



impregnated with lead acetate solution and into an absorber tube containing SDDC dissolved in pyridine forming red complex, which is measured spectrophotometrically at wavelength of 535 nm.

4.3.2 RSM Filter with Activated Alumina Technology

A crack was visible on the cover of the upper chamber of one of the units and the valve below the iron removal candle to which the sachet of activated alumina is connected in the lower chamber was found to be broken. This must have occurred during transit from Kolkata to Nagpur. Hence, the studies were carried out using another unit which was found to be intact and in good condition. The upper chamber of the unit was filled with 10 litres of synthetic water with arsenite concentration of 131 ppb followed by 637 ppb of arsenic. The filtered water was collected at 0, 2, 4, 6 and 24 hours interval. The filtered water from the outlet was found to be milky when collected at 0 and 2 hours, which is evident from the values of turbidity as may be seen from **Table 1**. The residual arsenite concentration was found to be above the BIS as well as the WHO guideline value for arsenic in drinking water even after 24 hrs for initial arsenite concentration of 131 ppb and 637 ppb. However, concentration of iron (except in the filtered water collected at 0 hour) and sulphate were found to be within the permissible limit prescribed by the BIS. After 48 hours of run the alumina sachet was found to be blocked. Further runs were carried out using aluminium sachet from another unit. However, for initial arsenite concentration of 154 ppb, concentration of arsenic in filtered water collected at regular intervals up to 24 hrs was found to be above the permissible limit given by WHO and BIS. The sachet was back-washed for 12 hrs and after repeated runs for initial arsenic concentrations of 144ppb, 112 ppb, and 154 ppb the residual concentration of arsenite was found to be slightly reduced to 19.2 ppb, 31.3 ppb and 33.3 ppb respectively after 24 hrs.; though more than the BIS and WHO guideline value for arsenic.

A fresh activated alumina sachet was procured from the Rural Sanitary Mart through UNICEF, Kolkata for want of obtaining desired removal for arsenic using the RSM filter. The upper chamber of the unit was filled with 10 litres of synthetic water with arsenite concentrations of 125 ppb, 507 ppb, 1240 ppb, 2064 ppb followed by 3057 ppb of arsenic. The filtered water was collected at 0, 2, 4 and 24 hours interval. The



residual arsenite concentrations (**Table 2**) were found to be above the BIS as well as the WHO guideline value for arsenic in drinking water even after 24 hrs, for runs carried out for initial arsenite concentrations ranging from 125 ppb to 3057 ppb. However, concentration of iron and sulphate were found to be within the permissible limit prescribed by the BIS.

Table 1

Removal of Arsenite using RSM Filter with Activated Alumina Technology

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	131	0	6.2	392	377	37.7	1.2	2.7
2		2	7.0	392	45	31.5	0.17	1.5
3		4	7.0	398	11.9	29.6	0.19	2.1
4		6	7.1	401	7	33.3	0.08	2.7
5		24	7.2	411	7	31.2	0.07	2.1
6	637	0	6.2	330	26	125.8	0.17	1.5
7		2	7.0	356	4	169.3	0.19	2.1
8		4	7.5	389	4	79.6	0.16	2.1
9		6	7.4	376	4	79.6	0.01	1.7
10		24	7.5	425	4	73.2	0.08	1.7
<p>After this reading Alumina sachet was found to be blocked. This sachet was replaced by another alumina sachet</p>								
1	154	0	6.1	344	61	64.8	0.04	2.7
2		2	7.2	304	24	77.8	0.09	2.1
3		4	7.1	299	9	93.4	0.08	1.5
4		24	7.3	304	10	53.7	0.08	2.7
<p>After this reading Alumina sachet was back-washed with water for 12 hrs.</p>								
1	144	0	6.2	389	21	110	0.19	2.1
2		2	6.7	325	10	64	0.11	2.7
3		24	7.1	343	14	19.2	0.19	2.7
1	112	24	7.2	363	20	31.3	0.17	3.8
1	154	24	7.6	401	21	33.3	0.19	3.8



Table 2

Removal of Arsenite using RSM Filter with Activated Alumina Technology (With New AA Sachet)

Sr. No.	Initial As(III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)	SO ₄ (mg/l)	Al (mg/l)
1	125	0	5.8	389	1	117	0.11	2.7	0.02
2		2	6.7	398	1	91	0.13	1.5	0.005
3		4	7.1	389	2	102	0.19	ND	0.001
4		24	7.1	389	1	117	ND	2.1	0.08
5	507	0	6.1	293	1	294	ND	ND	0.01
6		2	7.4	274	1	340	0.19	1.1	0.026
7		4	7.5	358	1	418	0.07	2.3	0.003
8		24	7.7	357	2	473	0.08	4.7	0.097
9	1240	0	6.3	361	2	732	0.11	5.9	0.097
10		2	7.2	394	1	594	ND	1.1	0.008
11		4	7.7	249	1	699	0.08	2.1	0.01
12		24	7.5	248	1	842	ND	3.5	0.02
Sr. No.	Initial As(III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)	SO ₄ (mg/l)	Al (mg/l)
13	2064	0	5.7	294	1	1555	0.16	ND	0.08
14		2	7.6	311	2	1994	ND	5.9	0.006
15		4	7.6	291	1	1702	0.08	ND	0.01
16		24	7.3	283	1	1973	0.12	2.7	0.01
17	3057	0	6.1	276	1	2272	0.13	ND	0.01
18		2	7.2	247	1	2988	ND	ND	0.005
19		4	7.4	325	1	2776	0.08	ND	0.026
20		24	7.8	299	1	2887	ND	ND	0.008

Similar studies were carried out using water contaminated with pentavalent arsenic having concentrations in the range of 119 ppb to 3020 ppb as given in **Table 3**. It is evident from the table that though arsenate removal was observed for all concentration ranges, the residual arsenate concentrations were found to be much higher than the WHO guideline value for arsenic. During all the runs the pH of the raw water was maintained between 5.5 and 6.5 as alumina exhibits better efficiency of removal in this pH range. In the backdrop of the results obtained for removal of As(III) and As(V), to carry out the removal studies with combination of As(III) and As(V) in various ratios using RSM filter was thought to be of no use so as to arrive at any positive conclusion. However, values for iron, sulphate and aluminium were found to be within the permissible limits of BIS. Thus, it was concluded that the simulated water from tap / dug well which was used as raw water source in the present laboratory studies, might not be compatible with the RSM filter which might have been the constraint in obtaining the desired removal of arsenic. Hence, the evaluation studies were carried out with RSM Filter in the arsenic affected area of North 24 Parganas using arsenic contaminated tube well water as the raw water source.

Table 3

Removal of Arsenate using RSM Filter with Activated Alumina Technology (With New AA Sachet)

Sr. No.	Initial As(V) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(V) (ppb)	Fe (mg/l)	SO ₄ (mg/l)	Al (mg/l)
1	119	0	6.2	392	1	44	0.12	2.7	0.08
2		2	7.0	392	1	49	0.17	1.5	0.026
3		4	7.0	390	1	49	0.19	2.1	0.01
4		24	7.2	391	2	48	0.07	2.1	0.03
5	519	0	6.2	530	1	235	0.17	1.5	0.006
6		2	7.0	356	1	253	0.19	2.1	0.008
7		4	7.3	389	1	256	0.16	2.1	0.01
8		24	7.1	425	1	262	0.08	1.7	0.026
9	1060	0	6.1	530	1	426	0.17	2.7	0.008
10		2	7.2	389	1	442	0.19	1.5	0.01
11		4	7.1	530	1	440	0.07	ND	0.02
12		24	7.0	391	2	428	0.17	2.1	0.08
13	2100	0	6.3	425	1	890	0.07	ND	0.006
14		2	7.3	391	2	898	0.17	1.1	0.01
15		4	7.4	391	2	924	0.08	2.3	0.01
16		24	7.3	389	1	920	0.19	4.7	0.01
17	3020	0	6.4	425	2	1460	0.07	5.9	0.03
18		2	7.3	530	1	1478	0.08	1.5	0.006
19		4	7.4	389	1	1502	0.19	ND	0.008
20		24	7.4	391	2	1512	0.07	2.1	0.01

4.3.3 NMRL-DRDO Household Water Filter

The trial runs were carried out using the NMRL-DRDO water filters made of stainless steel as well as polypropylene separately for arsenite and arsenate with initial arsenic concentrations of ranging from 100ppb to 3000 ppb. Twelve litres water each with initial arsenite concentrations of 154 ppb, 485 ppb, 1158 ppb, 2120 ppb, and 3092 ppb were passed through the filter respectively and samples were collected from the filter outlet at intervals ranging between 0 to 24 hrs for each concentration. **Table 4** shows that hundred percent removals were obtained for arsenite for various concentrations of arsenic containing water used in the study. Iron concentrations in filtered waters were found to be within the permissible limits prescribed by the BIS.

Similar studies were carried out using water contaminated by pentavalent arsenic with initial arsenate concentrations ranging from 192 ppb to 3080 ppb. However, from the concentrations for residual arsenate obtained in filtered water, it was not possible to draw any conclusion as is evident from **Table 5**, though at many instances arsenate concentrations below WHO guideline value of 10 ppb were obtained. The expected trend in the removal of arsenate might not have been obtained as the quantity of sand supplied by the supplier was not sufficient. The special type of sand (Ganga sand) used in this filter was again procured from the supplier. The concentrations of iron in the filtered water were found to be within the permissible limits of BIS.



Table 4
Removal of Arsenite using NMRL-DRDO Stainless Steel Household Water Filter

Sr. No.	Initial As(III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)
1	154	0	7.8	100	11	ND	1.76
2		2	8.0	113	8	ND	0.71
3		4	7.9	107	11	ND	0.75
4		24	8.3	110	5	ND	0.65
5	485	0	8.1	108	10	ND	1.09
6		2	8.1	124	9	ND	1.08
7		4	8.1	127	10	ND	0.91
8		24	8.2	122	10	ND	1.22
9	1158	0	8.3	119	10	ND	1.0
10		2	8.2	114	9	ND	0.6
11		4	8.2	124	9	ND	0.55
12		24	8.2	113	8	ND	0.58
13	2120	0	8.3	114	9	ND	0.6
14		2	8.3	134	7	ND	0.81
15		4	8.2	131	6	ND	1.08
16		24	8.3	124	8	ND	1.22
17	3092	0	8.5	138	4	ND	0.44
18		2	8.5	127	4	ND	0.08
19		4	8.4	132	4	ND	0.60
20		24	8.3	131	3	ND	0.91

Table 5
Removal of Arsenate using NMRL-DRDO Stainless Steel
Household Water Filter

Sr. No.	Initial As(V)Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(V) (ppb)	Fe (mg/l)
1	192	0	7.8	132	4	6.47	0.17
2		2	7.8	121	3	21.18	0.14
3		4	7.7	131	3	12.95	0.13
4		24	7.7	124	3	0.067	0.18
5	514	0	7.8	126	1	7.4	0.1
6		2	7.7	151	2	0.93	0.1
7		4	7.7	123	2	7.75	0.08
8		24	7.7	126	2	15.7	0.08
9	1493	0	7.8	132	3	9.25	0.18
10		2	7.7	121	3	1.85	0.24
11		4	7.6	131	4	9.25	0.16
12		24	7.7	150	3	12.95	0.21
13	2507	0	7.7	124	2	9.25	0.28
14		2	7.7	131	2	18.5	0.29
15		4	7.8	126	3	12.02	0.38
16		24	7.6	135	3	ND	0.32
17	3080	0	7.6	129	4	9.25	0.90
18		2	7.6	133	4	9.25	0.21
19		4	7.8	140	3	11.85	0.14
20		24	7.5	128	3	18.5	0.22

Subsequent to the procurement of sand from the supplier 10 litres of 3000 ppb of Arsenic (V) water was passed through the filter daily up to 11 days to have trial runs and optimize the quantity of sand to be used to obtain desired removal of arsenic. The results are given in **Table 6**. It was observed that after fourth day of trial run As (V) concentration was above

permissible limit for arsenic prescribed by the WHO. Hence, additional quantity of sand was added in the filter so as to obtain arsenic removal below the WHO guideline value.

The trial runs were repeated with initial arsenate concentrations of 115 ppb, 489 ppb, 1059 ppb, 2100 ppb, and 3019 ppb respectively and samples were collected from the filter outlet at intervals ranging between 0 to 24 hrs. The collected samples were analysed for arsenic. The results are given in **Table 7**. The residual arsenate concentrations in filtered waters of various concentrations of arsenic containing water used in the study were found to be well within the guideline limits for arsenic given by the WHO. Iron and manganese concentrations in filtered waters were found to be within the permissible limits prescribed by the BIS.

Table 6
Eleven Days Trial Run for Optimization of Quantity of Sand for Removal of Arsenate using NMRL-DRDO Stainless Steel Household Water Filter

Days	Initial As(V) conc(ppb).	Residual As (ppb)	Total volume (litre)
1	2957	ND	110
2	3080	0.925	
3	3080	ND	
4	3268	4.63	
5	3268	74.94	
6	3010	21.28	
7	3010	261.84	
8	3010	715.21	
9	3010	57.36	
10	3010	110.17	
11	3180	257	

Table 7
Removal of Arsenate using NMRL-DRDO Stainless Steel Household Water Filter

Sr.No.	Initial As (V) conc (ppb)	Sampling interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(V) (ppb)	Fe (mg/l)	Mn (mg/l)
1	115	0	7.6	90	1	ND	0.011	ND
2		2	7.9	114	1	5.55	0.2	ND
3		4	8.0	105	1	1.18	0.22	ND
4		24	7.9	106	0.9	3.7	ND	ND
5	489	0	8.1	117	0.9	0.925	ND	ND
6		2	8.3	127	0.7	ND	0.18	ND
7		4	8.0	132	0.9	3.7	ND	ND
8		24	8.1	117	1	6.48	ND	ND
9	1059	0	8.0	130	1	3.7	0.018	ND
10		2	8.0	142	2	4.63	ND	ND
11		4	8.1	132.0	1	1.18	ND	ND
12		24	8.1	136	1	ND	0.09	ND
13	2100	0	8.2	129	2	4.63	ND	ND
14		2	8.2	124	1	2.63	0.022	ND
15		4	8.2	122	1	1.86	ND	ND
16		24	8.2	125	2	3.7	0.15	ND
17	3019	0	8.14	138	0.8	ND	ND	ND
18		2	8.13	136	1	1.81	ND	ND
19		4	8.14	134	1	0.925	0.12	ND
20		24	8.15	137	1	4.63	ND	ND

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 8 through 12**. 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 manganese were found to be within the desirable limits of BIS.



Table 8
Removal of Arsenic using NMRL-DRDO Stainless Steel
Household Water Filter
As III: As V (1:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	111	0	7.8	132	4	6.48	0.17	ND
2		2	7.8	121	3	5.55	0.14	ND
3		4	7.7	131	3	5.44	0.13	ND
4		24	7.7	124	3	6.02	0.18	ND
5	520	0	7.8	126	1	5.23	0.1	ND
6		2	7.7	151	2	5.12	0.1	ND
7		4	7.7	123	2	5.24	0.08	ND
8		24	7.7	126	2	5.55	0.08	ND
9	1142	0	7.8	132	3	5.23	0.18	ND
10		2	7.7	121	3	6.02	0.24	ND
11		4	7.6	131	4	6.02	0.16	ND
12		24	7.7	150	3	5.23	0.21	ND
13	2010	0	7.7	124	2	5.45	0.28	ND
14		2	7.7	131	2	5.55	0.29	ND
15		4	7.8	126	3	4.40	0.38	ND
16		24	7.6	135	3	4.63	0.32	ND
17	3117	0	7.6	129	4	5.23	1.19	ND
18		2	7.6	133	4	6.02	0.21	ND
19		4	7.8	140	3	6.02	0.14	ND
20		24	7.5	128	3	6.02	0.22	ND

Table 10

Removal of Arsenic using NMRL-DRDO Stainless Steel Household Water Filter
As III: As V (1:3)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	150	0	7.8	128	3	4.20	0.02	ND
2		2	7.8	129	3	5.24	0.10	ND
3		4	7.5	125	3	5.55	0.20	ND
4		24	7.8	124	3	5.23	0.12	ND
5	589	0	7.8	128	3	4.63	0.21	ND
6		2	7.7	122	3	4.63	0.28	ND
7		4	7.8	128	3	5.23	0.20	ND
8		24	7.7	200	3	5.55	0.02	ND
9	1123	0	7.7	201	4	5.23	0.10	ND
10		2	7.5	122	3	4.63	0.20	ND
11		4	7.7	128	4	5.23	0.12	ND
12		24	7.8	200	3	6.02	0.21	ND
13	2040	0	7.8	201	3	5.55	0.21	ND
14		2	7.8	129	4	5.23	0.14	ND
15		4	7.7	128	3	4.63	0.14	ND
16		24	7.4	129	4	4.63	0.02	ND
17	3120	0	7.8	125	4	5.23	0.10	ND
18		2	7.7	124	4	6.02	0.20	ND
19		4	7.7	125	3	6.02	0.12	ND
20		24	7.8	128	3	6.02	0.14	ND



Table 11
Removal of Arsenic using NMRL-DRDO Stainless Steel
Household Water Filter
As III: As V (2:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	102	0	7.5	128	3	6.02	0.02	ND
2		2	7.6	200	3	6.21	0.10	ND
3		4	7.5	201	3	6.12	0.20	ND
4		24	7.6	122	3	6.02	0.12	ND
5	524	0	7.5	128	3	6.20	0.21	ND
6		2	7.5	200	3	6.03	0.21	ND
7		4	7.5	201	3	6.20	0.14	ND
8		24	7.6	200	3	7.01	0.02	ND
9	998	0	7.7	201	3	7.23	0.10	ND
10		2	7.6	122	3	6.92	0.20	ND
11		4	7.6	128	3	6.30	0.12	ND
12		24	7.7	124	3	6.82	0.21	ND
13	2460	0	7.5	125	3	6.20	0.21	ND
14		2	7.7	128	3	6.03	0.14	ND
15		4	7.7	201	3	6.20	0.14	ND
16		24	7.6	122	3	7.01	0.02	ND
17	3026	0	7.5	128	3	7.23	0.10	ND
18		2	7.6	200	3	6.03	0.20	ND
19		4	7.6	201	3	6.20	0.12	ND
20		24	7.6	200	3	7.01	0.14	ND



Table 11
Removal of Arsenic using NMRL-DRDO Stainless Steel
Household Water Filter
As III: As V (2:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	102	0	7.5	128	3	6.02	0.02	ND
2		2	7.6	200	3	6.21	0.10	ND
3		4	7.5	201	3	6.12	0.20	ND
4		24	7.6	122	3	6.02	0.12	ND
5	524	0	7.5	128	3	6.20	0.21	ND
6		2	7.5	200	3	6.03	0.21	ND
7		4	7.5	201	3	6.20	0.14	ND
8		24	7.6	200	3	7.01	0.02	ND
9	998	0	7.7	201	3	7.23	0.10	ND
10		2	7.6	122	3	6.92	0.20	ND
11		4	7.6	128	3	6.30	0.12	ND
12		24	7.7	124	3	6.82	0.21	ND
13	2460	0	7.5	125	3	6.20	0.21	ND
14		2	7.7	128	3	6.03	0.14	ND
15		4	7.7	201	3	6.20	0.14	ND
16		24	7.6	122	3	7.01	0.02	ND
17	3026	0	7.5	128	3	7.23	0.10	ND
18		2	7.6	200	3	6.03	0.20	ND
19		4	7.6	201	3	6.20	0.12	ND
20		24	7.6	200	3	7.01	0.14	ND



Table 12
Removal of Arsenic using NMRL-DRDO Stainless Steel
Household Water Filter
As III: As V (3:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	190	0	7.7	218	3	5.23	0.02	ND
2		2	7.7	220	4	4.63	0.21	ND
3		4	7.5	220	4	4.63	0.14	ND
4		24	7.7	213	4	5.24	0.14	ND
5	534	0	7.8	218	3	5.55	0.02	ND
6		2	7.8	220	3	5.23	0.10	ND
7		4	7.7	220	4	4.63	0.20	ND
8		24	7.7	220	3	4.63	0.20	ND
9	1088	0	7.5	218	4	5.23	0.10	ND
10		2	7.7	218	3	4.63	0.20	ND
11		4	7.8	218	4	5.55	0.12	ND
12		24	7.8	220	3	5.23	0.21	ND
13	2112	0	7.8	220	3	4.63	0.21	ND
14		2	7.7	230	4	4.63	0.14	ND
15		4	7.5	270	4	5.23	0.14	ND
16		24	7.7	280	3	4.63	0.02	ND
17	3098	0	7.8	270	3	5.23	0.10	ND
18		2	7.8	280	4	6.02	0.20	ND
19		4	7.8	280	3	6.02	0.12	ND
20		24	7.7	280	4	6.02	0.14	ND

The size of the polypropylene filter is smaller than the stainless steel filter; hence runs were carried out separately using 7 litres of water each for initial concentrations of arsenite - 114 ppb, 485 ppb, 1007 ppb, 2294 ppb and 3092 ppb. Hundred percent removals were obtained for arsenite as is evident from **Table 13**. The concentration of iron was found to be within the permissible limits of BIS except for few instances.



Table 13

Removal of Arsenite using NMRL-DRDO Polypropylene Household Water Filter

Sr. No.	Initial As (III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity ($\mu\text{S}/\text{cm}$)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)
1	114	0	8.3	84	25	ND	1.77
2		2	8.2	106	16	ND	1.12
3		4	8.2	94	10	ND	0.65
4		24	8.2	114	10	ND	0.07
5	485	0	8.6	103	8	ND	2.04
6		2	8.9	123	6	ND	0.48
7		4	8.5	111	6	ND	0.43
8		24	8.4	116	6	ND	0.65
9	1007	0	8.4	100	10	ND	1.76
10		2	8.4	114	6	ND	0.75
11		4	8.4	114	5	ND	0.55
12		24	8.3	111	6	ND	0.09
13	2294	0	8.3	114	11	ND	0.65
14		2	8.2	112	4	ND	0.08
15		4	8.3	110	5	ND	0.43
16		24	8.2	116	5	ND	0.07
17	3092	0	8.2	124	3	ND	0.85
18		2	8.2	122	2	ND	0.48
19		4	8.3	117	3	ND	0.43
20		24	8.3	120	2	ND	0.08

Similar studies were carried out using water with initial concentrations of arsenic pentavalent as 192 ppb, 514 ppb, 1493 ppb, 2507 ppb, and 3080 ppb respectively. However, from the concentrations for residual arsenate obtained in filtered water, it was not possible to draw any



conclusions as is evident from **Table14**, though at many instances arsenate concentrations below WHO guideline value of 10 ppb were obtained. The concentrations of iron and manganese were found to be below the levels.

Table 14
Removal of Arsenate using NMRL-DRDO Polypropylene Household Water Filter

Sr. No.	Initial As(V) Conc. (ppb)	Sampling Interval (hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As(V) (ppb)	Fe (mg/l)	Mn (mg/l)
1	192	0	8.3	119	4	ND	0.18	ND
2		2	8.2	119	3	9.25	0.21	ND
3		4	8.3	117	2	ND	0.15	ND
4		24	8.4	120	3	ND	0.3	ND
5	514	0	8.3	117	4	9.24	0.2	ND
6		2	8.4	121	4	ND	0.22	ND
7		4	8.2	131	4	0.925	0.33	ND
8		24	8.1	120	3	0.925	0.36	ND
9	1493	0	8.3	104	2	ND	0.14	ND
10		2	8.3	121	3	ND	0.21	ND
11		4	8.3	131	2	ND	0.18	ND
12		24	8.2	161	4	ND	0.28	ND
13	2507	0	8.5	121	4	401.55	0.22	ND
14		2	8.3	125	4	112.87	0.38	ND
15		4	8.3	131	4	327.55	1.29	ND
16		24	8.3	127	5	0.095	0.29	ND
17	3080	0	8.3	190	4	4.62	0.21	ND
18		2	8.2	124	8	7.4	0.32	ND
19		4	8.4	132	4	112.87	0.14	ND
20		24	8.3	120	23	0.925	0.21	ND

As in stainless steel filter 10 litres of 3000 ppb of Arsenic (V) water was passed through the polypropylene filter daily up to 11 days to have trial runs and optimize the quantity of sand to be used to obtain desired removal of arsenic. The results are given in **Table15**. It was observed that after second day of trial run As (V) concentration was observed to be above



permissible limit for arsenic prescribed by the WHO. Hence, additional quantity of sand was added in the filter so as to obtain arsenic removal below the WHO guideline value.

Table 15
Eleven Days Trial Run for Optimization of Quantity of Sand for Removal of Arsenate using NMRL-DRDO Polypropylene Household Water Filter

Sr. No.	Initial As(V) Conc(ppb)	Residual As (ppb)	Total volume (litre)
1	2957	ND	110
2	3080	2.78	
3	3268	717	
4	3268	915	
5	3011	287	
6	3011	318	
7	3180	700	

The trial runs were repeated with initial arsenate concentrations of 115 ppb, 489 ppb, 1059 ppb, 2100 ppb, and 3019 ppb respectively and samples were collected from the filter outlet at intervals ranging between 0 to 24 hrs. The collected samples were analysed for arsenic. The results are given in **Table16**. The residual arsenate concentrations in filtered waters of various concentrations of arsenic containing water used in the study were found to be well within the guideline limits for arsenic given by the WHO. Iron and manganese concentrations in filtered waters were found to be within the permissible limits prescribed by the BIS.

Table 16

Removal of Arsenate using NMRL-DRDO Polypropylene Household Water Filter (After Addition of Sand)

Sr. No.	Initial As (III) (ppb)	Sampling interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	115	0	8.16	109.2	1.86	ND	ND	ND
2		2	8.12	111.2	2.16	0.925	0.001	ND
3		4	8.10	107.2	2.21	1.18	ND	ND
4		24	8.20	109.5	1.51	ND	0.12	ND
5	489	0	8.25	107.9	1.43	1.82	0.1	ND
6		2	8.22	109.5	2.05	4.63	ND	ND
7		4	8.27	112.0	1.98	0.925	0.008	ND
8		24	8.35	126.2	0.65	10.18	ND	ND
9	1059	0	8.32	137.4	1.38	3.7	ND	ND
10		2	8.27	140.5	1.94	10.18	0.009	ND
11		4	8.31	141.6	1.97	4.63	ND	ND
12		24	8.37	142.9	1.68	3.7	ND	ND
13	2100	0	8.32	146.0	2.18	1.18	0.012	ND
14		2	8.36	141.4	2.45	0.925	ND	ND
15		4	8.32	148.3	2.51	2.63	0.12	ND
16		24	8.26	151.8	2.22	0.925	0.11	ND
17	3019	0	8.14	160.3	2.60	ND	ND	ND
18		2	8.19	150.6	2.67	0.925	ND	ND
19		4	8.22	147.2	2.97	2.63	0.1	ND
20		24	8.28	141.3	3.05	ND	ND	ND

Studies were carried out with 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 using polypropylene filter. The results are given in **Tables 17 through 21**. 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 manganese were found to be within the desirable limits of BIS.



Table 17
Removal of Arsenic using NMRL-DRDO Polypropylene
Household Water Filter
As III: As V (1:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity ($\mu\text{S}/\text{cm}$)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	111	0	8.3	119	4	5.23	0.18	ND
2		2	8.2	119	3	5.55	0.21	ND
3		4	8.3	117	2	5.55	0.15	ND
4		24	8.4	120	3	6.03	0.30	ND
5	530	0	8.3	117	4	6.22	0.20	ND
6		2	8.4	121	4	6.33	0.22	ND
7		4	8.2	131	4	6.03	0.33	ND
8		24	8.1	120	3	5.55	0.36	ND
9	1142	0	8.3	104	2	6.02	0.14	ND
10		2	8.3	121	3	6.66	0.21	ND
11		4	8.3	131	2	6.50	0.18	ND
12		24	8.2	161	4	7.23	0.28	ND
13	2113	0	8.5	121	4	7.02	0.22	ND
14		2	8.3	125	4	6.02	0.38	ND
15		4	8.3	131	4	6.48	1.29	ND
16		24	8.3	127	5	6.42	0.29	ND
17	3117	0	8.3	190	4	6.96	0.21	ND
18		2	8.2	124	8	7.22	0.32	ND
19		4	8.4	132	4	7.22	0.14	ND
20		24	8.3	120	3	6.98	0.21	ND

Table 18
Removal of Arsenic using NMRL-DRDO Polypropylene
Household Water Filter
As III: As V (1:2)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	145	0	8.3	120	4	5.55	0.30	ND
2		2	8.3	104	3	6.02	0.14	ND
3		4	8.2	121	2	6.66	0.21	ND
4		24	8.4	131	3	6.50	0.18	ND
5	568	0	8.3	161	4	7.23	0.28	ND
6		2	8.2	121	4	7.02	0.30	ND
7		4	8.4	125	4	6.02	0.20	ND
8		24	8.3	131	3	6.48	0.22	ND
9	1890	0	8.3	127	2	6.66	0.33	ND
10		2	8.3	190	3	6.50	0.30	ND
11		4	8.3	124	2	6.50	0.20	ND
12		24	8.3	132	4	6.21	0.22	ND
13	2435	0	8.2	120	4	7.02	0.33	ND
14		2	8.4	121	4	6.02	0.21	ND
15		4	8.3	125	4	6.05	0.15	ND
16		24	8.3	131	5	6.02	0.30	ND
17	3006	0	8.2	127	4	6.66	0.20	ND
18		2	8.4	131	8	6.50	0.22	ND
19		4	8.3	127	4	7.23	0.30	ND
20		24	8.4	190	23	7.20	0.24	ND

Table 19
Removal of Arsenic using NMRL-DRDO Polypropylene
Household Water Filter
As III: As V (1:3)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity ($\mu\text{S/cm}$)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	110	0	8.2	131	3	5.12	0.12	ND
2		2	8.4	127	3	6.02	0.18	ND
3		4	8.3	190	3	5.26	0.12	ND
4		24	8.3	124	5	5.65	0.12	ND
5	546	0	8.2	132	5	5.55	0.14	ND
6		2	8.4	120	4	5.23	0.14	ND
7		4	8.3	120	2	5.22	0.21	ND
8		24	8.4	182	5	5.06	0.18	ND
9	1254	0	8.4	192	3	6.02	0.28	ND
10		2	8.3	201	5	6.23	0.30	ND
11		4	8.3	112	5	6.25	0.30	ND
12		24	8.2	201	4	6.58	0.30	ND
13	2421	0	8.4	104	3	6.25	0.14	ND
14		2	8.3	115	5	6.25	0.21	ND
15		4	8.3	104	3	6.45	0.18	ND
16		24	8.3	121	3	6.45	0.28	ND
17	3365	0	8.3	131	5	5.25	0.30	ND
18		2	8.3	161	3	5.55	0.20	ND
19		4	8.3	121	4	5.26	0.22	ND
20		24	8.3	125	4	6.32	0.33	ND

Table 20
Removal of Arsenic using NMRL-DRDO Polypropylene
Household Water Filter
As III: As V (2:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	143	0	8.3	120	3	6.02	0.21	ND
2		2	8.3	104	3	6.66	0.15	ND
3		4	8.2	121	3	6.50	0.30	ND
4		24	8.4	131	2	7.23	0.12	ND
5	587	0	8.3	161	5	7.20	0.20	ND
6		2	8.2	121	2	5.55	0.13	ND
7		4	8.4	125	4	6.02	0.20	ND
8		24	8.3	121	2	6.66	0.14	ND
9	1278	0	8.3	125	3	6.50	0.21	ND
10		2	8.3	104	2	7.23	0.18	ND
11		4	8.3	121	3	5.55	0.20	ND
12		24	8.3	131	3	6.02	0.22	ND
13	2434	0	8.3	161	2	6.66	0.33	ND
14		2	8.3	121	5	6.50	0.20	ND
15		4	8.2	104	2	7.23	0.22	ND
16		24	8.4	121	2	6.65	0.30	ND
17	3233	0	8.3	131	3	6.21	0.24	ND
18		2	8.2	161	3	7.02	0.20	ND
19		4	8.4	121	3	6.02	0.22	ND
20		24	8.3	104	3	6.05	0.33	ND



Table 21
Removal of Arsenic using NMRL-DRDO Polypropylene
Household Water Filter
As III: As V (3:1)

Sr. No.	Initial As Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (μ S/cm)	Turbidity (NTU)	Residual As (ppb)	Fe (mg/l)	Mn (mg/l)
1	187	0	8.3	192	4	5.25	0.22	ND
2		2	8.3	189	5	5.26	0.33	ND
3		4	8.2	185	4	5.24	0.30	ND
4		24	8.3	195	8	6.02	0.20	ND
5	576	0	8.3	185	4	6.25	0.22	ND
6		2	8.4	195	3	6.25	0.33	ND
7		4	8.5	158	4	6.25	0.21	ND
8		24	8.3	158	3	6.24	0.30	ND
9	1450	0	8.3	168	2	6.21	0.14	ND
10		2	8.4	148	3	6.24	0.21	ND
11		4	8.3	195	2	6.21	0.18	ND
12		24	8.4	185	4	6.24	0.28	ND
13	2553	0	8.3	168	4	6.25	0.30	ND
14		2	8.3	158	4	6.54	0.20	ND
15		4	8.5	198	4	6.23	0.30	ND
16		24	8.3	158	3	6.54	0.14	ND
17	3577	0	8.4	188	2	5.55	0.21	ND
18		2	8.3	189	3	6.58	0.18	ND
19		4	8.3	185	4	6.55	0.28	ND
20		24	8.4	195	4	6.54	0.30	ND

The manufacturers have recommended addition of a pinch of potassium permanganate (KMnO₄) to the raw water prior to the start of the experiment. The above studies were carried out following the procedure given by the manufacturer. KMnO₄ is a strong oxidising agent and even acts as a disinfectant in water treatment. Similar studies were carried out separately using arsenic trivalent and pentavalent but without the addition of KMnO₄ for evaluation of stainless steel as well as polypropylene arsenic removal filters to study difference in the results, if any. Trial runs were carried out using ten litres of raw water each with initial arsenite concentrations of 101 ppb, 514 ppb and 1016 ppb respectively but without adding KMnO₄ in stainless steel DRDO unit and samples were collected at regular intervals till 24 hours. Simultaneously, studies were carried out using raw water with arsenate concentrations of 98 ppb, 514 ppb and 1069 ppb without addition of KMnO₄ and the samples were collected at regular intervals. The arsenic as well as iron concentrations were found to be below the permissible limits as is evident from **Tables 22 and 23**.

Table 22

Removal of Arsenite using NMRL-DRDO Stainless Steel Household Water Filter (Without KMnO₄)

Sr. No.	Initial As(III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity (µS/cm)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)
1	101	0	8.0	146	4	0.925	ND
2		2	8.2	151	5	ND	0.6
3		4	8.0	149	2	ND	0.4
4		24	8.3	146	3	0.925	ND
5	514	0	8.4	156	1	ND	0.6
6		2	8.3	155	5	ND	0.2
7		4	8.4	154	2	ND	ND
8		24	8.2	153	2	ND	0.2
9	1016	0	8.6	154	4	ND	0.6
10		2	7.5	160	5	ND	0.6
11		4	7.9	151	6	ND	0.6
12		24	8.0	149	3	ND	ND



Table 23

**Removal of Arsenate using NMRL-DRDO Stainless Steel
Household Water Filter
(Without KMnO_4)**

Sr. No.	Initial As(V) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity ($\mu\text{S/cm}$)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)	SO_4 (mg/l)
1	98	0	8.2	142	3	0.92	ND	2.85
2		2	8.1	137	4	1.85	0.8	5.11
3		4	8.0	131	3	1.85	0.9	4.02
4		24	8.1	120	3	0.92	0.7	3.57
5	514	0	8.0	137	2	0.92	1.2	ND
6		2	8.1	120	1	ND	ND	0.24
7		4	8.2	119	2	0.92	0.9	8.26
8		24	8.3	115	1	ND	1.3	2.70
9	1069	0	8.0	119	2	ND	1.0	1.19
10		2	8.1	115	3	1.85	0.7	ND
11		4	8.2	119	3	0.92	0.6	0.83
12		24	8.3	120	3	0.92	ND	ND

As the capacity of polypropylene filter is less, 6l of raw water with initial arsenite concentrations of 101 ppb, 514 ppb and 1016 ppb respectively but without adding KMnO_4 were used and samples were collected at regular intervals till 24 hours. Simultaneously, studies were carried out using raw water with arsenate concentrations of 98 ppb, 514 ppb and 1069 ppb with DRDO polypropylene unit without addition of KMnO_4 and the samples were collected at regular intervals. The arsenic as well as iron concentrations were found to be below the permissible limits as is evident from **Tables 24 and 25**.

Table 24

Removal of Arsenite using NMRL-DRDO Polypropylene Household Water Filter (Without KMnO_4)

Sr. No.	Initial As(III) Conc. (ppb)	Sampling Interval (Hr.)	pH	Conductivity ($\mu\text{S/cm}$)	Turbidity (NTU)	Residual As(III) (ppb)	Fe (mg/l)
1	101	0	8.3	118	3.7	0.925	0.11
2		2	8.2	119	2.9	ND	ND
3		4	8.3	116	1.9	ND	0.06
4		24	8.4	120	2.9	ND	0.04
5	514	0	8.1	117	3.7	1.85	ND
6		2	8.3	120	3.7	0.92	0.18
7		4	8.2	131	3.5	ND	0.18
8		24	8.4	120	2.8	ND	ND
9	1016	0	8.2	104	2.1	1.85	0.03
10		2	8.4	120	2.2	ND	0.22
11		4	8.6	130	3.6	0.92	0.04
12		24	8.5	161	4.3	ND	0.11