WELL SUMMARY

Parameter	Units	Bangladesh acceptable range	Well 1		Well 2		Well 3		Well 4		Well 5			Mean	Standard deviation
			Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation			
Ferrous Iron	mg/l		0.56	0.87	0.02	0.03	0.38	0.23	0.46	0.08	0.03	0.05		0.29	0.41
pH		6.5 - 8.5	7.48	0.46	7.74	0.04	7.34	0.38	7.25	0.05	7.81	0.05		7.53	0.32
Eh	mV		-19.00	17.32	-22.40	2.61	-16.33	0.58	4.67	4.04	-17.33	1.15		-14.03	11.99
Conductivity			1.99	0.01	1.11	0.03	0.67	0.01	0.70	0.03	0.69	0.01		1.03	0.52
Temperature	°C		26.83	0.49	26.00	0.42	26.13	0.38	26.63	0.29	26.13	0.76		26.33	0.55
Dissolved Oxygen	%		3.80	2.10	1.92	0.44	1.93	0.46	4.37	0.71	4.73	1.21		3.33	1.60
Total Iron	mg/l	0.3 - 9	0.77	0.26	0.25	0.06	0.20	0.20	0.49	0.19	0.02	0.03		0.34	0.31
Turbidity	NTU		5.86	1.91	5.59	0.00	0.19	0.06	2.86	0.00	1.26	0.10		2.69	3.03
Sulphide	mg/l		0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00		0.00	0.01
Alkalinity	mg/l		637	15.28	550	11.55	400	20.00	300	0.00	420	20.00		461	123.22
Manganese	mg/l	<0.1	0.02	0.00	0.23	0.01	0.52	0.01	0.00	0.00	0.18	0.15		0.29	0.32
Phosphate	mg/l	<6	30.36	2.90	6.10	0.95	5.63	1.39	6.41	0.98	5.89	1.61		10.88	10.19
Chloride	mg/l	150-600	181.0	20.13	66.33	24.09	5.07	3.43	0.00	0.00	0.00	0.00		56.66	73.49
Fluoride	mg/l	<1	2.13	0.20	0.51	0.32	0.61	0.15	0.44	0.01	0.46	0.07		0.83	0.68
Aluminium	mg/l		0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.01	0.01		0.01	0.02
Nitrate	mg/l	<10	0.58	0.12	0.05	0.04	0.03	0.05	0.00	0.00	0.02	0.00		0.13	0.24
Sulphate	mg/l	<100	20.00	6.00	3.67	5.51	0.00	0.00	0.00	0.00	12.50	0.00		6.40	9.94

HAJIGANJ – WELL SUMMARY

Parameter	Units	Bangladesh Acceptable Range	Well 1		Well 2		Well 3		Well 4		Well 5		Mean	Standard deviation
			Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation		
Ferrous Iron	mg/l		2.25	0.53	0.05	0.05	1.17	1.69	1.56	0.59	0.38	0.49	1.08	1.10
pH		6.5 - 8.5	7.07	0.02	7.70	0.11	7.06	0.02	7.20	0.04	7.70	0.03	7.34	0.31
Eh	mV		17.00	0.00	-20.00	4.36	15.00	1.00	10.00	2.00	-7.00	1.00	1.87	14.39
Conductivity			0.52	0.02	0.38	0.03	0.51	0.01	0.92	0.01	0.71	0.34	0.61	0.23
Temperature	°C		25.57	0.12	18.17	13.59	25.50	0.20	24.97	0.45	25.40	0.69	23.92	5.95
Dissolved Oxygen	%		2.30	0.26	2.77	0.55	1.53	0.21	3.87	0.50	3.83	1.57	2.86	1.15
Total Iron	mg/l	0.3 - 9	2.80	0.25	0.57	0.16	1.06	0.27	1.84	0.54	0.50	0.49	1.35	0.95
Turbidity	NTU		1.65	1.04	1.66	0.80	0.31	0.10	46.55	1.06	5.06	0.90	7.94	15.78
Sulphide	mg/l		0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Alkalinity	mg/l		260	20.00	213	11.55	273	11.55	347	23.09	287	11.55	276	46.72
Manganese	mg/l	<0.1	0.09	0.07	0.04	0.00	0.13	0.01	0.12	0.00	0.03	0.00	0.08	0.05
Phosphate	mg/l	<6	3.38	1.29	9.21	0.29	5.55	0.10	7.65	1.65	6.14	0.09	6.39	2.19
Chloride	mg/l	150-600	7.00	3.08	8.47	0.60	10.87	0.70	89.00	15.56	7.60	0.44	19.99	29.62
Fluoride	mg/l	<1	0.09	0.16	0.38	0.24	0.45	0.02	0.27	0.13	0.00	0.00	0.24	0.21
Aluminium	mg/l		BDL	BDL	0.00	0.00	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Nitrate	mg/l	<10	0.15	0.21	0.02	0.02	0.03	0.05	0.00	0.00	0.00	0.00	0.03	0.08
Sulphate	mg/l	<100	0.00	0.00	16.33	23.29	0.00	0.00	0.00	0.00	22.67	19.66	7.80	15.32

ISWARDI – WELL SUMMARY

Parameter	Units	Bangladesh acceptable range	Well 1		Well 2		Well 3		Well 4		Well 5		Mean	Standard deviation
			Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation		
Ferrous Iron	mg/l		0.04	0.02	1.04	0.29	0.11	0.05	0.61	0.47	0.08	0.01	0.19	0.31
pH		6.5 - 8.5	7.18	0.09	7.02	0.14	7.13	0.02	7.22	0.01	7.00	0.06	6.59	1.98
Eh	mV		7.00	4.36	16.67	5.51	9.00	1.00	8.00	1.00	33.67	4.04	13.31	12.09
Conductivity			0.84	0.02	1.01	0.02	0.95	0.02	0.92	0.01	1.81	0.10	1.04	0.50
Temperature	°C		26.30	1.61	24.80	0.99	25.60	0.62	25.93	0.21	25.00	0.00	23.73	7.18
Dissolved Oxygen	%		2.17	0.31	3.27	0.49	1.90	0.36	6.27	1.46	4.23	0.60	3.36	2.14
Total Iron	mg/l	0.3 - 9	0.09	0.04	3.27	0.03	0.17	0.02	0.92	0.27	1.67	0.53	0.66	0.71
Turbidity	NTU		0.28	0.09	11.87	8.26	0.10	0.03	1.05	0.29	6.57	0.44	1.77	2.77
Sulphide	mg/l		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alkalinity	mg/l		353	90.18	493	64.29	567	11.55	520	0.00	707	11.55	495	198.69
Manganese	mg/l	<0.1	0.38	0.30	1.04	0.01	0.24	0.02	0.91	0.11	0.27	0.02	0.42	0.33
Phosphate	mg/l	<6	5.15	4.31	0.31	0.54	3.73	0.29	2.90	0.80	3.31	0.57	3.48	2.25
Chloride	mg/l	150-600	7.03	2.11	43.00	6.73	6.53	0.78	28.20	1.40	2.30	2.02	10.17	10.63
Fluoride	mg/l	<1	0.25	0.31	0.31	0.29	0.15	0.06	0.46	0.20	0.40	0.02	0.29	0.22
Aluminium	mg/l		BDL	BDL	0.04	0.02	0.06	0.02	0.00	0.00	0.00	0.00	0.01	0.03
Nitrate	mg/l	<10	0.03	0.03	0.00	0.00	0.12	0.10	0.07	0.03	0.17	0.15	0.09	0.10
Sulphate	mg/l	<100	0.00	0.00	13.67	16.50	0.00	0.00	16.67	1.15	35.33	2.52	12.00	15.06

KALAROA – WELL SUMMARY

Parameter	Units	Bangladesh acceptable range	Well 1		Well 2		Well 3		Well 4		Well 5		Mean	Standard deviation
			Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation		
Ferrous Iron	mg/l		0.94	0.21	2.20	1.14	4.12	2.03	1.21	0.90	0.58	0.80	1.62	1.76
pH		6.5 - 8.5	6.85	0.07	6.97	0.01	6.95	0.01	6.92	0.03	7.18	0.15	6.42	1.93
Eh	mV		27.67	2.52	21.33	0.58	21.33	0.58	25.00	1.73	30.50	2.89	23.85	7.93
Conductivity			0.88	0.01	1.03	0.01	1.04	0.01	0.98	0.01	0.85	0.07	0.86	0.27
Temperature	°C		26.63	0.45	25.13	0.67	25.63	0.42	27.33	0.15	25.00	0.00	22.45	8.84
Dissolved Oxygen	%		1.77	0.74	1.83	0.67	1.77	0.15	4.87	0.81	5.63	1.02	3.07	2.04
Total Iron	mg/l	0.3 - 9	6.44	2.67	5.57	0.89	10.03	0.31	4.10	0.96	1.40	0.94	5.14	3.65
Turbidity	NTU		0.89	0.25	25.57	10.99	0.52	0.04	4.06	1.92	9.07	1.16	3.24	3.99
Sulphide	mg/l		0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.08	155.31
Alkalinity	mg/l		320	20.00	533	83.27	553	11.55	560	0.00	375	44.35	372	195.86
Manganese	mg/l	<0.1	0.61	0.77	0.13	0.02	0.10	0.02	0.12	0.00	0.20	0.07	0.72	1.70
Phosphate	mg/l	<6	5.03	0.85	2.67	1.09	3.49	2.20	6.19	0.90	2.48	1.03	4.26	2.92
Chloride	mg/l	150-600	22.97	4.72	19.00	5.89	1.21	1.70	10.67	2.52	3.15	0.66	8.47	9.68
Fluoride	mg/l	<1	0.50	0.47	0.40	0.16	0.05	0.08	0.47	0.33	0.50	0.59	0.35	0.43
Aluminium	mg/l		BDL	BDL	0.03	0.00	0.17	0.09	0.02	0.02	0.01	0.01	0.05	0.08
Nitrate	mg/l	<10	0.17	0.12	0.00	0.00	0.00	0.00	0.03	0.06	0.80	0.50	0.25	0.44
Sulphate	mg/l	<100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX 4b

ARSENIC REMOVAL RESULTS FOR TECHNOLOGIES

AND

FEED WATER ARSENIC CONCENTRATIONS

Alcan Enhanced Activated Alumina
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	207	32	15	11	100%
	Rep. B			13	18	100%
	Rep. C			6	6	100%
Well 2	Rep. A	423	33	2	4	100%
	Rep. B			0	0	100%
	Rep. C			0	0	100%
Well 3	Rep. A	271	21	24	15	100%
	Rep. B			8	8	100%
	Rep. C			19	11	100%
Well 4	Rep. A	172	35	4	4	100%
	Rep. B			3	3	100%
	Rep. C			10	4	100%
Well 5	Rep. A	81	26	4	4	100%
	Rep. B			10	10	100%
	Rep. C			3	6	100%
Well 1		**207**	32	11	12	100%
Well 2		**423**	33	1	2	100%
Well 3		**271**	21	17	13	100%
Well 4		**172**	35	6	5	100%
Well5		**81**	26	6	7	100%
Sitakunda		**231**	118	8	8	100%

Alcan Enhanced Activated Alumina
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	175	7	8	11	100%
	Rep. B			3	4	100%
	Rep. C			17	15	100%
Well 2	Rep. A	295	32	11	15	100%
	Rep. B			19	10	100%
	Rep. C			19	29	75%
Well 3	Rep. A	246	33	6	12	100%
	Rep. B			16	10	100%
	Rep. C			10	3	100%
Well 4	Rep. A	159	26	6	10	100%
	Rep. B			9	9	100%
	Rep. C			6	5	100%
Well 5	Rep. A	95	5	7	8	100%
	Rep. B			5	10	100%
	Rep. C			2	2	100%
Well 1		**175**	7	9	11	100%
Well 2		**295**	32	16	18	92%
Well 3		**246**	33	11	9	100%
Well 4		**159**	26	7	8	100%
Well5		**95**	5	5	7	100%
Hajiganj		**207**	81	10	6	98%

Alcan Enhanced Activated Alumina
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% Samples passed
Well 1	Rep. A	174	67	3	2	100%
	Rep. B			5	4	100%
	Rep. C			5	6	100%
Well 2	Rep. A	121	25	3	1	100%
	Rep. B			3	1	100%
	Rep. C			3	1	100%
Well 3	Rep. A	71	26	2	2	100%
	Rep. B			1	2	100%
	Rep. C			1	2	100%
Well 4	Rep. A	89	5	5	1	100%
	Rep. B			5	1	100%
	Rep. C			5	1	100%
Well 5	Rep. A	402	65	4	3	100%
	Rep. B			2	2	100%
	Rep. C			1	1	100%
Well 1		**174**	67	4	4	100%
Well 2		**121**	25	3	1	100%
Well 3		**71**	26	1	2	100%
Well 4		**89**	5	5	1	100%
Well5		**402**	65	2	2	100%
Iswardi		**159**	118	3	3	100%

Alcan Enhanced Activated Alumina
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	175	7	1	1	100%
	Rep. B			2	1	100%
	Rep. C			1	1	100%
Well 2	Rep. A	295	32	2	1	100%
	Rep. B			0	0	100%
	Rep. C			4	5	100%
Well 3	Rep. A	300	65	1	1	100%
	Rep. B			3	7	100%
	Rep. C			0	1	100%
Well 4	Rep. A	159	26	4	1	100%
	Rep. B			6	6	100%
	Rep. C			5	2	100%
Well 5	Rep. A	95	5	0	0	100%
	Rep. B			2	3	100%
	Rep. C			2	2	100%
Well 1		**175**	7	1	1	100%
Well 2		**295**	32	2	3	100%
Well 3		**300**	65	1	4	100%
Well 4		**159**	26	5	3	100%
Well5		**95**	5	1	2	100%
Kalaroa		**211**	85	2	2	100%

Ardasha
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	268	71	238	10	0%
	Rep. B			221	49	0%
	Rep. C			246	13	0%
Well 2	Rep. A	464	95	351	15	0%
	Rep. B			298	47	0%
	Rep. C			317	52	0%
Well 3	Rep. A	311	69	173	106	25%
	Rep. B			273	71	0%
	Rep. C			271	58	0%
Well 4	Rep. A	141	57	126	21	0%
	Rep. B			160	34	0%
	Rep. C			102	77	25%
Well 5	Rep. A	96	67	80	11	0%
	Rep. B			59	14	50%
	Rep. C			57	21	25%
Well 1		**268**	71	235	29	0%
Well 2		**464**	95	322	44	0%
Well 3		**311**	69	239	88	8%
Well 4		**141**	57	130	54	9%
Well5		**96**	67	66	18	25%
Sitakunda		**256**	146	199	198	8%

Ardasha
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	227	25	133	51	0%
	Rep. B			172	28	0%
	Rep. C			128	25	0%
Well 2	Rep. A	585	44	391	162	0%
	Rep. B			404	66	0%
	Rep. C			334	95	0%
Well 3	Rep. A	173	103	176	15	0%
	Rep. B			167	15	0%
	Rep. C			148	33	0%
Well 4	Rep. A	270	39	179	93	25%
	Rep. B			189	128	25%
	Rep. C			211	42	0%
Well 5	Rep. A	673	91	324	51	0%
	Rep. B			352	80	0%
	Rep. C			422	169	0%
Well 1		**227**	25	146	39	0%
Well 2		**585**	44	376	109	0%
Well 3		**173**	103	164	24	0%
Well 4		**270**	39	193	87	17%
Well5		**673**	91	366	110	0%
Hajiganj		**391**	215	251	108	3%

Ardasha
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	204	96	91	10	0%
	Rep. B			94	20	0%
	Rep. C			87	41	0%
Well 2	Rep. A	133	47	61	22	25%
	Rep. B			51	12	50%
	Rep. C			41	21	50%
Well 3	Rep. A	64	8	54	17	50%
	Rep. B			69	20	0%
	Rep. C			53	17	50%
Well 4	Rep. A	101	24	65	23	25%
	Rep. B			54	3	0%
	Rep. C			50	11	50%
Well 5	Rep. A	365	0	58	10	25%
	Rep. B			41	8	100%
	Rep. C			52	9	25%
Well 1		**204**	96	91	25	0%
Well 2		**133**	47	51	19	42%
Well 3		**64**	8	58	18	33%
Well 4		**101**	24	56	15	25%
Well5		**365**	0	50	11	50%
Iswardi		**173**	115	**61**	61	**30%**

Ardasha
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	161	17	68	34	25%
	Rep. B			51	18	25%
	Rep. C			71	31	25%
Well 2	Rep. A	258	47	134	20	0%
	Rep. B			89	21	0%
	Rep. C			142	21	0%
Well 3	Rep. A	252	59	92	72	0%
	Rep. B			86	43	0%
	Rep. C			115	63	0%
Well 4	Rep. A	183	28	46	11	25%
	Rep. B			59	21	25%
	Rep. C			53	10	25%
Well 5	Rep. A	85	7	94	28	0%
	Rep. B			89	43	25%
	Rep. C			76	32	25%
Well 1		**161**	17	63	27	25%
Well 2		**258**	47	121	31	0%
Well 3		**252**	59	97	56	0%
Well 4		**183**	28	53	15	25%
Well5		**85**	7	86	33	17%
Kalaroa		**181**	74	84	29	13%

BUET Activated Alumina
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	213	22	3	6	100%
	Rep. B			2	4	100%
	Rep. C			5	6	100%
Well 2	Rep. A	455	94	1	1	100%
	Rep. B			3	4	100%
	Rep. C			7	10	100%
Well 3	Rep. A	304	66	16	5	100%
	Rep. B			32	19	75%
	Rep. C			11	3	100%
Well 4	Rep. A	123	30	9	18	100%
	Rep. B			5	5	100%
	Rep. C			5	6	100%
Well 5	Rep. A	107	73	5	6	100%
	Rep. B			5	8	100%
	Rep. C			1	3	100%
Well 1		**213**	22	3	5	100%
Well 2		**455**	94	4	6	100%
Well 3		**304**	66	19	14	92%
Well 4		**123**	30	6	10	100%
Well5		**107**	73	4	6	100%
Sitakunda		**240**	141	7	7	98%

BUET Activated Alumina
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	253	35	4	4	100%
	Rep. B			0	0	100%
	Rep. C			18	17	100%
Well 2	Rep. A	627	59	2	4	100%
	Rep. B			37	56	75%
	Rep. C			29	30	67%
Well 3	Rep. A	238	13	0	0	100%
	Rep. B			2	4	100%
	Rep. C			15	19	100%
Well 4	Rep. A	223	89	2	4	100%
	Rep. B			0	0	100%
	Rep. C			4	5	100%
Well 5	Rep. A	520	183	4	7	100%
	Rep. B			1	2	100%
	Rep. C			3	6	100%
Well 1		**253**	35	7	12	100%
Well 2		**627**	59	22	37	82%
Well 3		**238**	13	6	12	100%
Well 4		**223**	89	2	4	100%
Well5		**520**	183	3	5	100%
Hajiganj		**379**	192	8	11	97%

BUET Activated Alumina
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	188	83	1	2	100%
	Rep. B			3	1	100%
	Rep. C			2	1	100%
Well 2	Rep. A	126	50	3	1	100%
	Rep. B			3	2	100%
	Rep. C			3	1	100%
Well 3	Rep. A	67	16	4	6	100%
	Rep. B			1	2	100%
	Rep. C			4	4	100%
Well 4	Rep. A	100	44	4	2	100%
	Rep. B			5	1	100%
	Rep. C			4	2	100%
Well 5	Rep. A	397	71	4	5	100%
	Rep. B			6	6	100%
	Rep. C			3	5	100%
Well 1		**188**	83	2	1	100%
Well 2		**126**	50	3	1	100%
Well 3		**67**	16	3	4	100%
Well 4		**100**	44	4	2	100%
Well5		**397**	71	4	5	100%
Iswardi		**164**	120	3	3	98%

BUET Activated Alumina
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	171	19	2	1	100%
	Rep. B			2	2	100%
	Rep. C			3	2	100%
Well 2	Rep. A	275	21	1	2	100%
	Rep. B			1	1	100%
	Rep. C			3	3	100%
Well 3	Rep. A	227	28	3	6	100%
	Rep. B			1	1	100%
	Rep. C			3	6	100%
Well 4	Rep. A	173	39	4	2	100%
	Rep. B			4	2	100%
	Rep. C			4	2	100%
Well 5	Rep. A	90	16	2	2	100%
	Rep. B			4	5	100%
	Rep. C			2	1	100%
Well 1		**171**	19	2	2	100%
Well 2		**275**	21	2	2	100%
Well 3		**227**	28	2	4	100%
Well 4		**173**	39	4	2	100%
Well5		**90**	16	2	3	100%
Kalaroa		**198**	61	2	1	100%

DPHE/Danida 2-bucket
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	265	77	260	31	0%
	Rep. B			219	61	0%
	Rep. C			201	27	0%
Well 2	Rep. A	466	49	168	28	0%
	Rep. B			171	12	0%
	Rep. C			114	25	0%
Well 3	Rep. A	266	101	54	25	25%
	Rep. B			45	18	50%
	Rep. C			24	24	75%
Well 4	Rep. A	175	61	22	35	75%
	Rep. B			9	9	100%
	Rep. C			11	13	100%
Well 5	Rep. A	73	37	34	29	75%
	Rep. B			9	7	100%
	Rep. C			14	12	100%
Well 1		**265**	77	227	46	0%
Well 2		**466**	49	151	34	0%
Well 3		**266**	101	41	24	50%
Well 4		**175**	61	14	21	92%
Well5		**73**	37	20	21	91%
Sitakunda		**249**	144	92	90	46%

DPHE/Danida 2-bucket
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	230	85	88	43	25%
	Rep. B			127	18	0%
	Rep. C			100	41	0%
Well 2	Rep. A	548	79	150	76	0%
	Rep. B			112	39	0%
	Rep. C			127	65	0%
Well 3	Rep. A	170	123	132	41	0%
	Rep. B			94	18	0%
	Rep. C			74	26	25%
Well 4	Rep. A	325	19	156	17	0%
	Rep. B			135	17	0%
	Rep. C			112	53	0%
Well 5	Rep. A	622	61	254	43	0%
	Rep. B			158	66	0%
	Rep. C			219	31	0%
Well 1		**230**	85	105	37	8%
Well 2		**548**	79	130	58	0%
Well 3		**170**	123	100	37	8%
Well 4		**325**	19	134	36	0%
Well5		**622**	61	210	61	0%
Hajiganj		**379**	188	136	60	3%

DPHE/Danida 2-bucket
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	149	71	47	14	50%
	Rep. B			25	10	100%
	Rep. C			36	14	100%
Well 2	Rep. A	119	23	49	13	50%
	Rep. B			45	12	75%
	Rep. C			37	10	100%
Well 3	Rep. A	67	16	16	2	100%
	Rep. B			32	6	100%
	Rep. C			28	11	100%
Well 4	Rep. A	100	44	19	8	100%
	Rep. B			9	4	100%
	Rep. C			10	4	100%
Well 5	Rep. A	369	81	49	28	50%
	Rep. B			58	27	25%
	Rep. C			55	24	50%
Well 1		**149**	71	36	15	83%
Well 2		**119**	23	44	12	75%
Well 3		**67**	16	25	10	100%
Well 4		**100**	44	12	7	100%
Well5		**369**	81	54	24	42%
Iswardi		**161**	118	34	20	80%

DPHE/Danida 2-bucket
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	186	37	78	30	25%
	Rep. B			100	37	0%
	Rep. C			76	13	0%
Well 2	Rep. A	263	21	74	14	0%
	Rep. B			75	13	0%
	Rep. C			80	10	0%
Well 3	Rep. A	235	39	159	25	0%
	Rep. B			168	3	0%
	Rep. C			161	44	0%
Well 4	Rep. A	170	40	81	32	25%
	Rep. B			74	22	0%
	Rep. C			74	23	25%
Well 5	Rep. A	90	16	79	10	0%
	Rep. B			83	30	0%
	Rep. C			63	4	0%
Well 1		**186**	37	85	28	8%
Well 2		**263**	21	76	12	0%
Well 3		**235**	39	163	27	0%
Well 4		**170**	40	76	24	17%
Well5		**90**	16	75	19	0%
Kalaroa		**189**	60	95	41	5%

GARNET							
Sitakunda							
		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	268	71	174	76	0%
	Rep. B			162	17	0%
	Rep. C			184	82	0%
Well 2	Rep. A	455	94	15	16	100%
	Rep. B			25	32	75%
	Rep. C			6	5	100%
Well 3	Rep. A	311	69	140	154	50%
	Rep. B			30	22	75%
	Rep. C			33	17	75%
Well 4	Rep. A	141	57	16	11	100%
	Rep. B			23	26	75%
	Rep. C			14	20	100%
Well 5	Rep. A	96	67	10	5	100%
	Rep. B			1	1	100%
	Rep. C			9	5	100%
Well 1		**268**	71	174	62	0%
Well 2		**455**	94	15	20	92%
Well 3		**311**	69	68	98	67%
Well 4		**141**	57	18	19	92%
Well5		**96**	67	7	6	100%
Sitakunda		**254**	144	54	56	71%

GARNET						
Hajiganj						
		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	227	25	81	48	25%
	Rep. B			50	50	50%
	Rep. C			67	20	25%
Well 2	Rep. A	610	79	203	101	0%
	Rep. B			180	134	25%
	Rep. C			145	74	0%
Well 3	Rep. A	196	78	8	8	100%
	Rep. B			43	21	50%
	Rep. C			30	8	100%
Well 4	Rep. A	300	53	18	15	100%
	Rep. B			43	8	100%
	Rep. C			53	38	50%
Well 5	Rep. A	646	93	30	26	75%
	Rep. B			6	7	100%
	Rep. C			31	28	75%
Well 1		**227**	25	66	40	33%
Well 2		**610**	79	176	99	8%
Well 3		**196**	78	27	20	83%
Well 4		**300**	53	38	26	83%
Well5		**646**	93	22	24	83%
Hajiganj		**416**	204	66	61	58%

GARNET						
Iswardi						
		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	204	96	30	12	100%
	Rep. B			13	9	100%
	Rep. C			18	3	100%
Well 2	Rep. A	130	47	12	11	100%
	Rep. B			25	7	100%
	Rep. C			29	6	100%
Well 3	Rep. A	62	9	44	16	75%
	Rep. B			75	27	25%
	Rep. C			57	34	50%
Well 4	Rep. A	101	24	19	1	100%
	Rep. B			25	3	100%
	Rep. C			27	5	100%
Well 5	Rep. A	365	0	28	14	100%
	Rep. B			22	22	100%
	Rep. C			29	7	100%
Well 1		**204**	96	20	11	100%
Well 2		**130**	47	22	11	100%
Well 3		**62**	9	59	27	50%
Well 4		**101**	24	23	5	100%
Well5		**365**	0	27	14	100%
Iswardi		**172**	116	30	30	90%

GARNET						
Kalaroa						
		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	161	17	30	3	100%
	Rep. B			22	9	100%
	Rep. C			31	5	100%
Well 2	Rep. A	264	47	45	8	50%
	Rep. B			68	16	0%
	Rep. C			73	7	0%
Well 3	Rep. A	250	56	28	10	100%
	Rep. B			10	10	100%
	Rep. C			11	7	100%
Well 4	Rep. A	185	25	33	20	100%
	Rep. B			19	9	100%
	Rep. C			27	11	100%
Well 5	Rep. A	92	19	38	11	75%
	Rep. B			25	12	100%
	Rep. C			28	12	100%
Well 1		**161**	17	28	7	100%
Well 2		**264**	47	62	16	17%
Well 3		**250**	56	16	12	100%
Well 4		**185**	25	26	13	100%
Well5		**92**	19	30	12	92%
Kalaroa		**201**	66	32	18	81%

Passive Sedimentation
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	282	59	339	151	0%
	Rep. B			288	83	0%
	Rep. C			259	109	0%
Well 2	Rep. A	437	72	435	54	0%
	Rep. B			340	170	0%
	Rep. C			384	126	0%
Well 3	Rep. A	292	46	314	19	0%
	Rep. B			308	78	0%
	Rep. C			319	76	0%
Well 4	Rep. A	152	51	162	50	0%
	Rep. B			203	129	0%
	Rep. C			220	12	0%
Well 5	Rep. A	84	45	96	46	0%
	Rep. B			72	14	0%
	Rep. C			102	45	0%
Well 1		**282**	59	**295**	112	0%
Well 2		**437**	72	**387**	121	0%
Well 3		**292**	46	**314**	60	0%
Well 4		**152**	51	**193**	80	0%
Well5		**84**	45	**90**	36	0%
Sitakunda		**249**	133	**259**	135	0%

Passive Sedimentation
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	267	80	212	35	0%
	Rep. B			205	59	0%
	Rep. C			230	78	0%
Well 2	Rep. A	610	79	474	116	0%
	Rep. B			550	58	0%
	Rep. C			493	37	0%
Well 3	Rep. A	228	91	218	102	0%
	Rep. B			203	43	0%
	Rep. C			206	141	0%
Well 4	Rep. A	283	57	272	55	0%
	Rep. B			273	42	0%
	Rep. C			315	114	0%
Well 5	Rep. A	621	79	650	86	0%
	Rep. B			539	59	0%
	Rep. C			592	109	0%
Well 1		**267**	80	**216**	55	0%
Well 2		**610**	79	**506**	78	0%
Well 3		**228**	91	**209**	97	0%
Well 4		**283**	57	**287**	72	0%
Well5		**621**	79	**594**	92	0%
Hajiganj		**402**	191	**367**	177	0%

Passive Sedimentation
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	204	96	124	43	0%
	Rep. B			120	0	0%
	Rep. C			140	47	0%
Well 2	Rep. A	133	47	119	36	0%
	Rep. B			123	24	0%
	Rep. C			115	16	0%
Well 3	Rep. A	64	8	68	17	25%
	Rep. B			73	12	0%
	Rep. C			58	11	25%
Well 4	Rep. A	94	28	98	44	0%
	Rep. B			113	49	0%
	Rep. C			116	50	0%
Well 5	Rep. A	365	0	331	27	0%
	Rep. B			324	19	0%
	Rep. C			327	11	0%
Well 1		**204**	96	128	34	0%
Well 2		**133**	47	119	25	0%
Well 3		**64**	8	66	14	17%
Well 4		**94**	28	109	44	0%
Well5		**365**	0	327	18	0%
Iswardi		**172**	117	150	97	3%

Passive Sedimentation
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	161	17	166	44	0%
	Rep. B			136	37	0%
	Rep. C			127	35	0%
Well 2	Rep. A	258	47	194	64	0%
	Rep. B			255	22	0%
	Rep. C			244	43	0%
Well 3	Rep. A	225	67	259	30	0%
	Rep. B			259	35	0%
	Rep. C			214	25	0%
Well 4	Rep. A	185	25	158	35	0%
	Rep. B			142	66	0%
	Rep. C			187	53	0%
Well 5	Rep. A	94	16	82	13	0%
	Rep. B			112	57	0%
	Rep. C			98	14	0%
Well 1		**161**	17	143	39	0%
Well 2		**258**	47	231	50	0%
Well 3		**225**	67	244	35	0%
Well 4		**185**	25	160	51	0%
Well5		**94**	16	97	34	0%
Kalaroa		**184**	64	175	69	0%

Sono 3-kolshi
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	226	39	13	16	100%
	Rep. B			42	13	75%
	Rep. C			28	5	100%
Well 2	Rep. A	463	47	3	5	100%
	Rep. B			13	7	100%
	Rep. C			17	14	100%
Well 3	Rep. A	309	59	22	12	100%
	Rep. B			25	12	100%
	Rep. C			23	6	100%
Well 4	Rep. A	204	39	9	7	100%
	Rep. B			10	7	100%
	Rep. C			12	9	100%
Well 5	Rep. A	65	36	4	5	100%
	Rep. B			7	11	100%
	Rep. C			15	11	100%
Well 1		**226**	39	28	17	92%
Well 2		**463**	47	11	10	100%
Well 3		**309**	59	23	9	100%
Well 4		**204**	39	10	7	100%
Well5		**65**	36	9	10	100%
Sitakunda		**253**	138	16	16	98%

Sono 3-kolshi
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	219	38	18	14	100%
	Rep. B			13	17	100%
	Rep. C			8	12	100%
Well 2	Rep. A	287	201	23	3	100%
	Rep. B			21	28	75%
	Rep. C			7	8	100%
Well 3	Rep. A	205	95	26	12	100%
	Rep. B			11	4	100%
	Rep. C			27	27	75%
Well 4	Rep. A	312	46	8	15	100%
	Rep. B			9	7	100%
	Rep. C			4	8	100%
Well 5	Rep. A	613	82	21	16	100%
	Rep. B			19	26	75%
	Rep. C			8	6	100%
Well 1		**219**	38	13	14	100%
Well 2		[redacted]	201	17	17	92%
Well 3		**205**	95	21	17	92%
Well 4		**312**	46	7	10	100%
Well5		**613**	82	16	17	92%
Hajiganj		**324**	185	15	8	95%

Sono 3-kolshi
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	148	69	7	6	100%
	Rep. B			3	2	100%
	Rep. C			3	2	100%
Well 2	Rep. A	110	27	12	7	100%
	Rep. B			11	6	100%
	Rep. C			12	9	100%
Well 3	Rep. A	72	26	10	3	100%
	Rep. B			13	5	100%
	Rep. C					
Well 4	Rep. A					
	Rep. B					
	Rep. C					
Well 5	Rep. A					
	Rep. B					
	Rep. C					
Well 1		**148**	69	4	4	100%
Well 2		**110**	27	12	7	100%
Well 3		**72**	26	11	4	100%
Well 4						
Well5						
Iswardi		**110**	51	9	6	100%

Wells 3,4 and 5 not surveyed - kolshi's broken in transit

Sono 3-kolshi
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	186	37	8	3	100%
	Rep. B			8	4	100%
	Rep. C			6	3	100%
Well 2	Rep. A	269	51	15	6	100%
	Rep. B			20	4	100%
	Rep. C			7	3	100%
Well 3	Rep. A	220	47	17	2	100%
	Rep. B			16	3	100%
	Rep. C			16	2	100%
Well 4	Rep. A	203	14	9	2	100%
	Rep. B			19	6	100%
	Rep. C			21	5	100%
Well 5	Rep. A	91	14	15	7	100%
	Rep. B			11	9	100%
	Rep. C			12	4	100%
Well 1		**186**	37	7	3	100%
Well 2		**269**	51	14	7	100%
Well 3		**220**	47	16	2	100%
Well 4		**203**	14	16	7	100%
Well5		**91**	14	13	6	100%
Kalaroa		**199**	64	13	5	100%

Stevens Institute
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	265	77	49	30	50%
	Rep. B			8	8	100%
	Rep. C			20	27	75%
Well 2	Rep. A	453	28	0	0	100%
	Rep. B			2	3	100%
	Rep. C			3	5	100%
Well 3	Rep. A	314	52	14	11	100%
	Rep. B			12	11	100%
	Rep. C			13	15	100%
Well 4	Rep. A	167	56	3	3	100%
	Rep. B			22	12	100%
	Rep. C			0	0	100%
Well 5	Rep. A	78	22	0	0	100%
	Rep. B			1	2	100%
	Rep. C			7	10	100%
Well 1		**265**	77	26	28	75%
Well 2		**453**	28	1	3	100%
Well 3		**314**	52	13	11	100%
Well 4		**167**	56	8	12	100%
Well5		**78**	22	3	6	100%
Sitakunda		**255**	137	10	17	95%

Stevens Institute
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	225	34	52	8	50%
	Rep. B			28	19	75%
	Rep. C			31	18	75%
Well 2	Rep. A	545	76	1	2	100%
	Rep. B			1	2	100%
	Rep. C			12	17	100%
Well 3	Rep. A	216	120	36	60	75%
	Rep. B			6	5	100%
	Rep. C			28	17	100%
Well 4	Rep. A	295	41	4	3	100%
	Rep. B			24	14	100%
	Rep. C			56	37	25%
Well 5	Rep. A	629	72	3	0	100%
	Rep. B			3	4	100%
	Rep. C			0	0	100%
Well 1		**225**	34	37	18	67%
Well 2		**545**	76	5	11	100%
Well 3		**216**	120	23	35	92%
Well 4		**295**	41	28	31	75%
Well5		**629**	72	2	4	100%
Hajiganj		**391**	184	19	26	87%

Stevens Institute
Iswardi

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	149	71	7	5	100%
	Rep. B			6	7	100%
	Rep. C			4	4	100%
Well 2	Rep. A	116	24	3	1	100%
	Rep. B			3	2	100%
	Rep. C			4	1	100%
Well 3	Rep. A	79	26	3	2	100%
	Rep. B			3	1	100%
	Rep. C			9	6	100%
Well 4	Rep. A	93	6	6	2	100%
	Rep. B			6	2	100%
	Rep. C			5	1	100%
Well 5	Rep. A	335	0	11	8	100%
	Rep. B			11	7	100%
	Rep. C			10	3	100%
Well 1		**149**	71	6	5	100%
Well 2		**116**	24	3	1	100%
Well 3		**79**	26	5	5	100%
Well 4		**93**	6	6	2	100%
Well5		**335**	0	11	6	100%
Iswardi		**154**	99	6	5	100%

Stevens Institute
Kalaroa

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	184	37	13	3	100%
	Rep. B			6	3	100%
	Rep. C			10	3	100%
Well 2	Rep. A	116	24	7	2	100%
	Rep. B			7	3	100%
	Rep. C			13	5	100%
Well 3	Rep. A	285	77	18	5	100%
	Rep. B			20	8	100%
	Rep. C			11	4	100%
Well 4	Rep. A	181	15	16	9	100%
	Rep. B			7	5	100%
	Rep. C			6	3	100%
Well 5	Rep. A	85	9	3	3	100%
	Rep. B			3	4	100%
	Rep. C			2	3	100%
Well 1		**184**	37	10	4	100%
Well 2		**116**	24	9	4	100%
Well 3		**285**	77	16	7	100%
Well 4		**181**	15	10	8	100%
Well5		**85**	9	3	3	100%
Kalaroa		**171**	81	9	7	100%

Tetra Hedron
Sitakunda

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	259	72	47	36	50%
	Rep. B			56	43	50%
	Rep. C			63	86	75%
Well 2	Rep. A	444	22	122	131	25%
	Rep. B			59	61	50%
	Rep. C			113	126	25%
Well 3	Rep. A	311	53	10	10	100%
	Rep. B			19	12	100%
	Rep. C			25	22	75%
Well 4	Rep. A	161	49	2	5	100%
	Rep. B			0	0	100%
	Rep. C			13	21	100%
Well 5	Rep. A	62	18	1	2	100%
	Rep. B			169	166	50%
	Rep. C			12	15	100%
Well 1		**259**	72	55	54	58%
Well 2		**444**	22	98	104	33%
Well 3		**311**	53	18	15	92%
Well 4		**161**	49	5	13	100%
Well5		**62**	18	61	118	83%
Sitakunda		**247**	138	47	47	73%

Tetra Hedron
Hajiganj

		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	243	45	63	35	50%
	Rep. B			74	48	25%
	Rep. C			78	85	50%
Well 2	Rep. A	545	76	236	158	0%
	Rep. B			243	177	25%
	Rep. C			180	86	0%
Well 3	Rep. A	247	22	7	8	100%
	Rep. B			9	5	100%
	Rep. C			13	2	100%
Well 4	Rep. A	246	104	42	78	75%
	Rep. B			74	104	50%
	Rep. C			45	48	75%
Well 5	Rep. A	664	82	132	67	25%
	Rep. B			45	60	75%
	Rep. C			12	12	100%
Well 1		**243**	45	72	55	42%
Well 2		**545**	76	[redacted]	135	8%
Well 3		**247**	22	10	6	100%
Well 4		**246**	104	54	74	67%
Well5		**664**	82	63	71	67%
Hajiganj		**396**	194	84	79	57%

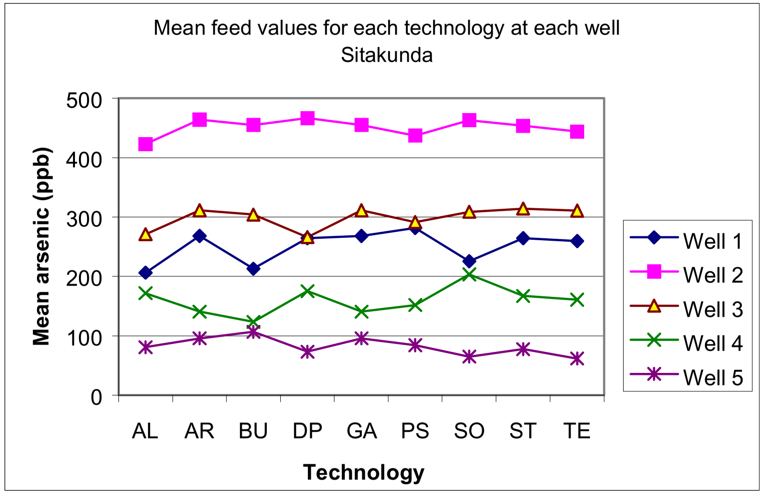
Tetra Hedron
Iswardi

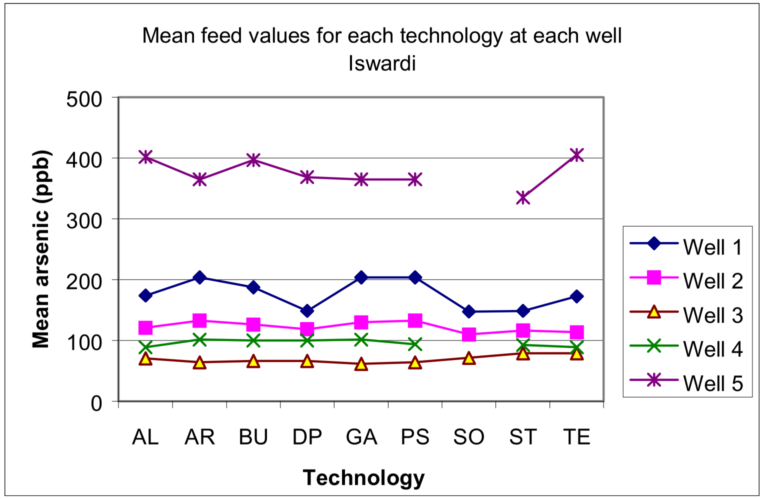
		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	173	68	11	4	100%
	Rep. B			6	3	100%
	Rep. C			5	4	100%
Well 2	Rep. A	114	26	5	3	100%
	Rep. B			5	4	100%
	Rep. C			6	4	100%
Well 3	Rep. A	79	26	3	3	100%
	Rep. B			2	3	100%
	Rep. C			3	3	100%
Well 4	Rep. A	89	5	9	6	100%
	Rep. B			7	2	100%
	Rep. C			8	3	100%
Well 5	Rep. A	405	81	11	9	100%
	Rep. B			20	19	100%
	Rep. C			13	6	100%
Well 1		**173**	68	7	4	100%
Well 2		**114**	26	5	3	100%
Well 3		**79**	26	3	3	100%
Well 4		**89**	5	8	3	100%
Well5		**405**	81	15	12	100%
Iswardi		**172**	130	7	7	100%

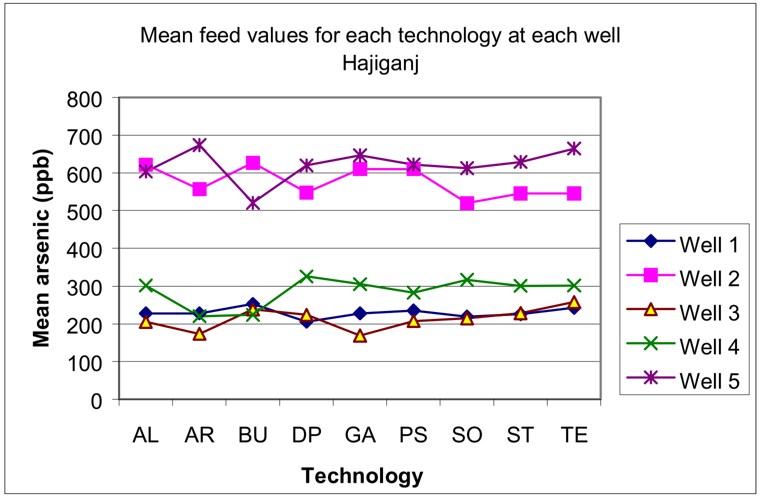
Tetra Hedron
Kalaroa

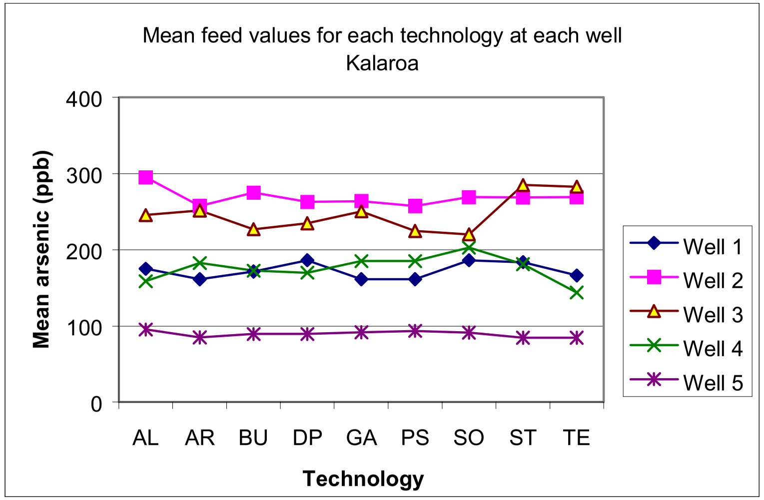
		Feed Mean	Feed Std. Dev	Treated mean	Treated Std. Dev	% samples passed
Well 1	Rep. A	166	19	15	5	100%
	Rep. B			8	3	100%
	Rep. C			6	6	100%
Well 2	Rep. A	269	20	27	17	100%
	Rep. B			43	16	50%
	Rep. C			18	12	100%
Well 3	Rep. A	283	79	3	4	100%
	Rep. B			7	5	100%
	Rep. C			6	6	100%
Well 4	Rep. A	144	59	16	14	100%
	Rep. B			17	19	100%
	Rep. C			19	23	75%
Well 5	Rep. A	85	9	9	3	100%
	Rep. B			20	4	100%
	Rep. C			29	8	100%
Well 1		**166**	19	9	6	100%
Well 2		**269**	20	29	18	83%
Well 3		**283**	79	5	5	100%
Well 4		**144**	59	17	17	92%
Well5		**85**	9	19	10	100%
Kalaroa		**201**	83	16	11	95%

MEAN ARSENIC CONCENTRATIONS FOR FEED WATER FOR EACH TECHNOLOGY AT EACH WELL









APPENDIX 4C

TREATED WATER
ALUMINIUM AND MANGANESE CONCENTRATIONS

SITAKUNDA

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	0.37	0.03	0.08
	2	BDL	0.17	0.23	0.15
	3	BDL	0.18	0.13	0.12
	4	BDL	BDL	1.16	0.54
	5	BDL	BDL	0.27	0.12
BUET	1	BDL	0.06	0.03	0.01
	2	BDL	BDL	0.23	BDL
	3	BDL	BDL	0.13	0.01
	4	BDL	0.05	1.16	0.01
	5	BDL	0.10	0.27	0.03
ALCAN	1	BDL	BDL		
	2	BDL	BDL		
	3	BDL	BDL		
	4	BDL	BDL		
	5	BDL	BDL		

Observations: -

- Mean aluminium concentrations of treated water from the DPHE/DANIDA technology are either below detection limit or greater than those of the filtered feed water .

- Mean manganese concentrations in the filtered feed water appear to be reduced by the DPHE/DANIDA technology at all wells except Well 1 where a slight increase of 0.05 mg/l occurs.

- Aluminium concentrations in feed waters passed through the BUET technology increase at three wells but are below detection limit at two. However, in all cases, aluminium concentrations in the treated water are below the guideline maximum drinking water standard of 0.2 mg/l.

- Manganese concentrations in the feed waters which are above the guideline maximum drinking water standard at four of the five wells, are reduced to well below the standard by the BUET technology.

- Mean Aluminium concentrations in both filtered feed water and treated water from the ALCAN activated alumina technology are below detection limit at all wells.

HAJIGANJ

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	0.17	0.09	0.32
	2	BDL	0.06	0.04	0.08
	3	BDL	0.28	0.13	1.02
	4	BDL	BDL	0.12	0.41
	5	BDL	0.38	0.03	0.19
BUET	1	BDL	BDL	0.09	0.06
	2	BDL	BDL	0.04	BDL
	3	BDL	BDL	0.13	0.04
	4	BDL	BDL	0.12	0.04
	5	BDL	BDL	0.03	BDL
ALCAN	1	BDL	BDL		
	2	BDL	BDL		
	3	BDL	BDL		
	4	BDL	BDL		
	5	BDL	0.12		

Observations: -

- Mean Aluminium and Manganese concentrations in treated water from the DPHE/DANIDA technology are invariably higher than those of the filtered feed water and in two cases, concentrations originally below the guideline drinking water standards in the feed waters exceed the guidelines in the treated waters.

- Mean Aluminium and Manganese concentrations in treated water from the BUET technology are either below detection limit or less than those in the filtered feed water suggesting that the elements are partially removed by the technology.

- Mean Aluminium concentrations in both filtered feed water and treated water from the ALCAN activated alumina technology are predominantly below detection limit except at Well 5 where there appears to be an increase in Aluminium concentration in the treated water.

ISWARDI

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	BDL	0.38	0.07
	2	BDL	0.13	1.04	1.35
	3	0.06	0.33	0.24	0.45
	4	BDL	BDL	0.91	0.78
	5	BDL	BDL	0.27	1.56
BUET	1	BDL	BDL	0.38	0.04
	2	BDL	BDL	1.04	0.43
	3	0.06	BDL	0.24	0.02
	4	BDL	BDL	0.91	0.03
	5	BDL	BDL	0.27	0.07
ALCAN	1	BDL	BDL		
	2	BDL	0.06		
	3	0.06	0.05		
	4	BDL	BDL		
	5	BDL	BDL		

Observations: -

- Mean aluminium concentrations in treated water from the DPHE/DANIDA technology are either below detection limit or higher than those of the filtered feed water suggesting that the technology is resulting in an increase in aluminium concentration.

- Mean managanese concentrations in treated water from the DPHE/DANIDA technology are lower than those in the feed water at wells 1 and 4. Conversely, they are higher than those in the filtered feed water at wells 2, 3 and 5. Treated water concentrations of manganese exceed the guideline drinking water standard (0.1 mg/l) at four wells.

- Mean aluminium and managanese concentrations in treated water from the BUET technology are either below detection limit or significantly less than those in the filtered feed water. Manganese concentrations of the filtered feed water appear to be at least halved by the technology.

- Mean aluminium concentrations in both filtered feed water and treated water from the ALCAN activated alumina technology are predominantly below, or close to, detection limit (0.05 mg/l).

KALAROA

Technology	Well No.	Mean Aluminium Concentration (mg/l)		Mean Manganese Concentration (mg/l)	
		Feed Water (filtered)	Treated Water	Feed Water (filtered)	Treated Water
DPHE/DANIDA	1	BDL	0.07	0.61	0.66
	2	BDL	0.11	0.13	0.62
	3	0.17	0.36	0.10	0.65
	4	BDL	BDL	0.12	0.81
	5	BDL	BDL	0.20	0.60
BUET	1	BDL	BDL	0.61	0.15
	2	BDL	BDL	0.13	0.02
	3	0.17	0.11	0.10	0.03
	4	BDL	BDL	0.12	0.03
	5	BDL	BDL	0.20	0.01
ALCAN	1	BDL	BDL		
	2	BDL	BDL		
	3	0.17	0.24		
	4	BDL	BDL		
	5	BDL	BDL		

Observations: -

- Mean aluminium concentrations in treated water from the DPHE/DANIDA technology are either below detection limit or higher than those of the filtered feed water suggesting that the technology is resulting in an increase in aluminium concentration. At Well 3, mean aluminium concentrations are increased to exceed the guideline maximum drinking water concentration (0.2 mg/l)

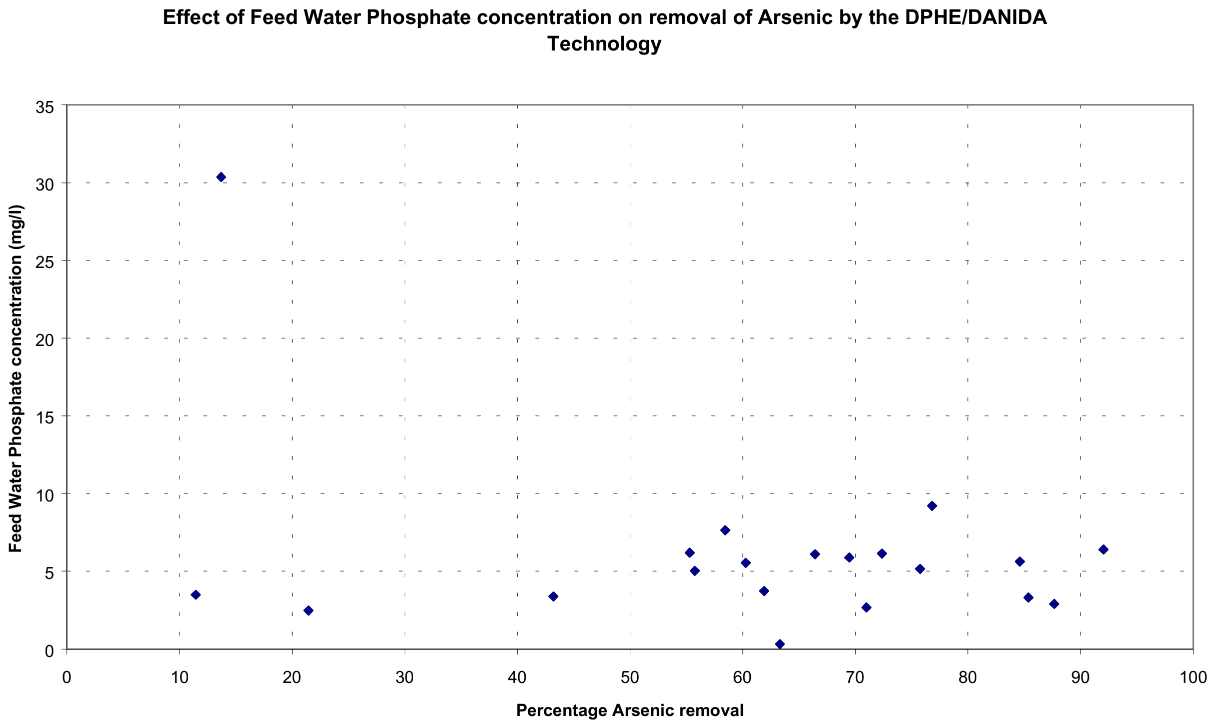
- Mean managanese concentrations in treated water from the DPHE/DANIDA technology are higher than those in the filtered feed water at all wells suggesting that the technology is resulting in an increase in manganese concentration. Both feed and treated water manganese concentrations all match or exceed the guideline maximum drinking water standard of 0.1 mg/l.

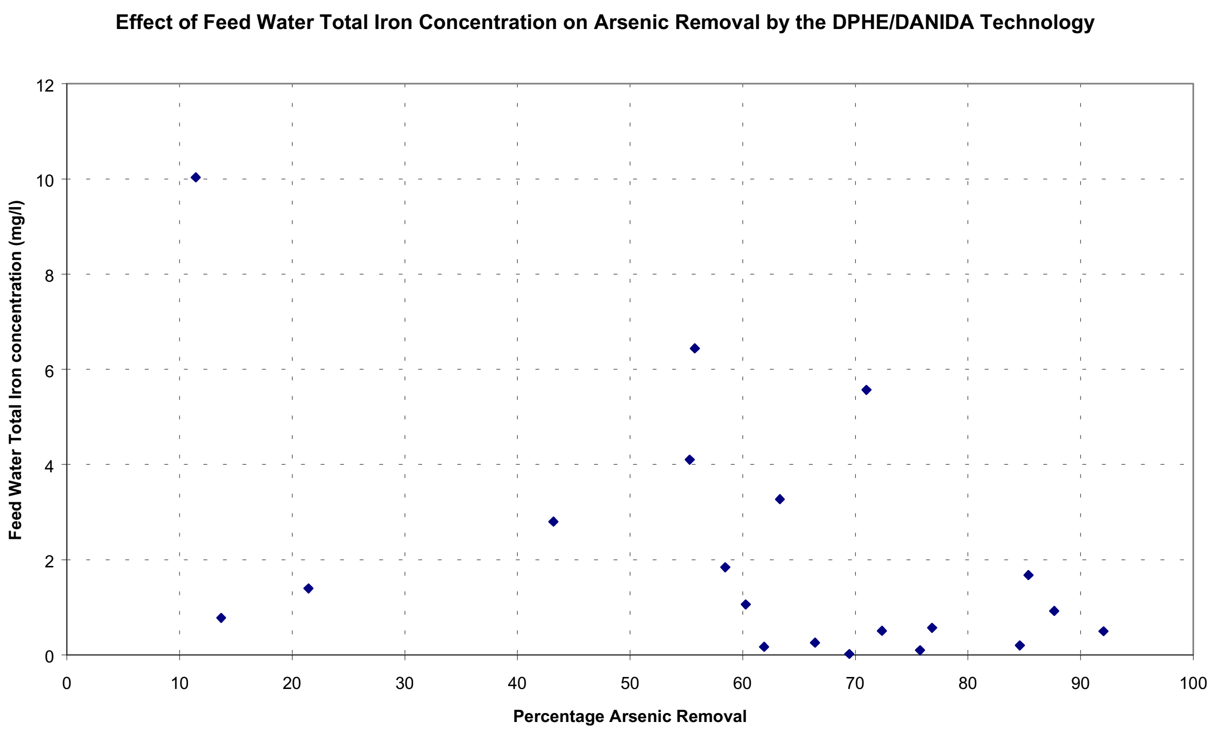
- Mean aluminium and managanese concentrations in treated water from the BUET technology are either below detection limit or significantly less than those in the filtered feed water. Manganese concentrations of the filtered feed water appear to be reduced by a factor of at least 3 and are reduced below the guideline maximum drinking water concentration at all but one well.

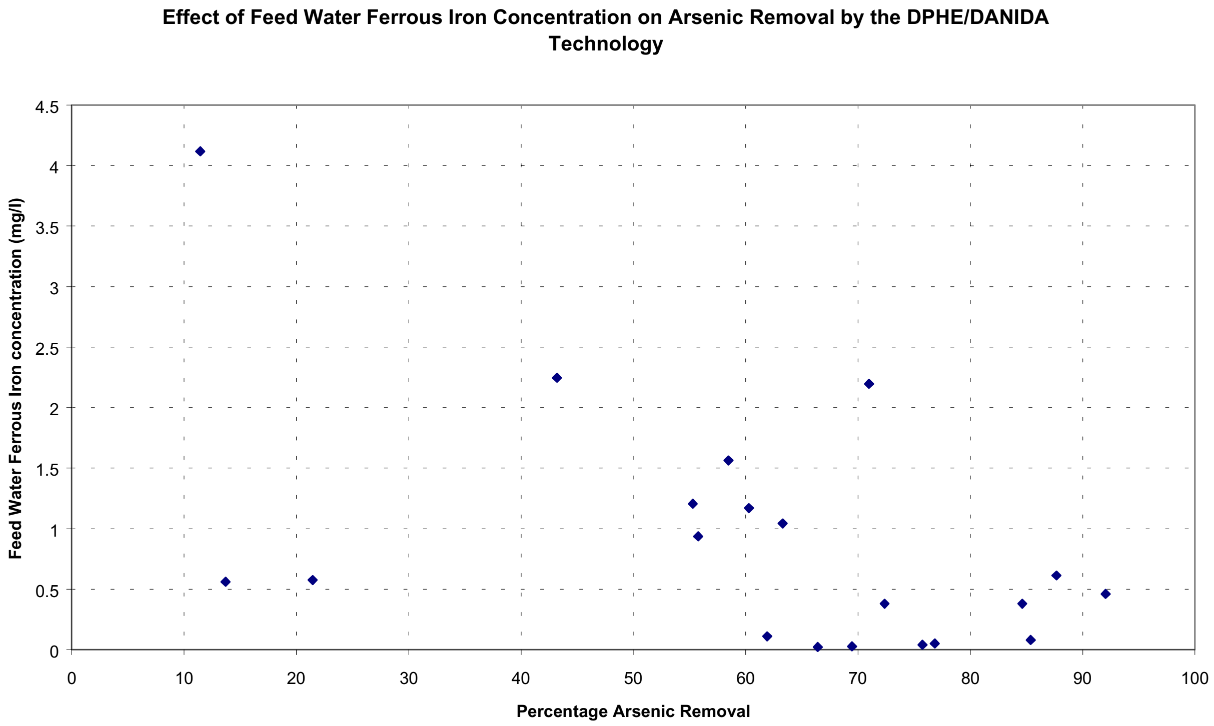
- Mean aluminium concentrations in both filtered feed water and treated water from the ALCAN activated alumina technology are predominantly below detection limit (0.05 mg/l) except at Well 3 where the mean aluminium concentration is increased by 0.05 mg/l.

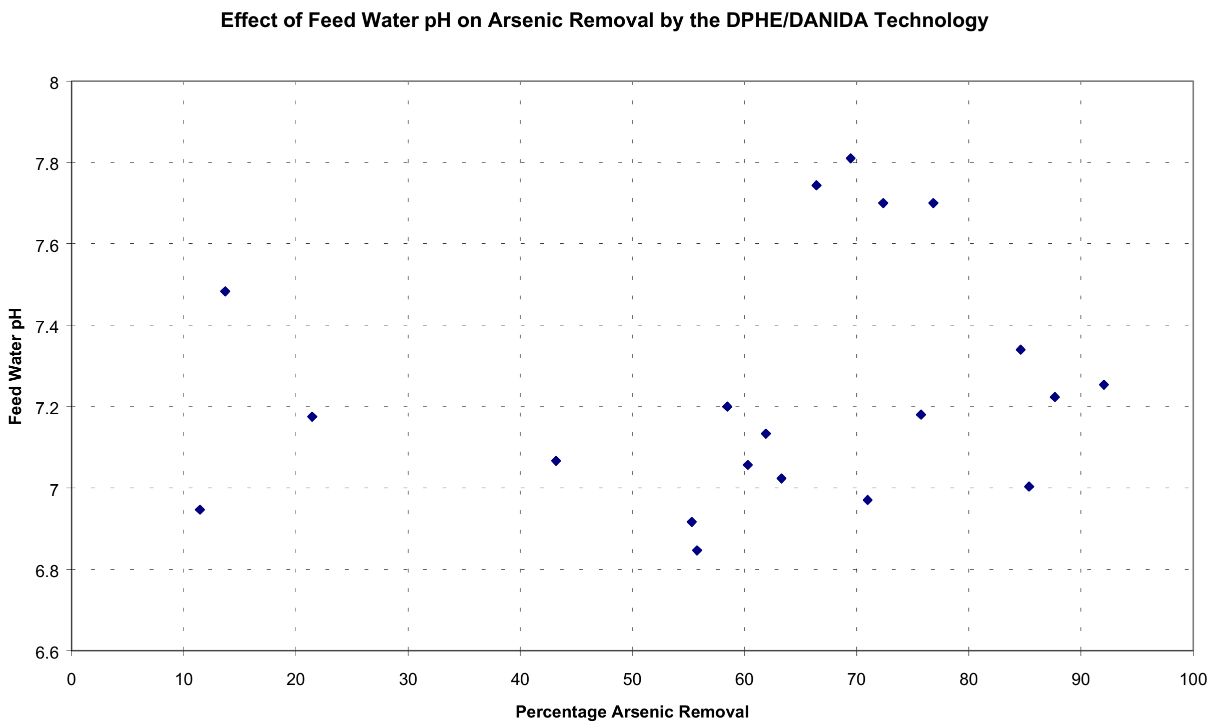
APPENDIX 5

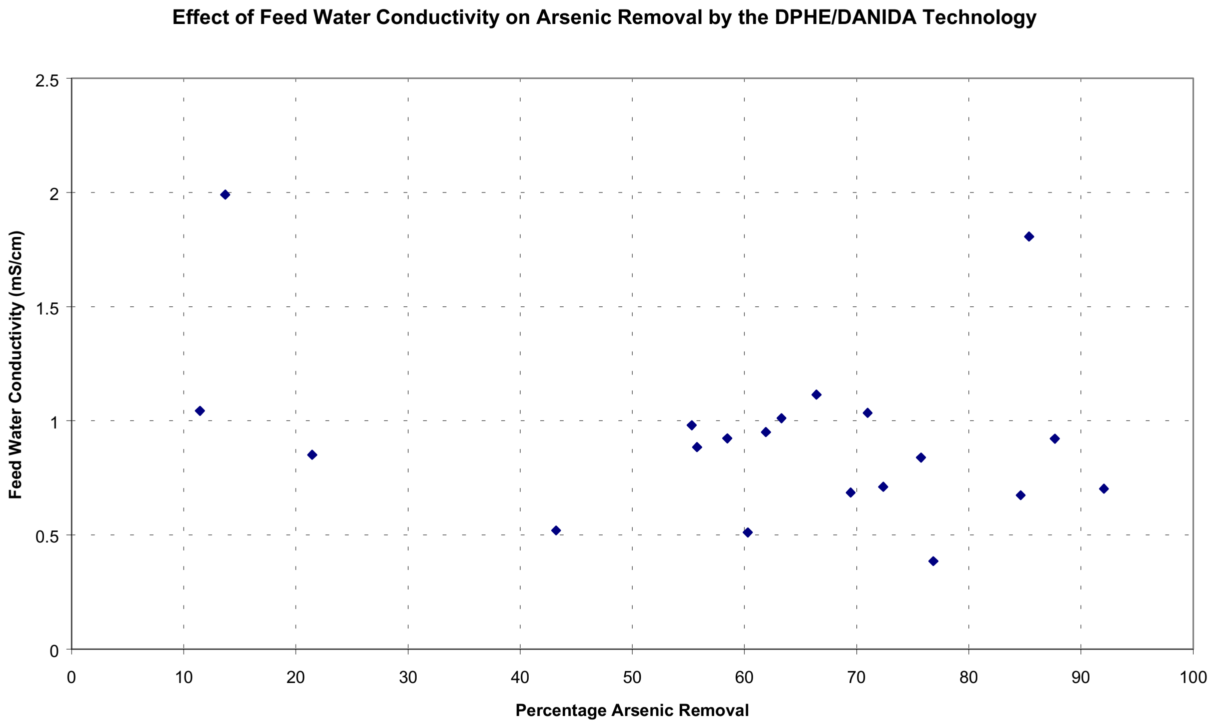
CORRELATION BETWEEN ARSENIC REMOVAL AND NON-ARSENIC PARAMETERS FOR TECHNOLOGIES WITH VARIABLE PERFORMANCE

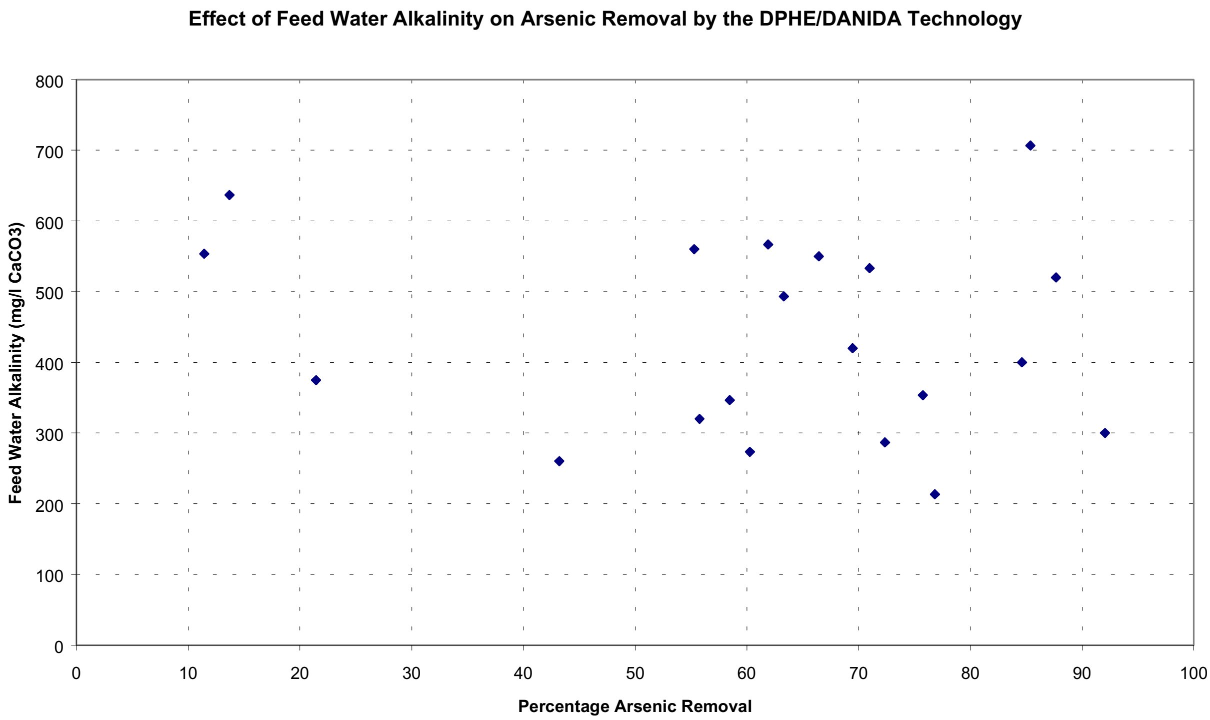

Effect of Feed Water Phosphate concentration on removal of Arsenic by the DPHE/DANIDA Technology
Feed Water Phosphate concentration (mg/l)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic removal


Effect of Feed Water Total Iron Concentration on Arsenic Removal by the DPHE/DANIDA Technology
Feed Water Total Iron concentration (mg/l)
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic Removal

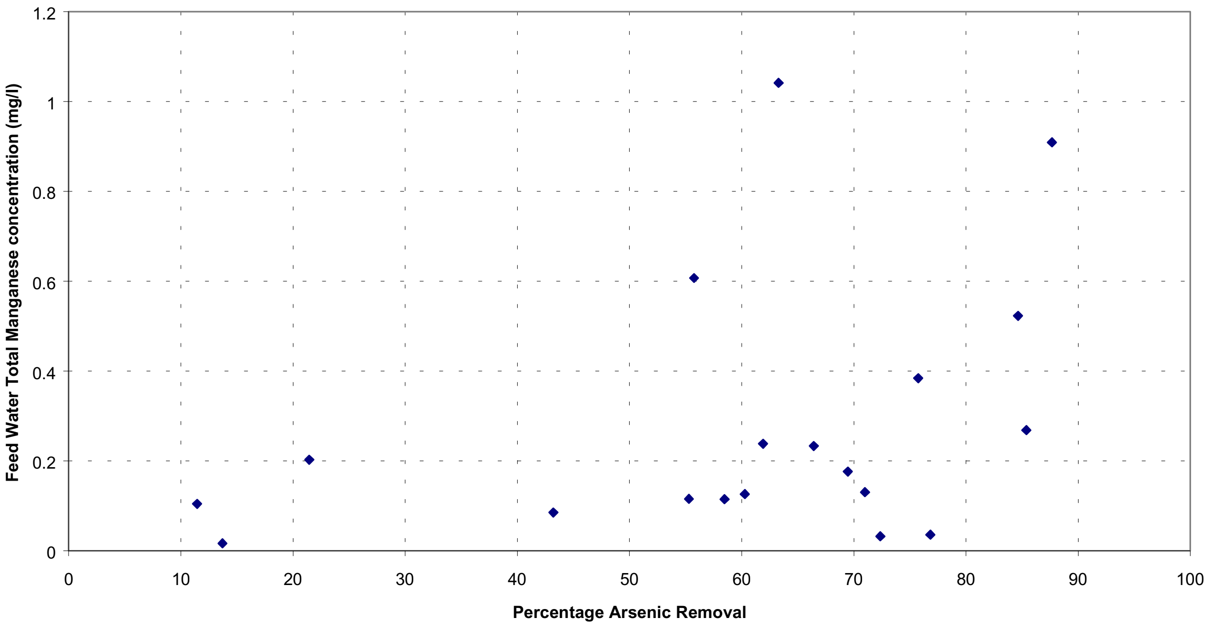

Effect of Feed Water Ferrous Iron Concentration on Arsenic Removal by the DPHE/DANIDA Technology
Feed Water Ferrous Iron concentration (mg/l)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic Removal


Effect of Feed Water pH on Arsenic Removal by the DPHE/DANIDA Technology
Feed Water pH
8
7.8
7.6
7.4
7.2
7
6.8
6.6
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic Removal

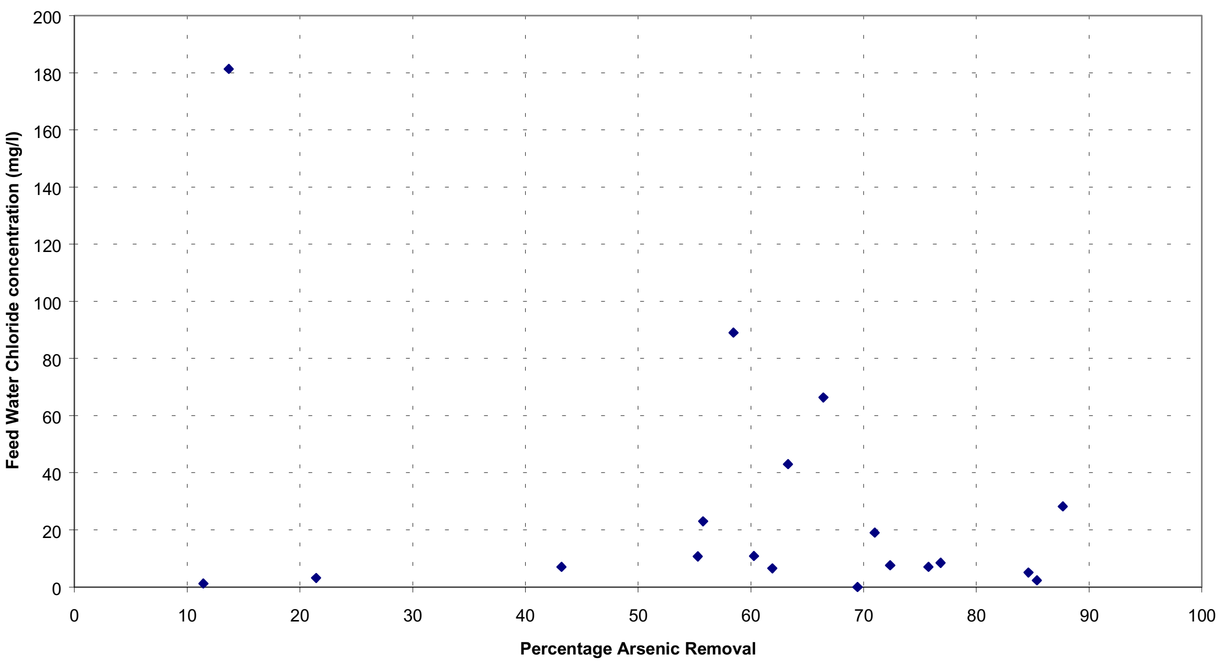

Effect of Feed Water Conductivity on Arsenic Removal by the DPHE/DANIDA Technology
Feed Water Conductivity (mS/cm)
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic Removal

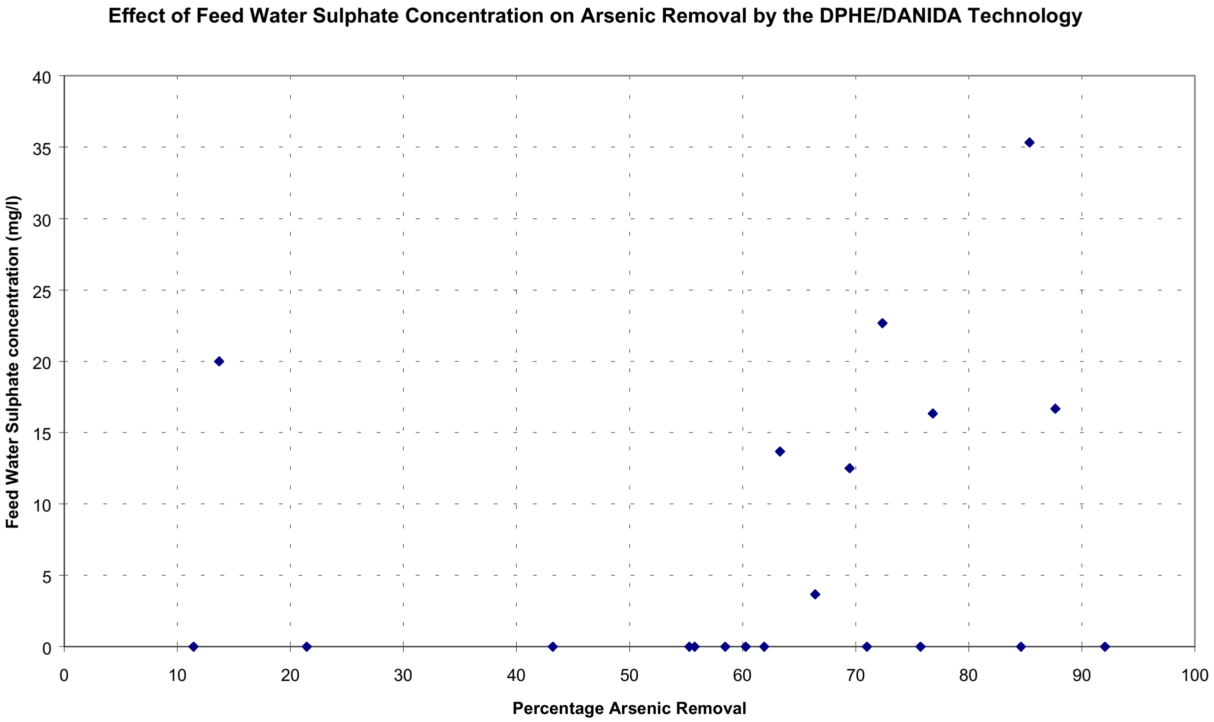

Effect of Feed Water Alkalinity on Arsenic Removal by the DPHE/DANIDA Technology
Feed Water Alkalinity (mg/l CaCO3)
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic Removal

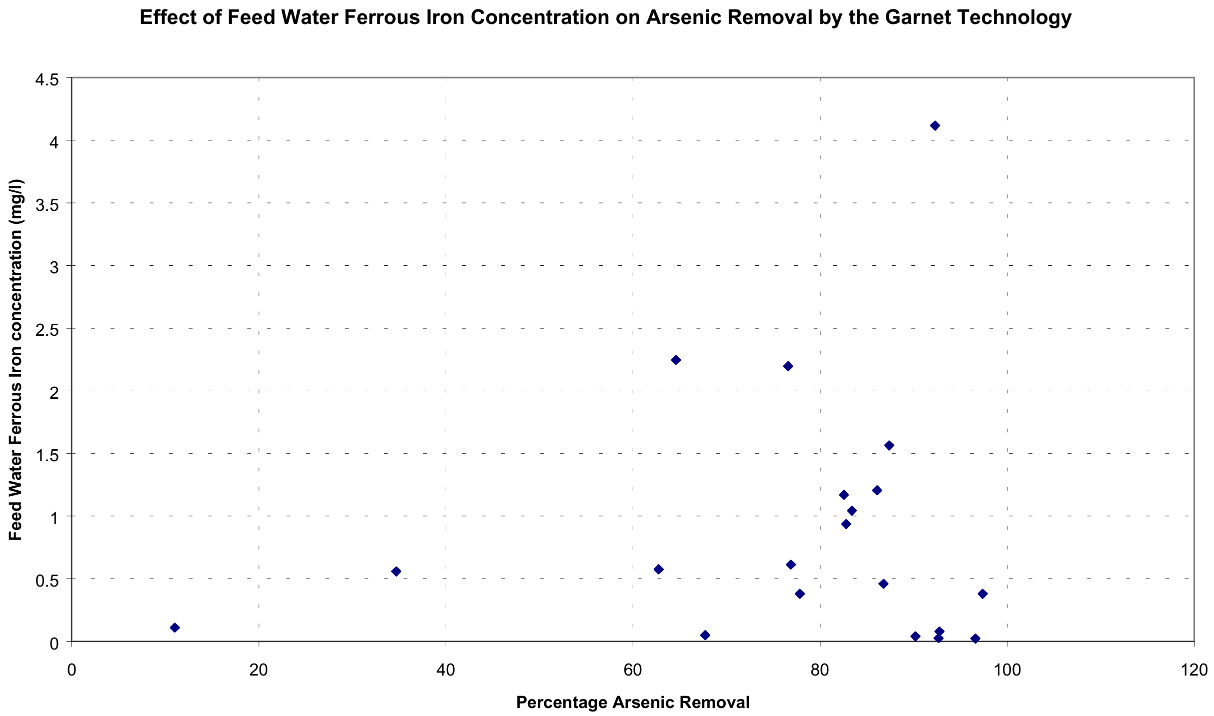
Effect of Feed Water Total Manganese Concentration on Arsenic Removal by the DPHE/DANIDA Technology

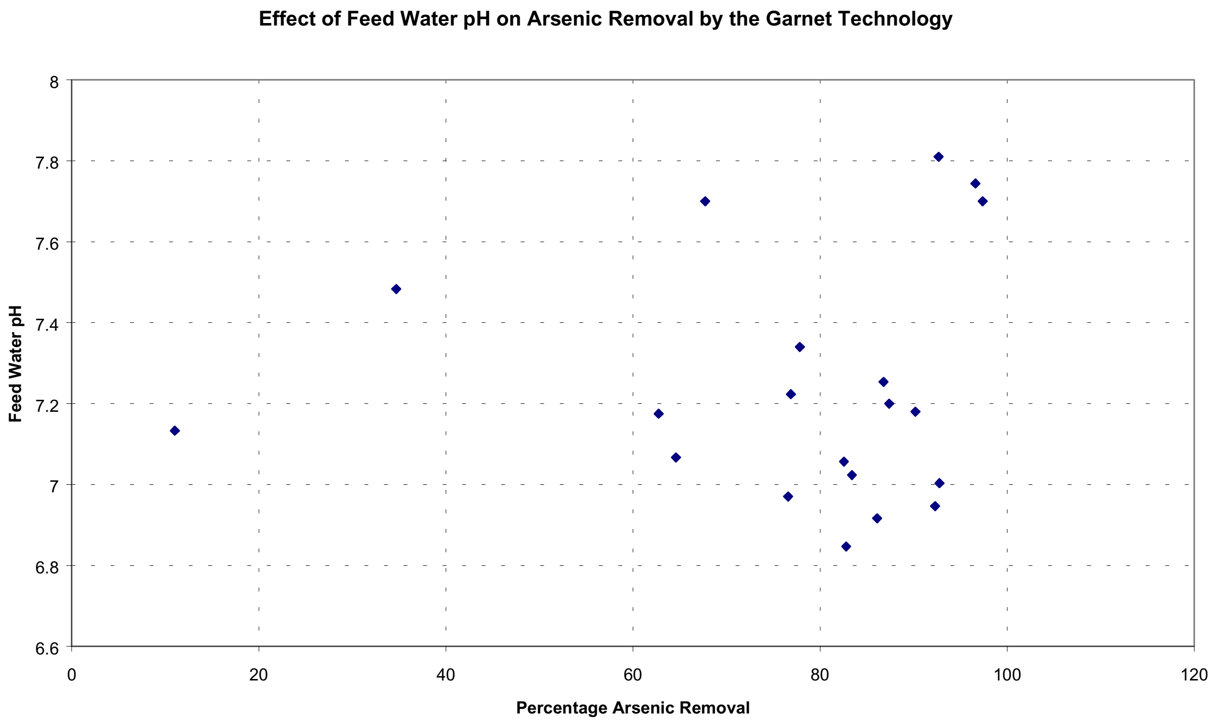


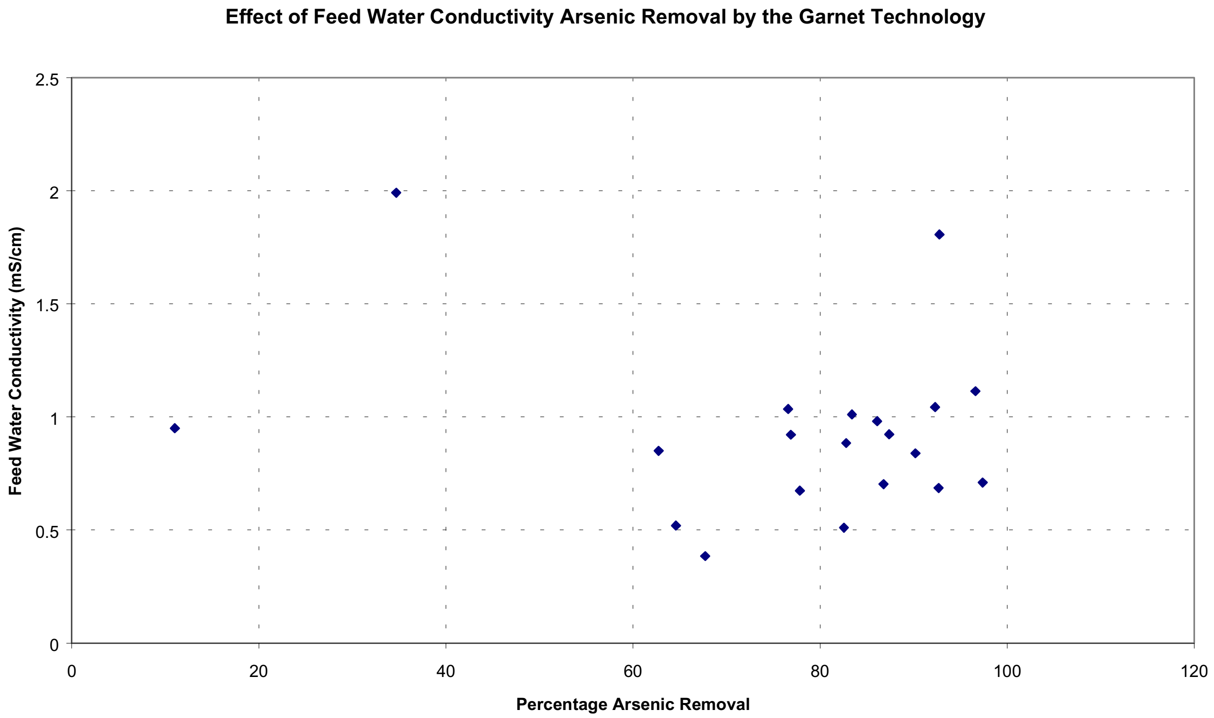
Effect of Feed Water Chloride Concentration on Arsenic Removal by the DPHE/DANIDA Technology

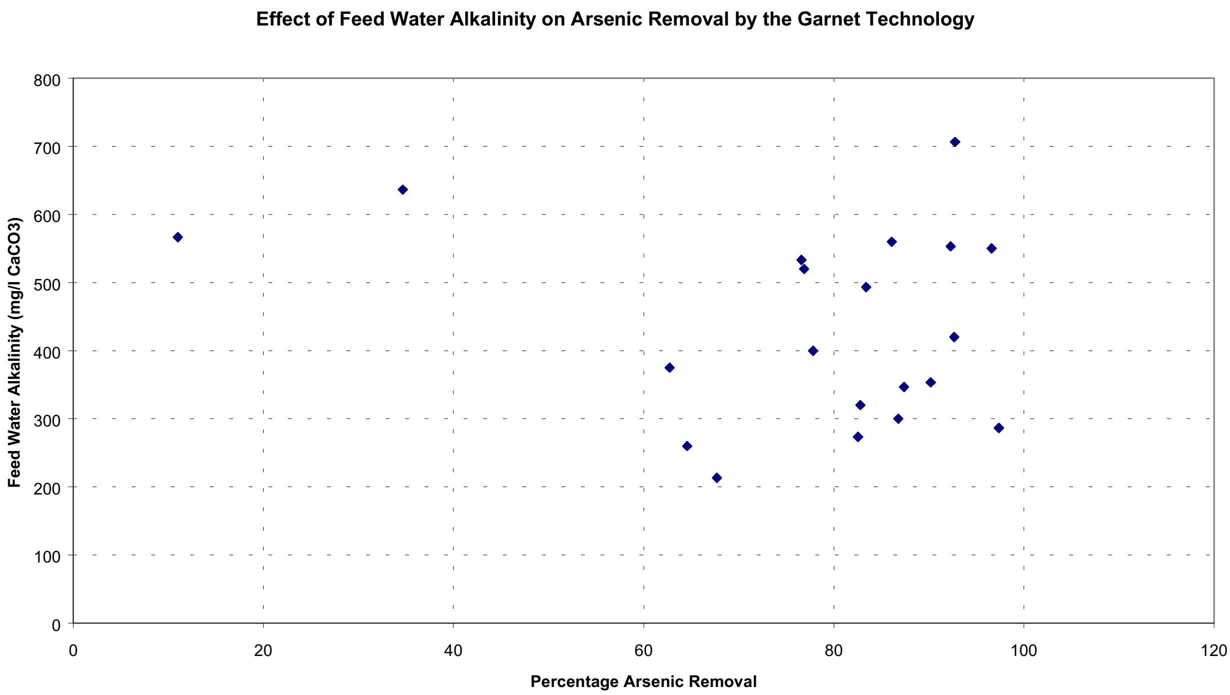



Effect of Feed Water Sulphate Concentration on Arsenic Removal by the DPHE/DANIDA Technology
Feed Water Sulphate concentration (mg/l)
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Percentage Arsenic Removal

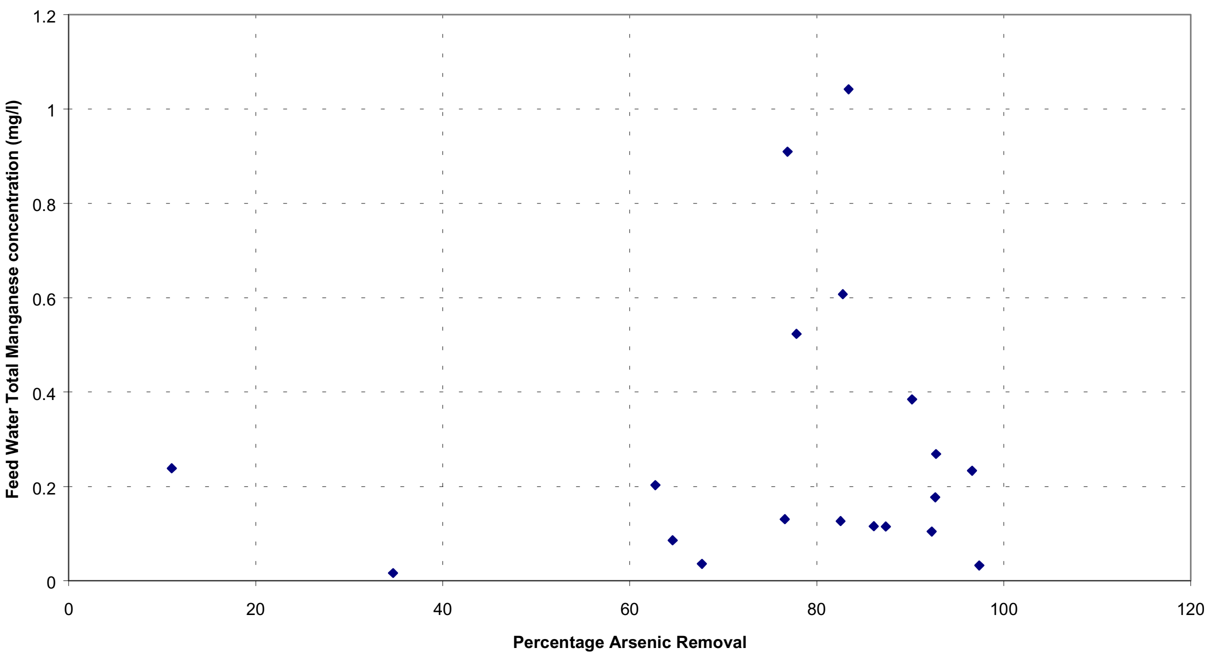

Effect of Feed Water Ferrous Iron Concentration on Arsenic Removal by the Garnet Technology
Feed Water Ferrous Iron concentration (mg/l)
Percentage Arsenic Removal
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
20
40
60
80
100
120


Effect of Feed Water pH on Arsenic Removal by the Garnet Technology
Feed Water pH
Percentage Arsenic Removal
6.6
6.8
7
7.2
7.4
7.6
7.8
8
0
20
40
60
80
100
120

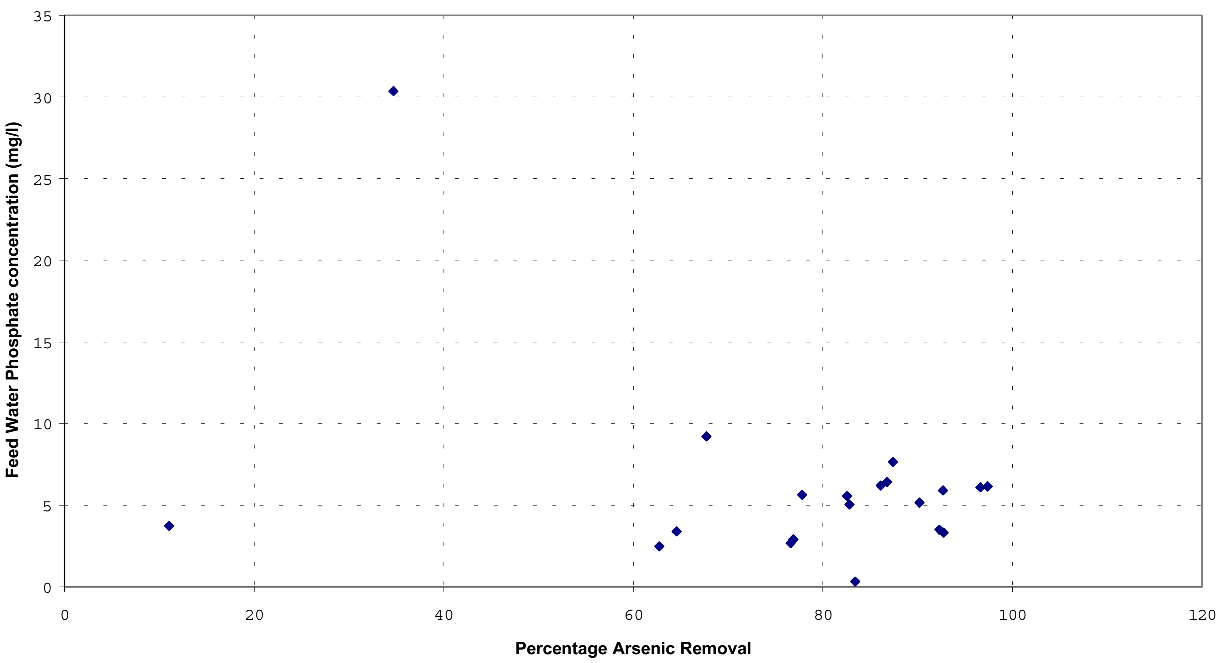

Effect of Feed Water Conductivity Arsenic Removal by the Garnet Technology
Feed Water Conductivity (mS/cm)
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
Percentage Arsenic Removal


Effect of Feed Water Alkalinity on Arsenic Removal by the Garnet Technology
Feed Water Alkalinity (mg/l CaCO3)
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
Percentage Arsenic Removal

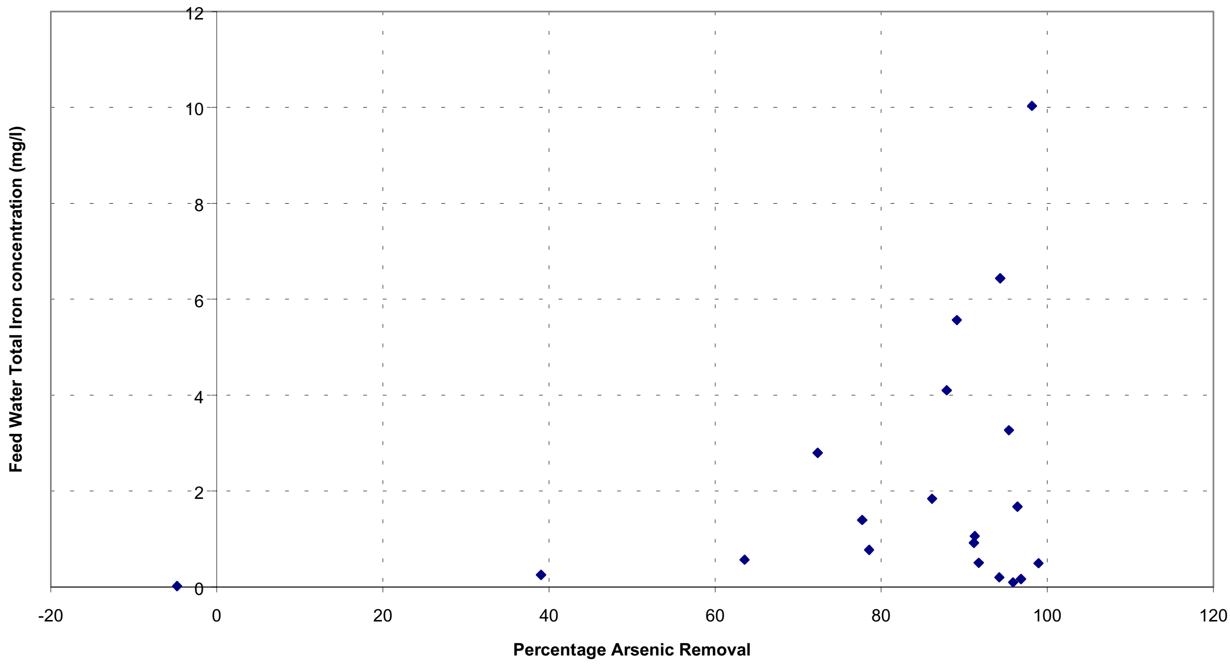
Effect of Feed Water Total Manganese Concentration on Arsenic Removal by the Garnet Technology



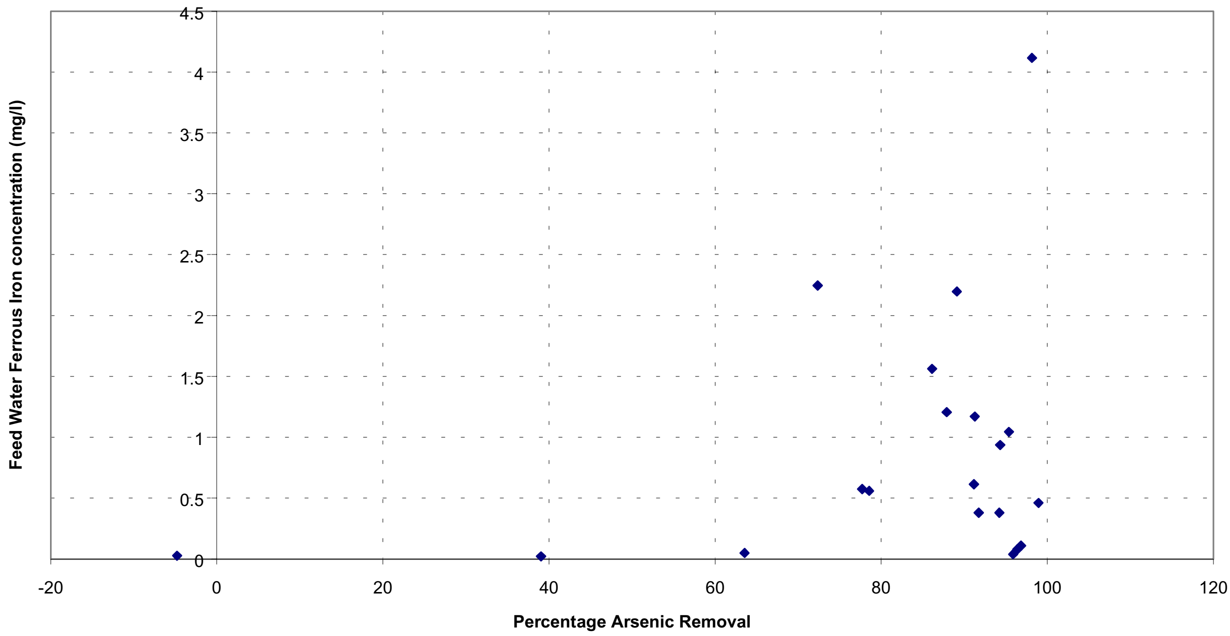
Effect of Feed Water Phosphate Concentration on Arsenic Removal by the Garnet Technology

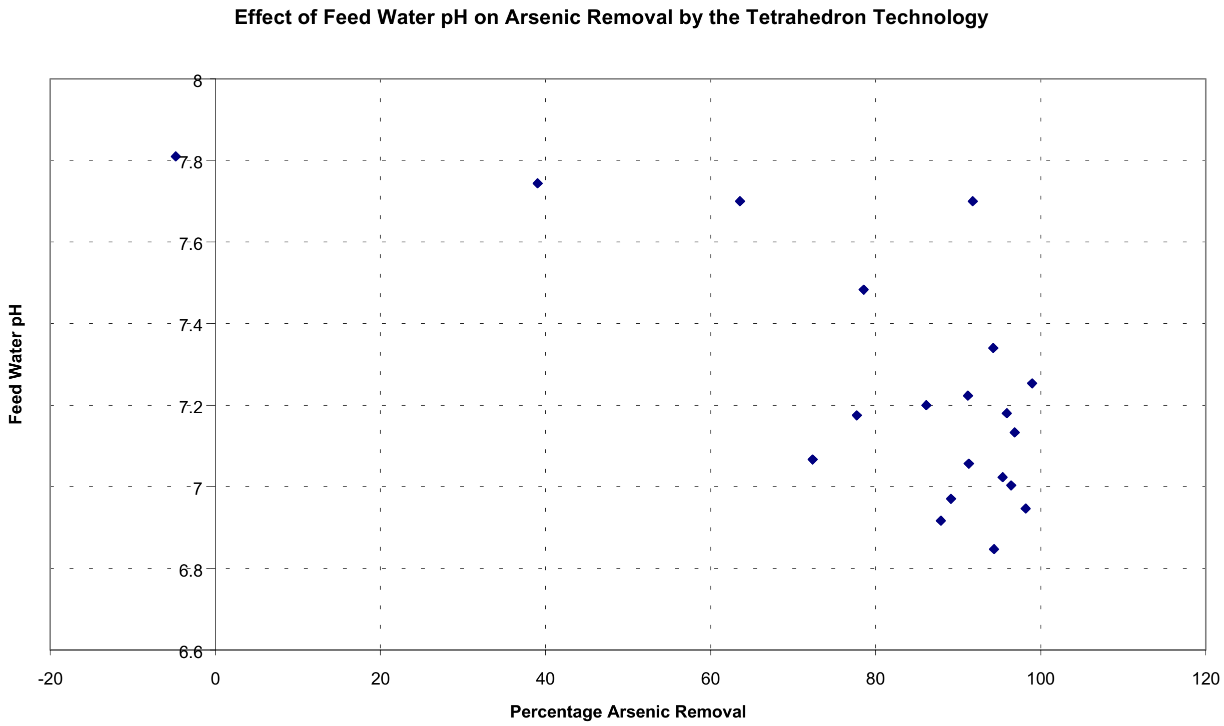


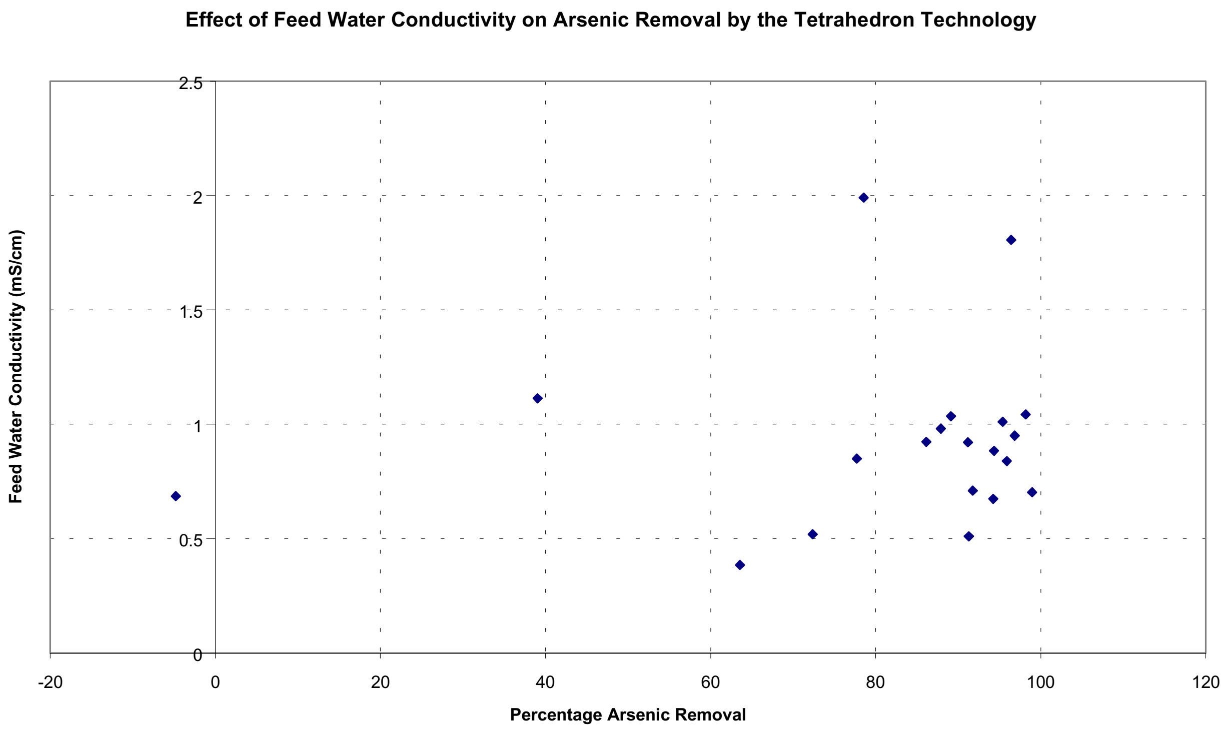
Effect of Feed Water Total Iron Concentration on Arsenic Removal by the Tetrahedron Technology



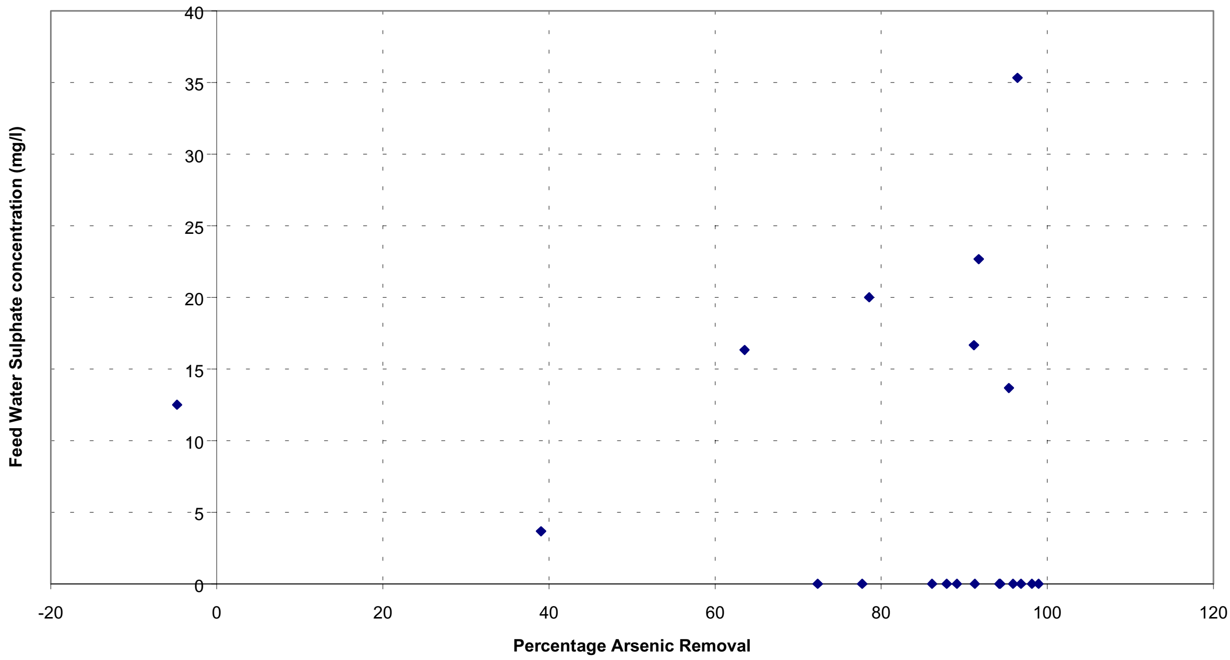
Effect of Feed Water Ferrous Iron Concentration on Arsenic Removal by the Tetrahedron Technology



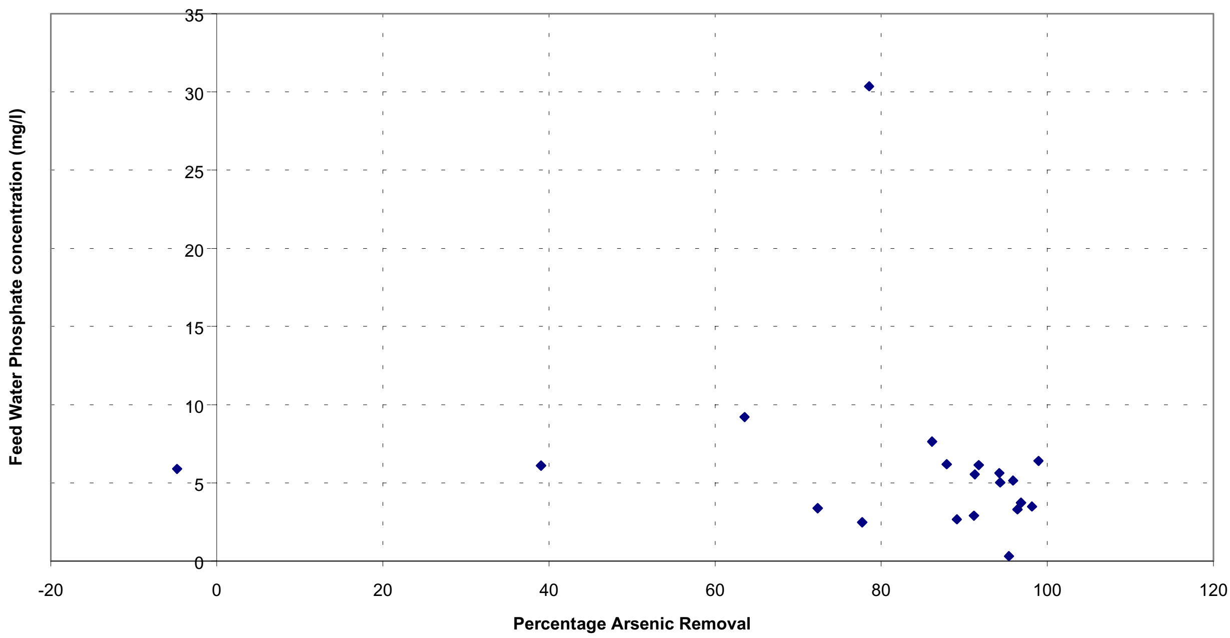

Effect of Feed Water pH on Arsenic Removal by the Tetrahedron Technology
Feed Water pH
8
7.8
7.6
7.4
7.2
7
6.8
6.6
-20
0
20
40
60
80
100
120
Percentage Arsenic Removal


Effect of Feed Water Conductivity on Arsenic Removal by the Tetrahedron Technology
Feed Water Conductivity (mS/cm)
2.5
2
1.5
1
0.5
0
-20
0
20
40
60
80
100
120
Percentage Arsenic Removal

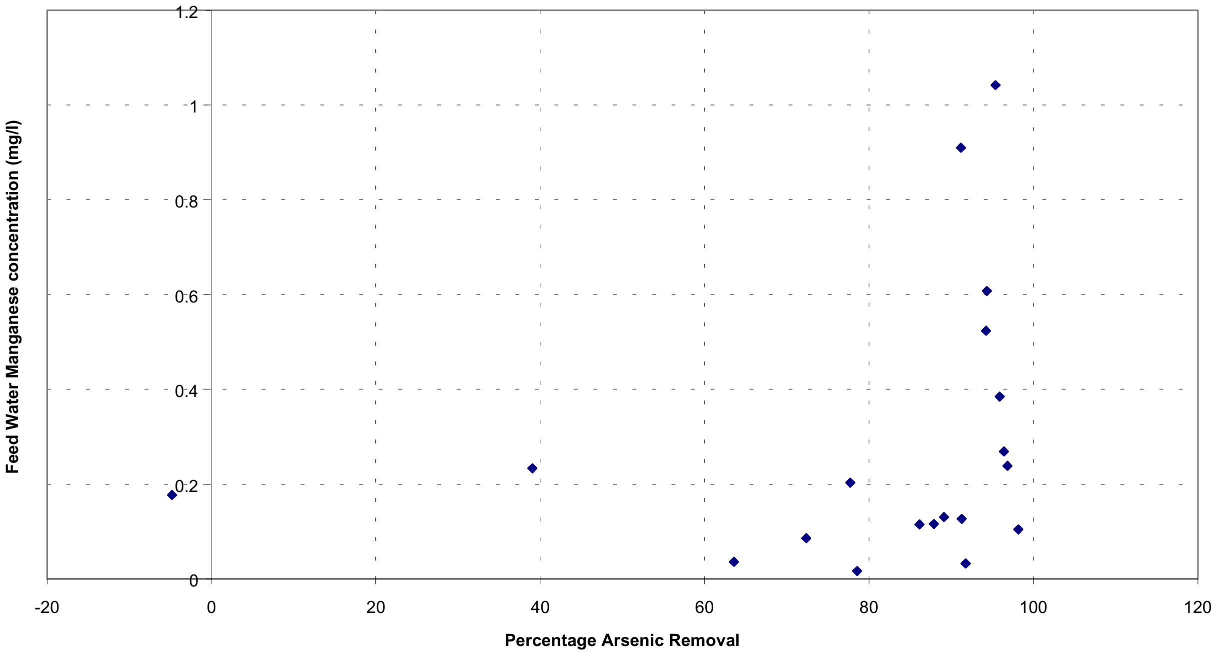
Affect of Feed Water Sulphate Concentration on Arsenic Removal by the Tetrahedron Technology



Affect of Feed Water Phosphate Concentration on Arsenic Removal by the DPHE/DANIDA Technology



Effect of Feed Water Manganese Concentration on Arsenic Removal by the Tetrahedron Technology



APPENDIX 6

WASTE DISPOSAL ISSUES

A PRELIMINARY REVIEW

WASTE DISPOSAL ISSUES – A PRELIMINARY REVIEW

Introduction

All technologies that remove arsenic from groundwater will at some point produce arsenic waste either as a solid or a liquid. The volume of waste, and concentration and chemical stability of arsenic, will depend upon the initial concentration of arsenic and the treatment technology used. Arsenic waste disposal from household level removal technologies has been investigated by several authors and there is a useful review in Johnston et al (2000) which is drawn upon here.

The objectives of this preliminary review are:

- **to provide an initial estimate of the likely types and volumes of waste that could be produced from the nine arsenic removal technologies being evaluated in this project;**
- **to summarise some of the factors that may affect the stability of the wastes;**
- **to consider some of the disposal options that could be applicable to rural settings in Bangladesh; and**

- **to identify issues that could be investigated further.**

Types of waste

The main types of waste that will be produced from the household level technologies are as follows.

1. **When no coagulant is used, the main type of arsenical sludge will be an iron oxyhydroxide onto which arsenic is strongly adsorbed. This oxyhydroxide will either be trapped within the matrix of filters (eg in the 3 Kolshi or Garnet filters) or may potentially occur as a separate sludge at the bottom of a bucket or kolshi (e.g. passive sedimentation).**

2. **When a coagulant is used (e.g. DPHE/Danida and Steven's Institute) aluminium and iron are introduced into the water producing larger volumes of co-precipitated arsenic-rich sludge that will, in the case of DPHE/Danida also contain aluminium hydroxides. These co-precipitates again may either occur trapped in filter matrices or as a sludge from the pre-filtration settlement stages.**

3. Ion exchange (IE) and activated alumina (AA) processes do not, under typical use, produce a solid waste stream because the media are regenerated. However, the periodic process of regeneration produces alkaline and acidic brines enriched in arsenic and other elements.

A summary of the main types of waste likely to be associated with the nine technologies being tested in this project is shown in Table 1.

Table 1 Summary of the main types of waste likely to be associated with the nine technologies being tested

Method	Nature of sludges and waste products
Passive sedimentation	• Arsenic-bearing iron oxyhydroxide flocs may settle to the base of the kolshi.
Ardasha	• The filter "candle" block will contain iron and arsenic as an iron oxyhydroxide. • Arsenic-bearing iron oxyhydroxide flocs will accumulate in the base of the upper compartment of the bucket.
Sono 3-Kolshi	• Arsenic-bearing iron oxyhydroxide will accumulate in both kolshis/ buckets containing filter materials.
Garnet	
DPHE/ Danida	• Coagulation will give rise to an amorphous arsenic, iron bearing sludge that will accumulate i) at the bottom of the pre-filtration bucket, and ii) within the sand filter. Additional elements present in the coagulant will occur in the sludge. For DHPE/Danida this will include alum.
Steven's Institute	
BUET	• Coagulation will give rise to an amorphous arsenic, iron bearing sludge that will accumulate i) at the bottom of the pre-filtration bucket, and ii) within the sand filter. • Alumina in the column would need to be periodically regenerated (see below). .
ALCAN	• Arsenic-bearing iron oxyhydroxide on the activated alumina can be backwashed out of the system – this effluent will need to be disposed of. • Regeneration of the alumina will also be necessary – this requires flushing with strong acids and alkalis and will need to be done at a centralised facility. The frequency will depend on the nature of the water being treated.
Tetra Hedron	• No backwashing facility appears to be available, but regeneration of the resin will also be necessary – this requires flushing with strong acids and alkalis and will need to be done at a centralised facility. As for the ALCAN system, the frequency will depend on the nature of the water being treated.

Mass of wastes produced

In order to identify reasonable disposal options, it is necessary to consider the likely masses / volumes of waste that will be produce. The following section provides some indicative estimates.

Mass of arsenic in waste per household

By making some estimates of the volume of water used by a household, and the concentration of arsenic, the mass of arsenic in treatment waste in a year can be estimated (assuming 100% removal). Assuming a household use of 30 liters per day and a concentration of arsenic of 0.5 mg/l in the initial water, some 15 mg of arsenic will be produced daily which is equivalent to an annual mass of about **5 g**.

By way of comparison, some calculations are presented in Johnston et al (2000) that estimate the mass of arsenic that could be applied annually to one hectare of land assuming an arsenic concentrations in irrigation water of 0.1 mg/l (guideline in US and Canada) and an irrigation rate of 1.2 metres/annum. The resultant arsenic loading is 1.2 kg/annum/hectare. In other words, the mass of arsenic produced by the household treatment technologies is relatively small which, as long as it is disposed of responsibly, should not present a significant environmental burden.

Mass of arsenic-bearing sludges

The mass of arsenic-bearing sludges produced by particular technologies will depend on the chemistry of the groundwater (particularly the iron content) and the nature of additive chemicals.

When no coagulant is used**, the main precipitate is iron oxyhydroxide. Assuming a relatively high iron content of 10 mg/l in the initial water, the annual mass of iron oxyhydroxide produced can be approximated:**

Annual volume of oxyhydroxide = C x V x R
= 10 mg/l x 10950 l x 1.75
= 192 g

Where C = Concentration of iron in influent water
V = Volume of water per household per year
R = Formula weight ratio of iron oxyhydroxide/Fe*

Assuming *Average formula of oxyhydroxide is $Fe_2O_3.2H_2O$ (Dzombak & Morel, 1990)

The oxyhydroxide will generally be as a water-rich slurry. The water:solid ratio of a slurry may be expected to be at least 20:1.

When a coagulant is used, taking the DPHE/Danida system as an example, 4 g of alum is introduced into a 20 l batch of water then approximately 2 kg of coagulant (dry weight) would be produced annually.

stability of the arsenic wastes

For the majority of the technologies, arsenic will be associated (through co-precipitation and adsoprtion) with iron (or aluminium) oxyhydroxides. There are three main factors that could lead to the release of arsenic from these precipitates are:

1. Dissolution of oxyhydroxides under mildly reducing conditions associated with solid waste can cause the release of arsenic. Since mildly reducing conditions could well develop in latrines, disposal pits and landfills, disposal to these settings needs to consider the possibility of arsenic remobilisation.

2. Bacterial activity in animal manure when mixed with arsenic-rich sludges has been shown to methylate arsenic transforming it into less toxic compounds. Transformation to arsine gas and release to air may occur in this setting.

3. Arsenic tends to desorb from oxyhydroxides under high pH conditions. This behaviour is opposite to that of typical metals which tend to be more strongly adsorbed under high pH conditions. When identifying disposal options, consideration should be given to the potential remobilisation of arsenic in alkaline settings.

In order to identify the likely leachate characteristics of wastes, the United Sates Environmental Protection Agency has developed a standard procedure known as the toxicity characteristic leaching procedure (TCLP). The method involves crushing the waste and leaching with weak acids to simulate conditions that may prevail in landfill, for example. This procedure is widely used and has been applied to wastes arising from arsenic treatment technologies. Some of the more significant findings are:

- **TCLP tests on arsenic sludges resulting from coagulation with alum and iron salts produced leachates with arsenic levels of 0.009 – 1.5 mg/l (Brewster, 1992; Chen et al., 1999). These levels are below the current threshold of 5 mg/l that would lead to the waste being classified as hazardous.**

- **TCLP tests on arsenic sludges that have been blended with cement have also been carried out by the Bengal Engineering College in India who found leachates to have negligible arsenic levels (Gupta et at., 2000). Since leachates from cementitious waste are alkaline, which could potentially enhance arsenic mobility, these results are encouraging for solidification disposal options including incorporation into cements or bricks.**

The general controls on the stability of arsenic wastes are reasonably well understood. However, research on wastes arising from household level removal technologies is active and a more comprehensive review of this current research is considered to be worthwhile.

Possible disposal options

Chemical stability is only one of several factors that needs to be considered when identifying potential disposal options. For example, in view of the relatively small volumes of waste that will be produced, it may be more advantageous to dispose

of sludge to a setting where remobilisation (and consequently dilution and dispersal) could occur but that is unlikely to give rise to direct human exposure, particularly by ingestion. In addition, consideration needs to be given to the practicalities of disposal options in rural settings.

Estimates on the mass of oxyhydroxide wastes that need to be disposed of by a household over a yearly period are less than 200 g when no coagulants are used and around 2 kg of oxyhydroxide for a coagulant treatment technique such as the DPHE/Danida two bucket system. Bearing these volumes in mind and the rural setting, the main options and associated issues are summarised in Table 2.

From this preliminary review, disposal to latrines or shallow pits would seem to be favorable option. Disposal to latrines is the currently advised option for the DPHE/Danida two bucket system. However, given the potential future scale arsenic removal treatment in Bangladesh it is recommended that further investigation of waste disposal issues are carried out.

Other Waste Disposal Issues

Arsenic-rich wastes produced from the majority of household level removal technologies will be in one of two forms:

1. Oxyhydroxide flocs in relatively large volumes of water such as the passive sedimentation bucket, settlement buckets from multi-stage systems or backwash waters from ALCAN;

2. Oxyhydroxide flocs trapped in the matrices (e.g. sand and bricks) of filter systems.

In the first form, a particulate-rich liquid waste, disposal to latrines should be feasible. For the flocs trapped in filter matrices the issue of separation / regeneration needs to be considered. Separation/regeneration methods will need to be considered on a technology-specific bases. This is probably best carried out after initial screening of the technologies in Phase 1 when the number of technologies should be reduced.

With regard to the activated alumina (ALCAN and BUET) and ion exchange (Tetrahedron) systems, treatment and disposal of regeneration wastes needs to be considered. As already discussed, regeneration typically involves flushing with highly acid and alkaline solutions and the resultant wastes will be saline, rich in arsenic and potentially other toxic elements, and will require pH correction. These sorts of activities should be carried out at a centralised facility.

Further work

Given the potential future scale of arsenic removal from groundwater in Bangladesh, there is scope for a dedicated investigation into waste disposal issues for household and community level technologies to assess potential environmental and health impacts and social acceptability of different disposal options.

Table 2. Preliminary summary of sludge disposal options issues

Disposal Option		Issues
1	Disposal to latrines	• Likely to be feasible for most households. • Awareness/training likely to be relatively straightforward. • The risk of remobilisation into shallow aquifers and re-abstraction from wells needs to be assessed. • Potential impacts of arsine release to confined space should be investigated either by desk or field trials.
2	Mixture with animal manure and disposal to shallow pit	• Likely to be feasible for most households. • Dedicated pit may need to be constructed . • The risk of remobilisation into shallow aquifers and re-abstraction from wells needs to be assessed. • Awareness/training required.
3	Disposal with solid waste	• Logistically difficult for the some households. • Scavenging from waste disposal sites could lead to human exposure.
4	Disposal to land	• The bulk of land is committed to agricultural production and intuitively this option seems illogical. • Seasonal considerations (wet/dry seasons and harvesting) would need to be taken into account. • Could be further assessed through a risk assessment.
5	Solidification by incorporation into bricks	• Logistically difficult for the majority of households. • Probably not justified if other options prove viable.
6	Solidification by incorporation into cement	• As for incorporation into bricks.

Summary

This report is only a brief review of waste disposal issues for household and should be read in this context.

1. The masses of arsenic-bearing sludges produced annually at a household level will be relatively small. The annual masses of waste are likely to be in the order of 5 g of arsenic in approximately 750 g of wet sludge for non-coagulant systems or around 10 kg of wet sludge for-coagulant based systems (taking DPHE/Danida as an example).

2. The general controls on the stability of arsenic wastes are reasonably well understood: arsenic is likely to be relativley immobile under oxidising neutral pH conditions but may be mobilised under slightly reducing and/or alkaline conditions. However, chemical stability is only one of several factors that needs to be considered when identifying disposal options.

3. In view of the relatively small volumes of waste that will be produced, it may be more advantageous to dispose of sludge to a setting where remobilisation (and consequently dispersal) could occur but that is unlikely to give rise to direct human exposure, particularly by ingestion.

4. From this preliminary review, disposal to latrines would seem to be a favorable option. However, given the potential scale of this issue, further study should be carried out.

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