Table 25
Removal of Arsenate using NMRL-DRDO Polypropylene Household Water Filter (Without $KMnO_4$)

Sr. No.	Initial As(V) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)
1	98	0	8.3	121	2	1.85	1.8
2		2	8.2	135	3	1.85	ND
3		4	8.1	160	4	0.92	0.7
4		24	8.1	140	3	0.92	0.1
5	514	0	8.0	119	2	1.85	2.0
6		2	8.0	131	4	ND	0.5
7		4	8.1	141	3	ND	ND
8		24	8.2	119	2	0.92	1.8
9	1069	0	8.0	112	4	ND	0.7
10		2	8.1	135	4	2.77	0.5
11		4	8.2	121	4	0.92	0.4
12		24	8.1	118	4	1.85	0.6

4.3.4 SONO Arsenic Mitigation Filter

To begin with the studies the filter was installed in the laboratory as per the instructions given in the manual provided by the supplier. However, the flow rate was found to be below normal. Hence the material inside the two containers of the filter was rearranged afresh. Trial runs were carried using ten litres water each of arsenite concentrations – 122 ppb, 462 ppb and 1038 ppb. The results of the removal of arsenite obtained are given in **Table 26**. The residual arsenite concentrations were found to be below the WHO guideline value for arsenic in drinking water. Iron concentrations in the filtered waters were found to be within the permissible limits given by BIS. The unit was again found to be blocked, hence the material inside the containers was rearranged again and the studies were continued further with initial arsenite concentrations of 2230 ppb and 3120 ppb. The residual arsenite

Similar runs were carried using ten litres water each of arsenate concentrations of 115 ppb, 563 ppb, 1131 ppb, 2112 ppb and 3080 ppb. The results obtained for the removal of arsenate are given in **Table 27**. The residual arsenate concentrations were found to be below the WHO guideline value for arsenic in drinking water. Iron and sulphate concentrations in the filtered waters were found to be within the permissible limits given by BIS.

Table 27

Removal of Arsenate using SONO Arsenic Mitigation Filter

Sr. No.	Initial As(V) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As(V) (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	**115**	0	7.8	145	6	ND	0.22	ND
2		2	7.7	166	6	ND	ND	ND
3		4	8.3	147	4	ND	0.11	0.48
4		24	8.0	150	2	ND	0.18	0.36
5	**563**	0	8.1	126	3	ND	ND	0.48
6		2	7.9	132	3	ND	0.03	0.36
7		4	7.9	130	2	6.26	0.07	3.61
8		24	8.2	127	3	ND	0.05	3.81
9	**1131**	0	8.3	115	2	7.75	0.02	0.48
10		2	7.8	115	3	7.75	0.03	0.36
11		4	8.0	113	3	4.63	0.07	ND
12		24	8.1	115	3	2.78	ND	ND
13	**2112**	0	7.8	121	3	9.25	0.11	0.48
14		2	8.2	117	3	4.6	0.04	ND
15		4	8.2	115	4	3.7	0.08	ND
16		24	8.1	119	4	3.7	0.1	0.38
17	**3080**	0	8.9	120	4	8.32	0.07	0.42
18		2	7.2	121	3	ND	0.11	0.56
19		4	7.5	126	4	ND	0.08	0.48
20		24	7.6	131	4	9.18	0.12	0.36

Similar studies were carried out using arsenic contaminated water containing arsenic both in trivalent and pentavalent forms; As(III) : As(V) ratios as 1:1, 1:2, 1:3, 2:1 and 3:1 respectively for subsequent trial runs. The results are given in **Tables 28 through32**. The results clearly indicate that the concentrations of residual arsenic in whatever proportions it may be were found to be well within the guideline value of 10 ppb given by the WHO for arsenic. Concentrations of iron were found to be within the desirable limits of BIS.

Table 28

Removal of Arsenic using SONO Arsenic Mitigation Filter As III: As V (1:1)

Sr. No.	Initial As Conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	**106**	0	7.97	110	3	4.62	0.18	29
2		2	7.99	111	2	1.10	0.09	34
3		4	7.97	112	4	4.62	0.11	34
4		24	7.92	118	2	2.78	0.04	35
5	**494**	0	8.10	127	2	0.925	0.03	28
6		2	8.19	126	2	3.70	ND	29
7		4	8.07	129	1	0.925	0.08	28
8		24	7.86	122	1	ND	0.11	28
9	**1036**	0	7.32	124	2	ND	0.09	27
10		2	7.51	117	2	3.70	0.22	27
11		4	7.42	118	1	3.70	0.15	30
12		24	7.30	121	1	ND	0.13	31
13	**2199**	0	7.04	129	4	ND	ND	31
14		2	7.45	119	2	ND	0.03	31
15		4	7.37	117	1	ND	0.04	32
16		24	7.30	120	1	ND	0.09	31
17	**3143**	0	7.27	126	2	0.06	0.06	34
18		2	7.37	123	2	0.11	0.11	32
19		4	7.40	127	2	0.92	0.10	33
20		24	7.41	126	2	2.77	ND	31

Table 29

Removal of Arsenic using SONO Arsenic Mitigation Filter
As III: As V (1:2)

Sr. No.	Initial As Conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	105	0	8.03	165	2	ND	0.09	ND
2		2	8.14	162	2	1.85	ND	ND
3		4	8.18	161	3	2.77	0.03	ND
4		24	8.38	164	2	2.77	0.08	ND
5	512	0	7.93	165	3	ND	0.12	0.08
6		2	7.94	160	3	1.85	0.23	ND
7		4	8.17	167	1	0.92	ND	ND
8		24	8.23	156	2	ND	0.09	ND
9	1155	0	8.07	158	2	5.55	ND	ND
10		2	7.71	160	1	0.925	0.22	0.2
11		4	8.47	165	2	4.63	0.11	ND
12		24	8.02	166	2	3.70	0.20	ND
13	2164	0	7.94	181	3	5.55	0.08	37
14		2	8.25	171	1	2.77	0.11	28
15		4	8.28	165	2	ND	0.04	24
16		24	8.18	162	3	ND	0.18	23
17	3012	0	7.76	158	2	ND	ND	ND
18		2	7.97	139	2	1.85	ND	ND
19		4	7.82	130	2	ND	0.09	ND
20		24	7.28	135	3	2.77	0.04	ND

Table 30

Removal of Arsenic using SONO Arsenic Mitigation Filter
As III: As V (1:3)

Sr. No.	Initial As Conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	**121**	0	8.36	150	1	ND	0.017	55
2		2	8.12	156	2	ND	ND	62
3		4	7.88	140	2	ND	ND	66
4		24	7.97	139	2	ND	0.13	59
5	**525**	0	7.58	176	2	0.92	ND	63
6		2	7.93	138	3	ND	0.09	62
7		4	8.00	142	1	ND	ND	61
8		24	8.28	137	1	0.92	0.13	58
9	**1434**	0	7.91	130	1	1.85	0.13	60
10		2	7.77	129	1	1.85	0.18	60
11		4	8.10	131	2	3.70	ND	60
12		24	7.88	135	2	1.85	0.17	59
13	**2507**	0	7.97	136	1	1.85	ND	60
14		2	8.29	135	1	ND	ND	59
15		4	8.24	133	1	3.70	0.9	59
16		24	8.14	135	1	4.62	0.11	59
17	**3254**	0	8.07	133	2	5.55	0.15	58
18		2	8.40	131	2	2.77	0.13	55
19		4	8.19	132	1	6.47	ND	53
20		24	8.10	129	1	ND	ND	59

Table 31

Removal of Arsenic using SONO Arsenic Mitigation Filter
As III: As V (2:1)

Sr. No.	Initial As Conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	102	0	7.40	130	1	ND	0.12	31
2		2	7.74	128	2	ND	ND	ND
3		4	7.51	161	2	0.92	ND	31
4		24	7.47	140	2	2.63	0.08	ND
5	512	0	7.44	133	1	1.85	ND	ND
6		2	7.50	131	2	1.85	0.01	31
7		4	7.68	133	2	ND	ND	ND
8		24	7.59	130	1	1.85	0.2	32
9	1285	0	7.69	129	2	ND	ND	ND
10		2	7.39	129	2	ND	0.01	ND
11		4	7.62	126	2	0.925	ND	ND
12		24	7.51	131	1	1.85	0.09	32
13	2038	0	7.48	135	2	ND	0.08	ND
14		2	7.69	133	1	1.85	ND	ND
15		4	7.63	139	2	3.84	0.09	34
16		24	7.71	135	1	ND	0.07	ND
17	3200	0	7.75	111	1	1.18	0.2	ND
18		2	7.61	130	1	0.925	0.12	34
19		4	7.70	132	2	ND	0.08	34
20		24	7.74	133	1	ND	ND	34

Table 32

Removal of Arsenic using SONO Arsenic Mitigation Filter
As III: As V (3:1)

Sr. No.	Initial As Conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	115	0	7.95	129	2	0.92	0.08	7
2		2	7.84	131	1	4.62	ND	20
3		4	7.79	135	1	5.55	0.2	22
4		24	8.01	141	1	ND	ND	14
5	489	0	8.20	132	2	0.925	0.12	4
6		2	7.87	137	2	4.62	ND	4
7		4	7.62	135	2	1.81	ND	5
8		24	7.98	139	1	ND	0.14	5
9	1059	0	8.00	135	1	3.70	0.008	5
10		2	8.13	136	1	0.92	ND	5
11		4	7.85	137.5	1	2.63	0.003	5
12		24	7.97	135	1	1.81	0.06	5
13	2100	0	8.03	136	1	3.7	0.12	4
14		2	8.45	131	2	1.81	ND	5
15		4	8.21	127	1	4.62	0.08	5
16		24	8.15	136.3	1	0.92	0.08	4
17	3019	0	7.90	127.8	2	ND	ND	5
18		2	8.12	128.6	2	1.85	0.06	5
19		4	8.21	129.3	2	ND	0.011	4
20		24	8.17	131.4	2	0.92	ND	3

4.3.5 Pureit Arsenic Cum Germ Removal Filter

The filter was installed as per the guidelines given in the instruction manual supplied by the manufacturer. Six litres of water each with initial arsenite concentrations of 162 ppb, 633 ppb, 1036 ppb, and 2300 ppb, followed by 3485 ppb were passed through the filter one by one and samples were collected from the filter outlet at intervals ranging between 0 to 24 hrs for each concentration. **Table 33** shows that the values for residual arsenite obtained for various initial concentrations of arsenic containing water used in the study were below the WHO guideline value for arsenic. Iron and sulphate concentrations in filtered waters were found to be within the permissible limits prescribed by the BIS. Similar studies were carried out using six litres each of water contaminated with pentavalent arsenic with initial arsenate concentrations ranging from 135 ppb to 3016 ppb. The results the removal of arsenate obtained are given in **Table 34**. Hundred percent removal of arsenate was obtained as is evident from Table 30. Iron concentrations in the filtered waters were found to be within the permissible limits stipulated by BIS.

Table 33

Removal of Arsenite using Pureit Arsenic Cum Germ Removal Filter

Sr. No.	Initial As(III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	162	0	7.7	585	5	ND	0.07	62
2		2	7.3	534	4	1.85	ND	76
3		24	7.1	520	6	ND	0.09	77
4	633	0	8.0	366	2	ND	0.08	58
5		2	7.8	310	1	ND	0.07	48
6		24	7.7	306	2	ND	0.07	51
7	1036	0	7.9	181	2	ND	0.14	44
8		2	7.8	172	1	1.8	0.32	38
9		24	7.8	192	1	ND	0.21	46
10	2300	0	7.8	173	3	5.55	0.18	38
11		2	7.7	170	4	2.77	0.18	34
12		24	7.8	181	2	ND	0.11	34
13	3485	0	8.3	170	2	0.92	0.09	39
14		2	8.6	167	3	0.92	0.03	38
15		24	8.4	161	2	5.56	0.22	7

Table 34

Removal of Arsenate using Pureit Arsenic Cum Germ Removal Filter

Sr. No.	Initial As(V) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As(V) (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	**135**	0	6.3	178	4.6	ND	0.11	32
2		2	6.5	169	2.5	ND	ND	31
3		24	6.9	170	3.2	ND	0.01	36
4	**535**	0	6.7	167	3.8	ND	0.01	38
5		2	6.8	176	4.8	ND	ND	36
6		24	6.9	167	5.6	ND	0.01	35
7	**1013**	0	6.5	166	3.6	ND	0.01	30
8		2	6.7	166	4.3	ND	0.01	36
9		24	6.9	178	3.6	ND	0.2	35
10	**2057**	0	6.8	161	6.0	ND	0.03	29
11		2	6.9	172	5.9	ND	0.08	30
12		24	7.1	161	4.9	ND	ND	28
13	**3016**	0	7.2	165	5.5	ND	0.01	34
14		2	7.0	157	5.4	ND	0.18	30
15		24	7.1	160	5.11	ND	0.08	27

Similar studies were carried out using arsenic contaminated water containing arsenic both in trivalent and pentavalent forms; As(III) : As(V) ratios as 1:1, 1:2, 1:3, 2:1 and 3:1 respectively for subsequent trial runs. The results are given in **Tables 35 through 39**. The results clearly indicate that the concentrations of residual arsenic in whatever proportions it may be were found to be well within the guideline value of 10 ppb given by the WHO for arsenic. Concentrations of iron and sulphate were found to be within the desirable limits of BIS.

Table 35

Removal of Arsenic using Pureit Arsenic Cum Germ Removal Filter As III: As V (1:1)

Sr. No.	Initial As Conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	**106**	0	8.4	169	2	1.8	0.18	42
2		2	7.6	161	2	0.92	0.18	37
3		24	8.1	165	2	4.6	0.09	38
4	**494**	0	8.0	167	2	ND	0.11	34
5		2	7.8	165	1	1.8	0.22	34
6		24	7.9	179	1	3.7	0.19	29
7	**1036**	0	6.13	163	1	ND	0.11	34
8		2	6.7	164	2	ND	0.19	32
9		24	7.0	159	2	0.92	0.23	31
10	**2199**	0	6.9	163	3	1.85	0.28	29
11		2	7.21	162	2	0.92	0.09	27
12		24	7.1	164	2	ND	0.11	32
13	**3143**	0	6.9	162	2	1.85	0.10	39
14		2	7.09	159	3	3.70	0.08	37
15		24	7.1	161	3	2.77	0.08	36

Table 36

Removal of Arsenic using Pureit Arsenic Cum Germ Removal Filter As III: As V (1:2)

Sr. No.	Initial As conc (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	105	0	7.6	124	2	ND	0.11	0.6
2		2	7.7	160	3	1.85	0.09	ND
3		24	7.5	128	2	1.85	0.09	1.4
4	512	0	7.9	131	2	ND	0.23	ND
5		2	7.7	127	2	ND	0.09	ND
6		24	7.5	123	2	ND	0.17	ND
7	1155	0	7.8	139	2	1.85	0.19	ND
8		2	7.9	122	2	ND	0.22	ND
9		24	8.0	124	2	0.925	0.11	ND
10	2164	0	7.6	128	2	1.85	0.23	ND
11		2	7.9	127	2	2.77	0.10	ND
12		24	7.0	132	2	3.70	0.08	ND
13	3012	0	7.93	164	2	ND	ND	1.4
14		2	7.9	165	3	3.70	0.11	1.2
15		24	7.7	167	2	ND	0.08	ND

Table 37

Removal of Arsenic using Pureit Arsenic Cum Germ Removal Filter As III: As V (1:3)

Sr. No.	Initial As conc (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	121	0	8.1	176	2	ND	0.11	2
2		2	8.0	175	4	ND	ND	4
3		24	7.8	175	3	ND	0.04	13
4	525	0	8.2	141	2	ND	ND	4
5		2	7.8	169	2	0.925	ND	2
6		24	7.8	170	3	1.85	0.18	2
7	1434	0	7.8	167	2	ND	0.03	3
8		2	7.9	165	2	ND	ND	2
9		24	8.0	162	2	3.70	0.22	2
10	2507	0	8.1	175	2	0.925	0.03	4
11		2	8.0	169	2	0.925	ND	3
12		24	7.9	165	2	ND	0.11	2
13	3254	0	8.3	167	2	4.62	ND	3
14		2	7.4	172	2	1.85	0.06	4
15		24	8.7	169	3	ND	0.03	2

Table 38

Removal of Arsenic using Pureit Arsenic Cum Germ Removal Filter As III: As V (2:1)

Sr. No.	Initial As conc (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	**102**	0	8.4	156	2	ND	0.15	8
2		2	8.3	157	3	ND	0.13	2
3		24	8.2	159	4	0.925	0.12	ND
4	**512**	0	8.3	154	4	ND	0.22	ND
5		2	8.2	159	4	2.63	ND	0.8
6		24	8.3	159	3	1.85	0.17	ND
7	**1285**	0	8.4	158	2	ND	0.15	ND
8		2	8.5	157	2	ND	ND	5
9		24	8.3	156	2	0.925	0.13	4
10	**2038**	0	8.3	164	3	ND	ND	4
11		2	8.1	163	3	ND	0.17	5
12		24	8.3	167	2	ND	ND	ND
13	**3200**	0	8.08	169	2	0.925	0.11	ND
14		2	8.0	172	2	1.18	ND	ND
15		24	8.4	166	3	ND	0.08	ND

Table 39

Removal of Arsenic using Pureit Arsenic Cum Germ Removal Filter As III: As V (3:1)

Sr. No.	Initial As conc. (ppb)	Sampling interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual AS (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	115	0	7.9	144	2	ND	0.12	6
2		2	7.8	170	2	3.02	0.18	5
3		24	8.0	137	2	5.55	ND	9
4	489	0	8.6	186	2	0.925	0.22	4
5		2	8.6	164	2	1.81	0.11	4
6		24	8.5	167	2	ND	ND	5
7	1059	0	8.6	318	3	1.85	0.008	4
8		2	8.6	164	3	2.63	ND	4
9		24	8.63	160	2	1.81	0.11	7
10	2100	0	8.7	157	4	0.925	0.13	6
11		2	8.6	159	3	3.7	ND	9
12		24	8.59	172	2	1.86	ND	4
13	3019	0	8.0	160	2	ND	0.15	5
14		2	8.1	159	3	ND	0.006	6
15		24	8.6	166	2	ND	ND	4

4.4 Field Evaluation of the Domestic Arsenic Removal units

4.4.1 Protocol for Evaluation of the Domestic Arsenic Removal units using field water

- Identify arsenic affected water sources and households using contaminated water for drinking purpose
- Analyse arsenic concentration in source water using standard method as explained earlier
- Install arsenic removal units in the households

- Explain operation of arsenic removal unit to the users (alternatively users already having arsenic removal unit can be chosen)
- Collect treated water from the unit at regular interval up to 6 hours
- Analyse arsenic content in treated water as per standard procedure as explained earlier

Field visits were carried out by a team of NEERI scientists accompanied by an official from UNICEF, Kolkata and local NGOs working in the rural arsenic affected areas during February, 2011. Two RSM and two Sono filters installed in households, school, etc. in village Karola of North 24 Parganas were selected to undertake the evaluation study. The raw water sources used for the study were the hand pumps adjacent to the household/school of which the water is consumed by the population residing in the vicinity. About 30-35 L of water from the same sources was transported to NEERI Zonal Centre at Kolkata to conduct similar studies using NMRL-DRDO Filter and Pureit Hindustan Unilever Filter. Filtered samples were collected at regular intervals up to 6 hours and then a sample was collected after 24 hours.) The filtered water samples were collected in 500 ml polythene bottles. The polythene bottles were thoroughly rinsed with the water sample before filling. The preservation of the samples was carried out by concentrated HCl for arsenic. The analysis were carried out as per Standard Methods i.e. SDDC method. The sampling location details are given in Table 40.

Table 40

Sampling Location Details

Sr. No.	Sample ID	Source	Location	Arsenic (ppb)
1.	RSM -1	Hand pump	Mr. Uttam Haldhar, Mathpara (Korola), N-24 Paraganas	298
2.	RSM -2	Hand pump	Shishu Shiksha Kendra, Mathpara (Korola), N-24 Paraganas	576
3.	DRDO -1	Hand pump	Mr. Shyamal Mitra, Mathpara (Korola), N-24 Paraganas	452
4.	DRDO - 2	Hand pump	Mr. Uttam Haldhar, Mathpara (Korola), N-24 Paraganas	298
5.	SONO -1	Hand pump	Mr. Shyamal Mitra, Mathpara (Korola), N-24 Paraganas	452
6.	SONO - 2	Hand pump	Mr. AshishKullu, Mathpara (Korola), N-24 Paraganas	250
7.	HUL -1	Hand pump	Mr. Ashish Kullu, Mathpara (Korola), N-24 Paraganas	250
8.	HUL - 2	Hand pump	Shishu Shiksha Kendra, Mathpara (Korola), N-24 Paraganas	576

4.4.2 RSM Filter with Activated Alumina Technology

RSM Filter installed in the house of Mr. Uttam Haldhar, Mathpara (Korola), N-24 Paraganas, was used for the study. A hand pump located adjacent to his house was used as a raw water source with arsenic concentration of 298 ppb. The raw water characteristics and arsenic removal results are given in **Table 41**. Filtered samples

were collected at regular intervals up to 6 hours and then a sample was collected after 24 hours. Arsenic concentrations were found to be below the WHO guideline value of 10 ppb for arsenic. Even the iron and sulphate concentrations are found to be within the permissible limit of BIS. Another RSM filtered installed in Shishu Shiksha Kendra, Mathpara(Korola), N-24 Paraganas with a nearby hand pump with arsenic concentration of 576 ppb as a raw water source was used for field evaluation. It is evident from the **Table 42** that the RSM Filter was effective in removing arsenic to the levels less than the WHO guideline value of 10 ppb for arsenic.

Table 41

Field Evaluation of RSM Filter
(Sample ID RSM – 1)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)
1	Raw	8.5	850	39	356	7.56	298	7
2	0	8.0	815	7	168	0.24	8.36	246
3	2	8.0	901	7	164	0.20	8.21	208
4	4	7.9	912	2	116	0.22	4.64	201
5	6	7.8	910	2	156	0.18	0.00	241
6	24	7.9	928	2	146	0.12	ND	247

Table 42
Field Evaluation of RSM Filter
(Sample ID RSM – 2)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)
1	Raw	8.2	750	10	300	5.27	576	4
2	0	8.0	726	10	80	0.35	7.43	236
3	2	8.0	789	2	152	0.24	6.50	249
4	4	8.1	892	1	182	0.26	5.57	239
5	6	8.1	868	4	280	0.32	0.00	245
6	24	8.2	858	2	264	0.29	ND	235

4.4.3 NMRL-DRDO Household Water Filter

Two raw water samples with arsenic concentrations of 452 ppb and298 ppb from hand pumps near Mr. Shyamal Mitra's house, and Mr. Uttam Haldhar's house, Mathpara (Korola), N-24 Paraganas, respectively were brought to the NEERI Zonal Laboratory, Kolkata where the DRDO stainless steel unit was installed for evaluation using the field samples. The results are shown in **Tables 43 and 44**. Filtered water was collected from the outlet at regular intervals and one sample after 24 hours. The concentrations of arsenic were found to be within the WHO guideline value for arsenic.

Table 43
Field Evaluation of NMRL-DRDO Filter
(Sample ID DRDO - 1)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)	Mn (ppm)
1	Raw	7.7	758	16	316	6.85	452	21	ND
2	0	7.9	700	10	265	0.32	3.71	11	ND
3	2	8.4	690	9	260	0.24	1.86	14	ND
4	4	8.3	750	10	218	0.26	0.00	101	ND
5	6	8.3	734	8	286	0.34	0.00	124	ND
6	24	8.7	701	7	256	0.28	ND	103	ND

Table 44
Field Evaluation of NMRL-DRDO Filter
(Sample ID DRDO - 2)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)	Mn (ppm)
1	Raw	8.5	850	39	356	7.56	298	7	8.5
2	0	8.4	979	13	312	0.04	ND	18	ND
3	2	8.4	918	9	286	0.12	0.93	3	ND
4	4	8.5	912	10	276	0.18	ND	6	ND
5	6	8.7	903	6	314	0.13	0.00	5	ND
6	24	8.7	873	7	346	0.01	ND	7	ND

4.4.4 SONO Arsenic Mitigation Filter

Sono Filters one each installed in the houses of Mr. Shyamal Mitra and Mr. Ashish Kullu residing in Mathpara (Korola), N-24 Paraganas were used for the study. Hand pump Sono–1 with arsenic concentration of 452 ppb and Sono–2 with arsenic concentration of 250 ppb located adjacent to their houses was used as a raw water source in respective Sono Filter. The raw water characteristics and arsenic removal results are given in **Tables 45 and 46**. Filtered samples were collected at regular intervals up to 6 hours and then a sample was collected after 24 hours. Arsenic concentrations were found to be below the WHO guideline value of 10 ppb for arsenic. Even the iron and sulphate concentrations are found to be within the permissible limit of BIS.

Table 45
Field Evaluation of Sono Filter
(Sample ID Sono - 1)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)
1	Raw	7.7	758	16	316	6.85	452	21
2	0	8.1	776	1	256	0.27	0.93	20
3	2	7.2	726	1	248	0.20	ND	7
4	4	7.9	824	2	80	0.12	4.64	6
5	6	8.0	814	1	238	0.18	ND	9
6	24	7.0	773	1	240	0.12	ND	8

Table 46
Field Evaluation of Sono Filter
(Sample ID Sono - 2)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)
1	Raw	7.6	773	15	284	3.81	250	6
2	0	7.8	853	16	316	0.02	ND	6
3	2	7.7	801	6	324	0.12	ND	13
4	4	7.9	828	2	296	0.06	ND	3
5	6	7.7	818	7	240	0.09	ND	3
6	24	7.8	809	8	224	0.22	0.93	2

4.4.5 Pureit Arsenic cum Germ Removal Filter

Two raw water samples with arsenic concentrations of 250 ppb and 576 ppb from hand pumps near Mr. Ashish Kullu's house, and Shishu Shiksha Kendra, Mathpara (Korola), N-24 Paraganas, respectively were brought to the NEERI Zonal Laboratory, Kolkata where the HUL Filter unit was installed for evaluation using the field samples. The results are shown in **Tables 47 and 48**. Filtered water was collected from the outlet at regular intervals and one sample after 24 hours. The concentrations of arsenic were found to be within the WHO guideline value for arsenic.

Table 47

Field Evaluation of Pureit Filter (Sample ID HUL - 1)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)	Mn (ppm)
1	Raw	7.6	773	15	284	3.81	250	6	ND
2	0	8.8	989	8	312	0.13	6.93	10	ND
3	2	8.6	981	7	268	0.24	8.07	9	ND
4	4	8.4	982	5	234	0.33	9.64	8	ND
5	6	8.4	916	4	288	0.34	8.71	9	ND
6	24	8.5	929	4	278	0.36	ND	9	ND

Table 48

Field Evaluation of Pureit Filter (Sample ID HUL - 2)

Sr. No.	Time interval (Hour)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Alkalinity (mg/l)	Fe (ppm)	As (ppb)	SO_4 (ppm)	Mn (ppm)
1	Raw	8.2	750	10	300	5.27	576	4	ND
2	0	8.5	881	4	332	ND	5.92	20	ND
3	2	8.2	816	3	238	0.09	1.92	5	ND
4	4	8.3	805	4	314	0.06	ND	6	ND
5	6	8.4	823	2	213	0.02	ND	7	ND
6	24	8.6	797	1	246	0.05	0.92	5	ND

In the backdrop of the aforementioned laboratory and field evaluation of four arsenic removal filters under study the summary of the results has been highlighted in **Table 49**.

Table 49
Laboratory and Field Evaluation of Arsenic Removal Filters – Summary Results

Sl. No.	Arsenic Conc (ppb)	Observations			
		RSM	NMRL-DRDO	Sono	Pureit
Laboratory Evaluation					
A. Removal of As (III)					
1.	100 500 1000 2000 3000	Arsenic removal was observed. Residual arsenite concentrations were above the WHO guideline value*	Arsenic removal obtained for all initial concentrations of arsenite with residual arsenite concentration less than WHO guideline value	Arsenic removal obtained for all initial concentrations of arsenite; residual arsenite concentration less than WHO guideline value	Arsenic removal obtained for all concentrations of arsenite; residual arsenite concentration less than WHO guideline value
B. Removal of As (V)					
2.	100 500 1000 2000 3000	Arsenic removal was observed. Residual arsenite concentrations were above the WHO guideline value*	Removal obtained for all concentrations of arsenate; residual arsenate concentration less than WHO guideline value	Arsenate removal obtained at all concentrations of arsenate, residual arsenate concentration less than WHO guideline value	Removal obtained for all concentrations of arsenate; residual arsenate concentration less than WHO guideline value
C. Removal of Combination of As (III) : As(V)					
3.	1:1 1:2 1:3 2:1 3:1	Removal of combination of As(III) : AS(V) were not carried out as significant removal was not obtained separately for As(III) and As(V)*	Removal was obtained for all the proportions of As(III):As(V), residual arsenic concentration less than the WHO guideline value	Removal was obtained for all the proportions of As(III):As(V), residual arsenic concentration less than the WHO guideline value	Removal was obtained for all the proportions of As(III):As(V), residual arsenic concentration less than the WHO guideline value

As Removal Filter	Observations			
	Arsenic Concentration (ppb)			
	298	576	452	250
Field Evaluation				
RSM-1	Arsenic concentration in filtered water less than WHO guideline value			
RSM-2		Arsenic Concentration in filtered water less than WHO guideline value		
DRDO-1			Arsenic Concentration in filtered water less than WHO guideline value	
DRDO-2	Arsenic Concentration in filtered water less than WHO guideline value			
SONO-1			Arsenic Concentration in filtered water less than WHO guideline value	
SONO-2				Arsenic Concentration in filtered water less than WHO guideline value
HUL-1				Arsenic Concentration in filtered water less than WHO guideline value
HUL-2		Arsenic Concentration in filtered water less than WHO guideline value		

5. Differential outcomes during laboratory and field investigations

It is evident from the result that the ONLY RSM Filter was effective in removing arsenic to the levels less than the WHO guideline value of 10 ppb for arsenic if field water is used. However, RSM units when evaluated in the laboratory, residual arsenic concentration was found to be above the BIS standard and WHO guideline value for arsenic in drinking water even after 24 hrs. This is explained below:

It is observed that RSM arsenic removal unit and Pureit arsenic removal unit use activated alumina for adsorption of arsenic, whereas other two units (NMRL-DRDO Household Water Filter and SONO Arsenic Mitigation Filter) use iron for co-precipitation. NMRL-DRDO filter and Sono filter contains reactance material i.e. iron and it works on the simple principle of co-precipitation of arsenic with iron and adsorption of this precipitate on iron oxy-hydroxides, followed by further retention of this precipitate in treated sand. Therefore presence of iron in field water does not affect arsenic removal mechanism of two units (NMRL-DRDO Household Water Filter and SONO Arsenic Mitigation Filter); hence these units are further discussed.

It is established that presence of iron along with arsenic promotes co-precipitation of arsenic. Therefore, iron present in the field water might assists co-precipitation in RSM arsenic removal unit. This is not observed in the laboratory due to absence of iron in synthetic water. It is therefore inferred that arsenic is removed when field water containing iron is used. In Pureit Arsenic cum Germ Removal Filter contains activated alumina and filtration through activated carbon which might be helping in removal of arsenic in synthetic water even in absence of iron. Moreover, treatment procedure and media used in Pureit are unknown and so as removal mechanism. It appears that filtration after arsenic removal is also an important treatment step. This additional filtration unit is not provided in RSM filter.

Interestingly, no reference could be identified citing reasons for differential outcome when field water is used for evaluation of arsenic removal units.

6. User's Experience

6.1 RSM Filter with Activated Alumina Technology

- The RSM Filter though compact, due care is needed during transit to avoid any hairline damages.
- It is quite convenient for the user to install the unit before use. The difficulty in fixing the alumina attachment can be overcome with practice.

6.2 NMRL-DRDO Household Water Filter

- The configuration of the filter is such that the filter and other accessories are to be carried separately to the place of installation
- Though the design of the filter after installation is compact the user has to get acclimatized with the multi chambered unit before use
- In the beginning, the user may experience difficulty in installing the three chambered fitter. However, with practice and experience, the difficulty would be overcome

6.3 SONO Arsenic Mitigation Filter

- The filter unit though heavy, is quite compact subsequent to installation
- There is a possibility of the filter media getting disarranged during transit prior to installation
- The user will have to confirm proper flow of arsenic contaminated water from the upper chamber through the outlet of lower chamber as the water passes from the upper chamber via lower chamber and then through the outlet. Improper flow may not fetch proper removal of arsenic from the contaminated water

6.4 Pureit Arsenic cum Germ Removal Filter

- The design of the filter though very attractive, requires experienced hand and practice for its installation

- The user experiences difficulty in dissembling and assembling the attachments and making it ready for reuse once its purification capacity is lost

7. Ranking of the Arsenic Removal Filters

For want of well-defined specifications and job requirements for arsenic removal units, a quantitative ranking of the evaluated units is not readily feasible. Nonetheless a qualitative ranking of the units under study has been attempted based on the following criteria.

i) Design of the filter unit
ii) Presence of essential media and convenience in it regeneration
iii) Time required to obtain arsenic safe water
iv) Arsenic removal capacity of the filter
v) Use of additional chemicals
vi) Provision to remove other impurities
vii) Occupational Hazards
viii) Cost of the filter
ix) Capacity of the filter
x) User friendliness
xi) Regeneration/ replacement frequency and cost
xii) Presence of Indicator for indication of getting safe or unsafe filtered water

In the backdrop of available technical information on arsenic removal filters under study from the manufacturers / suppliers, the results of their laboratory and field evaluation and user's experience, a comparative assessment of the units has been made as summarized in **Table 50.**

Table 50
Comparative Evaluation of the Arsenic Removal Units

S. No.	Parameter	RSM	NMRL-DRDO	SONO	Pureit
1.	Filter Design	- Compact & heavy - Ferro cement body - Candle made up of burning soil & paddy husk - Activated Alumina Sachet	- Compact with three chambers - Stainless steel/ - Polypropylene body - Contains iron rich reactant material & sand	- Compact & heavy - Plastic body (two chambered) placed on iron stand - Contains composite iron matrix as reactant material &coarse sand and brick chips	- Compact & light weight - Engineering Plastics body, food safe, non-toxic - Contains micro-fibre mesh, carbon trap, germ kill processor and polisher - Alumina based filter media
2.	Filter Capacity	23 litres (both chambers)	It works like instant filter. The capacity of filtered water chamber is 10 litres for stainless steel unit and 5 litres for polypropylene unit	10 litres for upper chamber	6 litres for each chamber
3.	Presence of essential media	- Filter candle - Activated alumina sachet	-Reactant material - Treated sand	- composite iron matrix as reactant material - sand and brick chips	- carbon trap - germ kill media - Polisher
4.	Time required to obtain arsenic safe water (At first installation)	1-2 hours	1 hour	1-1.5 hours	Immediate
5.	Contact Time	15 min	- 20 min (Stainless Steel Unit) - 15min (Polypropylene Unit)	15 min	Immediate
6.	Rate of Filtration	10 L/h	15L/h	15L/h	15L/h
7.	Breakthrough Studies (Based on total Quantity of arsenic contaminated water passed through each filter)	-	1000 L	1000L	1000L

S. No.	Parameter	RSM	NMRL-DRDO	SONO	Pureit
8.	Arsenic removal capacity	< 10 ppb	< 10 ppb	<10 ppb	<10 ppb
9.	Use of additional chemicals	Not required	Required ($KMnO_4$)	Recommended disinfection with hot water	Not required
10.	Provision to remove other impurities	Iron and fluoride	Iron and bacteria	iron, manganese, heavy metals, nitrate, nitrite and many anions	Viruses, bacteria, parasites, odour, pesticides
11.	Occupational hazards	None	Waste utilization in the form of non-leachable M-25 grade cement bricks	Manufacturers Claim: TCLP results reveal that the media is non-hazardous	None
12.	Cost of filter	Rs.575/-	SS Filter: Rs.2000/- PVC Filter: Rs.1000/-	$40	Rs.2700/-
13.	User friendliness	Easy to use	- Easy to operate - Needs practice	- Easy to operate - Needs practice	- Installation needs practice - Easy to operate -
14.	Regeneration/ replacement frequency and cost	Six monthly for Rs. 100/-	Waste utilization in the form of non-leachable M-25 grade cement bricks	- NO regeneration required - Expiry after 5 years - The material to be disposed on identified dumping sites (Claim: TCLP results reveal that the media is non-hazardous)	- Battery to be charged after 1500 Litres of purification. - Expiry after 2 years - Cost of germkill kit Rs.700 - Expired Germ kill kit to be disposed of safely with dry domestic waste
15.	Presence of Indicator for indication of getting safe or unsafe filtered water	Not present	Not present	Not present	Present (The setting is such that the Chlorine Life Indicator is Proxy for arsenic as well)

8. Suggestions for Improvement of Arsenic Removal Filters

In the backdrop of the studies an attempt has been made to delineate guidelines for the use of procured arsenic removal units and develop and suggest generic standards for domestic arsenic removal unit.

- ✓ The arsenic removal unit should be compact, preferably made of durable material.
- ✓ The material of the unit should be such that the filtered water should not become warm during hot season. Otherwise the consumers should be advised to store the arsenic safe water in earthen pot subsequent to filtration to have cool water for drinking purposes.
- ✓ The unit should be convenient to carry during transportation and user friendly.
- ✓ The unit should contain arsenic removal media and/or filter media in sufficient quantity necessary to bring about arsenic removal to desired residual arsenic concentrations.
- ✓ The components of arsenic removal unit should not be susceptible to rust or damage by the media or material used for arsenic removal or the reaction products leading to inaccurate results.
- ✓ Must provide consistent arsenic removal to less than 10 ppb regardless of the level of influent arsenic contamination.
- ✓ The arsenic removal unit should be capable of removing total arsenic in the arsenic contaminated water irrespective of the form (arsenite, arsenate) in which it is present.
- ✓ The inner architecture / configuration of the unit should be such as to retain the contents in place without being disarranged during transit. Also, any delicate part or attachment should remain intact during transit.
- ✓ The consumables used in the unit should be easily and conveniently replenished.
- ✓ The chemicals / reagents to be added from outside should be such as to complete the initial reactions as fast as possible.
- ✓ The shelf life of the filter media should be long as possible. The date of manufacture and the time of expiry, if any, should be indicated.

- ✓ The unit should not involve direct contact with hazardous material(s) with the hands so as to pose any health hazard to the user.
- ✓ In addition to arsenic the unit should have an inbuilt provision for elimination of at least turbidity and bacterial contamination, if present in the arsenic contaminated water to make it safe for drinking.
- ✓ The volume of arsenic contaminated water, the concentration and volume / weight .of the media and necessary chemicals should be such as to enable removal of higher concentrations of arsenic to the desired minimum concentration of arsenic.
- ✓ In the absence of regular monitoring of arsenic levels in filtered water by the NGO the consumers should be taught to detect residual arsenic levels using field test kit for arsenic and inform the village head / sarpanch, for the needful, if alarming concentrations of arsenic are observed in filtered water.
- ✓ Should not produce any sludge requiring disposal as part of its normal operation. However, if unavoidable safe disposal methodology to be delineated.
- ✓ The unit should contain illustrated instructions in simple language (English and local language) to enable the user perform the process scientifically and accurately.

Annexure I

Protocol for Evaluation of Domestic Arsenic Removal Filters

A. RSM Filter with Activated Alumina Technology - Domestic Arsenic Removal Filter

1. Both inside and outside portions of the filter are to be washed properly with clean water before use. The filter is kept on a stool so that it is 8-10 inches above the floor level
2. Water is to be put in the upper chamber. Filtration starts and the filtered water is stored in the clear water chamber. After sometime, the upper part of the filter is detached and the sachet of the activated alumina is removed. Raw water in the upper chamber and water stored in the bottom chamber is thrown away
3. The filter is now clean and ready for use. The sachet of activated alumina is fitted again in the valve and the upper part of the filter is placed on the top of the lower part. Take care so that the rubber gasket keeps the two portions in position properly.
4. The upper chamber is filled up with raw/tube well water. Filtered water is stored in the bottom chamber.

B. NMRL-DRDO Household Water Filter

1. Filter material bag is soaked overnight in tap water and placed in first Container.
2. Sand bag is placed in second container.
3. Arsenic contaminated water is allowed to flow in to the first container.
4. Initial 1-2 L of water is rejected.
5. Arsenic-free water is collected from bottom-most (3^{rd}) container and can be used for drinking and cooking purpose
6. Filter material and sand is replaced periodically, as per usage.

C. Procedure for Operation of Sono Filter and collection of filtered water

1. Close the taps of both red & green buckets.
2. After installation, discard 2 batches of filtered water. Thereafter follow the steps of disinfection, using hot water. If the filter is not in use for a long period, again disinfection steps are to be followed.

3. There is a container attached with the cover of red bucket. Take out the cover of the container and pour water. About 18-20 L of water can be poured in red bucket. Instead of pouring water in the container, if one pours directly in the bucket, in that case filtering capacity of the unit may be lost
4. For collecting filtered water, place a clean pot below the tap of green bucket
5. Open the outlets of red and green buckets alternately, and collect filtered water from the tap of green bucket.
6. If filtered water is not required keep both the taps of the buckets closed.

Strictly to Remember

1. The users must take care of cleanliness of individual and filter assembles
2. At initial stage, water of first two batches is to be discarded. Thereafter, filtered water is to be disinfected, prior to use for drinking purpose
3. Only at dry condition or when no water is left for filtering the assembly can be cleaned with hot water
4. The pot used for arsenic contaminated tube well water must be different from that used for collection / storing of filtered water.

D. Pureit Arsenic Cum Germ Removal Filter

1. Six litres of arsenic contaminated water is poured in the unit.
2. The water from the dwell chamber moves upward through the arsenic scavenger, which contains granular activated carbon (GAC) and active media to remove Arsenic.
3. The water first passes through the granular activated carbon polisher, which removes the residual Chlorine from the water.
4. This water then passes through the activated Alumina, where the Arsenic gets adsorbed on the surface.
5. The purified water that is free from Arsenic then gets collected in the bottom chamber for consumption.
6. The entire flow of water through the purifier is hydrostatically balanced through precisely designed various components used in the purifier.