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Family scale rural water treatment plant: intermittent slow sand filtration

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the site. The use of the plant was discontinued in the winter months because the family could not get sufficient water!

8.2 Mafefe continuous flow pilot filter

8.2.1 Introduction

The Mafefe district is situated in the North Eastern Drakensberg, some 100 km south-east of Pietersburg. The population comprises 11 500 people living in 27 villages. The mining of asbestos, which commenced in the area around 1920 and continued until 1965, has had a wide ranging effect on the area. Asbestos constitutes a major environmental health hazard with some 80% of the population suffering from serious respiratory ailments.

The removal of asbestos from the water is important because, although asbestos polluted water does not constitute a threat to health if it is drunk, it is a problem when used for washing clothes. When the clothes dry, fibers are released into the atmosphere and inhaled.

8.2.2 Design

The most appropriate water treatment method for this area appears to be slow sand filtration. The streams are fast running and carry a heavy silt load during the rainy season. Pretreatment will therefore be necessary, using horizontal roughing filters. However, before full scale plants can be designed it was considered necessary to test the methodology with the use of a pilot plant.

The source of the water used to supply the plant is the village reticulation system. This is supplied by an unlined earthen irrigation canal and the water is not treated. The pilot filter plant was designed on the same principle as the small scale home plants:- slow sand filtration with a 24 hour retention period. The filter is plumbed directly into the untreated reticulation system and is designed on a continuous flow basis. The hydraulic control system is similar to the small scale plant but is governed by float valves. The filter supplies a separate clear-water reservoir.

The filter was required to substantially reduce the bacteria in the water, without the use of chemicals, and to remove asbestos fibers from the water. A further requirement was that the filter should be constructed from locally available materials because it would be too expensive to import materials to such a remote location. Unsieved river sand from the nearby Olifants River was therefore used. This sand has a high concentration of asbestos. A further variation was the use of filter fabric to wrap the collection pipe because it is relatively cheap and easy to transport compared to the alternative use of graded stone filter material.

Two types of amphibole asbestos are found in the area, crocodilite and amosite. Typically these fibers are 2-3 microns in length. The assumption to be tested in the pilot plant was that asbestos already present in the filter sand would be retained by the filter and that the fibers suspended in the raw water would be removed. The results of the bacteria and asbestos tests are recorded below and reported fully in appendix B2.

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The pilot plant design is summarized below -

Diameter	1.03	meter
Depth of tank	1.84	meter
Filter rate	350.00	mm/day
Retention time	24	hours
Filter voids	30.00	%
Depth of stone	0.00	mm
Depth of supernatant	250.00	mm
Area	.83	meter^2
Flow Rate	.20	litre/min
Flow Rate	12.08	litre/hour
Depth of sand	1.32	meter
Daily output	289.93	litre
People @ 20 l/head	14	
People @ 50 l/head	6	
Volume of sand	1.09	m^3
Volume of 19mm stone	0.00	m^3
Free board	273.33	mm

COSTS

Pipe work		95.00
Filter tank		304.00
Delivery		35.00
Sand		40.00
Stone		15.00
Total		489.00
Gst.		58.68
Filter total	R	547.68
Storage tank 220 l		109.00
Gst.		13.08
Storage total	R	122.08
GRAND TOTAL	R	669.76

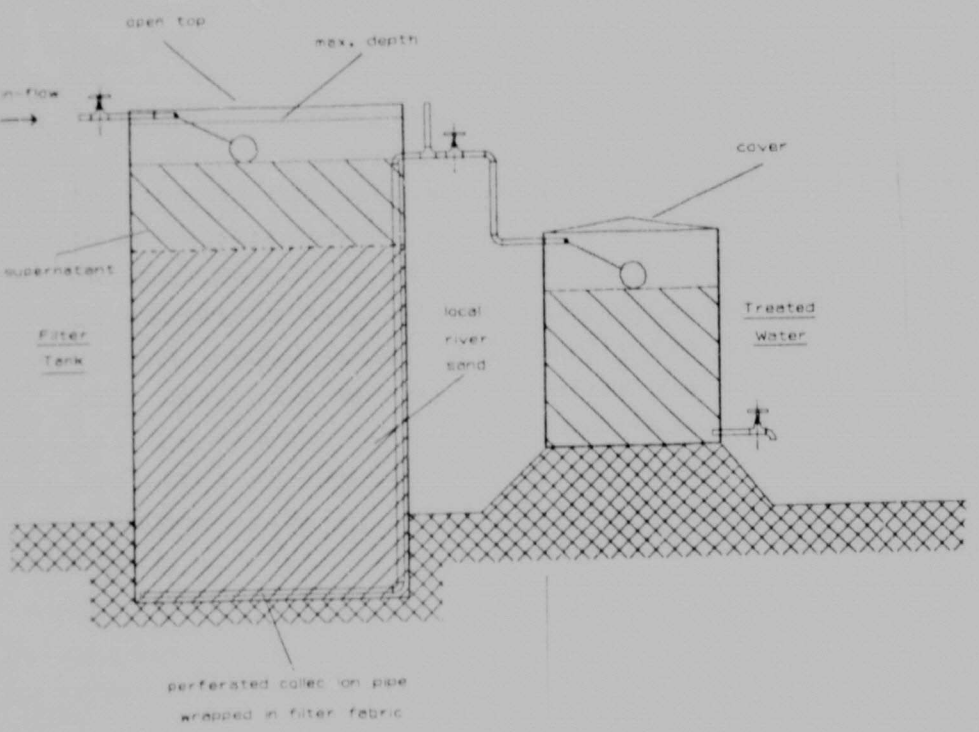

Diagram 8.1 Mafefe pilot filter plant.

8.2.3 Results

Table 8.1 Results - Mafefe pilot filter

	Raw	Treated
Faecal-Coliform [/100ml]		
Mean	3 850	0.17
Maximum	8 500	1
Minimum	700	0
Asbestos Fiber [fpcc]		
Mean	2 285	79 *

* Johannesburg tap water - 14

The results indicate that the filter reduces asbestos to acceptable levels, and all but eradicates the faecal coliform bacteria. Further tests are being conducted to establish the optimum flow rate for the filter without compromising the treated water quality. This will determine the size required for the full scale treatment filters. Penetration tests will also be conducted at the surface of the filter to asses the entrapment process and the depth of penetration of the fibers.

9. CONCLUSIONS

The conclusions which may be drawn from this research project are as follows.

* The small scale rural water treatment plant is an effective, low cost method for treating water for individual families. Although only limited field testing of the plant has been conducted, the plant appears to be socially acceptable.

* The test results indicate very effective removal of faecal coliform bacteria. Reductions of the order of 10^4 were achieved. The treated water was of a high quality with very low turbidity.

* The Mafefe field pilot plant results indicate that the method can be successfully used on a larger scale and on a continuous flow basis.

Further research needs to be done in the following areas:-

The micro-biological processes of slow sand filtration.

The effects of the depletion of dissolved oxygen on bacteria reduction.

The effectiveness of ultra slow sand filtration on a village scale.

The economics of USSF at larger scales.

The optimum flow rates of USSF.

The social acceptance of the individual family treatment philosophy.

The results serve to indicate that there are many possible useful applications and variations to established methods of SSF in Southern African rural water supply techniques.

APPENDICES

Appendix A Listed results

Appendix A.1 Complete results

L.J. ABRAMS MSc Small Scale Rural Water Treatment Plant - RESULTS

Item Number	Sample Number	Location	Date	Time	Temp. C.	Type R/T	Conduct. uS/m	Turbid. NTU	pH	E-Coli /100ml	TPC /ml	Sl
1.00	301	HOME	1/12/86	2200	20.60	T	45.80	.30	7.03	-	140	
2.00	302	HOME	1/12/86	2200	16.00	R	58.60	15.00	7.14	393400	1060000	
3.00	303	HOME	2/12/86		18.50	R	80.40	6.50	7.15	21000	3720000	
4.00	304	HOME	2/12/86	-	21.50	T	89.80	.23	6.81	-	480	
5.00	305	HOME	3/12/86	1845	23.00	R	52.20	18.00	7.05	950000	8700000	
6.00	306	HOME	3/12/86	1945	21.50	T	67.50	.34	7.05	-	1000	
7.00	307	HOME	4/12/86	1730	23.50	R	68.00	13.00	7.60	2400000	3100000	
8.00	308	HOME	4/12/86			T	80.70	.32	7.64	-	980	
9.00	309	HOME	5/12/86	1745	25.00	R	59.50	9.50	-	820000	104000	
10.00	310	HOME	5/12/86	2100	23.00	T	65.80	.21	-	-	560	
11.00	311	HOME	6/12/86	1800	23.50	R	61.60	4.00	-	37000	103000	
12.00	312	HOME	6/12/86	1800	23.50	T	67.50	.35	-	-	460	
13.00	313	HOME	7/12/86	2130	19.00	R	21.20	20.00	-	102000	244000	
14.00	314	HOME	7/12/86	2200	18.00	T	60.20	.23	-	-	140	
15.00	315	HOME	8/12/86	1600	21.00	R	16.00	28.00	-	4000	7000	
16.00	316	HOME	8/12/86	1700	19.50	T	41.00	.32	-	-	250	
17.00	317	HOME	9/12/86	20	22.00	R	74.00	8.20	-	32000	460000	
18.00	318	HOME	9/12/86	20	20.00	T	36.00	.63	-	32000	540	
19.00	319	HOME	10/12/86	18	20.00	R	80.00	5.60	-	230000	1330000	
20.00	320	HOME	10/12/86	20	17.50	T	38.00	.56	-	-	170	
21.00	321	HOME	11/12/86	2020	18.00	R	88.00	6.80	-	740000	201000	
22.00	322	HOME	11/12/86	2055	16.50	T	67.00	.36	-	-	60	
23.00	323	HOME	12/12/86	2030	21.00	R	74.00	7.20	-	1970000	840000	
24.50	324	HOME	12/12/86	2030	19.00	T	62.00	.21	-	-	200	
25.00	325	HOME	13/12/86	2030	22.00	R	76.00	5.60	-	130000	136000	
26.00	326	HOME	13/12/86	2030	22.00	T	76.00	.27	-	-	50	
27.00	327	HOME	14/12/86/	19	23.00	R	73.00	4.60	-	74000	162000	
28.00	328	HOME	14/12/86	19	23.00	T	54.00	.25	-	-	140	
29.00	329	HOME	15/12/86	2045	22.00	R	74.00	4.50	-	52000	204000	
30.00	330	HOME	15/12/86	2045	24.00	T	76.00	.24	-	-	130	
33.00	331	HOME	17/12/86	1840	17.00	R	6.50	32.00	-	200000	147000	
34.00	332	HOME	17/12/86	1830	17.00	T	67.00	.27	-	-	10	
35.00	333	HOME	18/12/86	2100	21.00	R	80.00	5.40	-	54000	42000	
36.00	334	HOME	18/12/86	2130	19.50	T	74.00	.21	-	-	160	
37.00	335	HOME	19/12/86	2100	19.00	R	11.00	35.00	-	370000	225000	
38.00	336	HOME	19/12/86	2030	19.00	T	36.00	11.00	-	-	220	
40.00	337	HOME	20/12/86	2100	21.00	R	86.00	4.10	-	47000	109000	
41.00	338	HOME	20/12/86	2100	21.50	T	66.00	.62	-	-	80	
42.00	339	HOME	21/12/86	2130	21.00	R	69.00	4.10	-	35000	42000	
43.00	340	HOME	21/12/86	2.00	21.50	T	32.00	1.20	-	-	170	
44.00	341	HOME	22/12/86	2100	22.50	R	96.00	4.40	-	61000	37000	
45.00	342	HOME	22/12/86	2100	22.50	T	74.00	.27	-	-	150	
46.00	345	HOME	24/12/86	2000	17.50	R	58.00	5.00	-	33000	15000	
47.00	346	HOME	24/12/86	2000	19.50	T	90.00	.25	-	-	120	
48.00	352	HOME	30/01/87	2130	20.00	R	77.00	3.40	-	70000	57000	
49.00	353	HOME	30/01/87	2130	20.00	T	79.00	.25	-	5000	2100	
50.00	354	HOME	01/02/87	2030	20.50	R	62.00	4.50	-	78000	116000	
51.00	355	HOME	01/02/87	2100	20.50	T	70.00	.23	-	2000	480	
52.00	357	HOME	04/02/87	2100	20.10	R	41.40	6.70	7.91	280000	440000	
53.00	358	HOME	04/02/87	2100	20.60	T	62.20	.24	7.55	500	8400	
54.00	359	HOME	05/02/87	2100	23.20	R	69.80	5.30	8.09	340000	1000000	
55.00	360	HOME	05/02/87	2100	21.10	T	48.00	.28	7.75	1000	960	
56.00	361	HOME	06/02/87	2100	21.70	R	59.20	3.90	8.07	120000	216000	
57.00	362	HOME	06/02/87	2000	21.40	T	42.80	.25	7.74	-	800	
58.00	364	HOME	08/02/87	2000	22.40	R	105.20	9.70	7.49	170000	330000	
59.00	365	HOME	08/02/87	2100	19.80	T	47.40	.28	7.90	-	280	
60.00	367	HOME	12/02/87	2100	22.20	R	76.20	4.50	7.93	31000	28000	
61.00	368	HOME	12/02/87	2100	20.00	T	78.70	.19	7.76	-	10	
62.00	369	HOME	13/02/87	2100	23.90	R	73.80	4.40	8.14	20000	17000	
63.00	370	HOME	17/02/87	2000	22.60	T	91.70	.21	7.80	-	90	
64.00	371	HOME	19/02/87	2015	22.20	T	67.40	.23	7.33	-	190	
"	"	"	"	"	"	T	-	-	-	-	160	
65.00	373	HOME	26/02/87	1910	22.20	R	81.90	9.00	8.30	100000	148000	
66.00	373	HOME	26/02/87	1910	21.20	T	68.60	.29	7.57		1390	
67.00	374	HOME	16/03/87	800	-	R	-	-	-	-	-	
68.00	375	HOME	16/03/87	800	-	T	-	-	-	-	1190	
"	"	"	"	"	-	T	-	-	-	-	1420	
"	"	"	"	"	-	T	-	-	-	-	1800	
69.00	376	HOME	17/03/87	0800	-	R	-	-	-	55000	-	
"	"	"	"	"	-	R	-	-	-	17000	-	
70.00	377	HOME	17/03/87	0800	-	T	-	-	-	2000	1670	
		HOME	17/03/87	0800	-	T	-	-	-	2000	1320	
		HOME	17/03/87	0800	-	T	-	-	-	-	980	
71.00	378	HOME	30/03/87	0800	-	R	-	-	-	150000	-	
"	"	"	"	"	-	R	-	-	-	60000	-	
"	"	"	"	"	-	R	-	-	-	80000	-	
72.00	380	HOME	23/04/87	2200	-	R	-	4.50	-	10000	-	
73.00	381	HOME	23/04/87	2200	-	T	-	.25	-	1	-	
"	"	"	"	"	-	T	-	"	-	2	-	
"	"	"	"	"	-	T	-	"	-	0	-	
74.00	382	HOME	24/04/87	2200	16.60	R	47.40	4.20	7.24	3000	-	
75.00	383	HOME	24/04/87	2200	16.40	T	53.20	.22	7.42	2	-	
76.00	384	HOME	25/04/87	2200	17.10	R	47.00	3.60	7.20	500	-	
77.00	385	HOME	25/04/87	2200	16.40	T	52.30	.22	7.26	2	-	
78.00	386	HOME	26/04/87	2200	18.20	R	46.30	6.10	7.12	24000	-	
79.00	387	HOME	26/04/87	2200	16.10	T	53.50	.25	7.35	0	-	
80.00	388	HOME	29/04/87	2200	18.30	R	57.90	3.80	7.82	1100	-	
81.00	389	HOME	28/04/87	2200	17.80	T	51.80	.21	7.74	5	-	
82.00	390	HOME	29/04/87	2200	-	R	-	-	-	2800	-	
83.00	391	HOME	29/04/87	2200	-	T	-	-	-	2	-	
"	"	"	"	"	-	T	-	-	-	2	-	
84.00	392	HOME	30/04/87	2200	-	R	-	-	-	6200	-	
85.00	393	HOME	30/04/87	2200	-	T	-	-	-	2	-	
"	"	"	"	"	-	T	-	-	-	1	-	
86.00	394	HOME	02/05/87	2200	-	R	-	-	-	3400	-	
87.00	395	HOME	02/05/87	2200	-	T	-	-	-	2	-	
"	"	"	"	"	-	T	-	-	-	1	-	
88.00	396	HOME	03/05/87	2200	15.70	R	50.20	2.80	7.65		-	
89.00	397	HOME	03/05/87	2200	14.60	T	50.60	.22	7.84		-	
90.00	398	HOME	04/05/87	2200	16.20	R	-	-	-	1200	-	
"	"	"	"	"	"	R	-	-	-	600	-	
91.00	399	HOME	04/05/87	2200	13.75	T	-	-	-	1	-	
"	"	"	"	"	"	T	-	-	-	1	-	
92.00	400	HOME	13/05/87	2235	10.60	R	37.90	42.00	8.30	26000	-	
93.00	401	HOME	13/05/87	2235	15.10	T	44.90	.32	7.71	32	138	
"	"	"	"	"	"	T	"	"	"	26	98	
94.00	402	HOME	15/05/87	2000	15.90	R	47.40	4.10	7.45	2900	168000	
95.00	403	HOME	15/05/87	2000	15.60	T	39.50	3.60	7.65	19	140	
"	"	"	"	"	"	T	"	"	"	27	210	
96.00	404	HOME	07/06/87	2230	8.40	R	43.60	2.00	7.88	1600	-	
"	"	"	"	"	"	R	"	"	"	200	-	
97.00	405	HOME	07/06/87	2230	8.20	T	44.20	.24	7.67	1	-	
"	"	"	"	"	"	T	"	"	"	5	-	
98.00	406	HOME	28/06/87	2000	10.50	R	43.10	5.10	-	11300	-	
99.00	407	HOME	28/06/87	2000	11.00	T	45.60	.26	-	3	-	
"	"	"	"	"	"	T	"	"	-	1	-	
"	"	"	"	"	"	T	"	"	-	3	-	
100.00	408	HOME	01/07/87	2030	11.50	R	43.50	10.00	7.00	1500	-	
"	"	"	"	"	"	R	"	"	"	1200	-	
101.00	409	HOME	01/07/87	2030	10.00	T	44.60	.26	7.00	0	-	
"	"	"	"	"	"	T	"	"	"	2	-	
"	"	"	"	"	"	T	"	"	"	2	-	
102.00	410	HOME	02/07/87	1800	12.00	R	36.00	22.00	7.00		-	
103.00	410	HOME	02/07/87	1800	10.50	T	45.90	.35	7.00	1	-	
"	"	"	"	"	"	T	"	"	"	1	-	
"	"	"	"	"	"	T	"	"	"	1	-	

Appendix A.2 Complete treated water results

Treated water results

Item Number	Sample Number	Location	Date	Time	Temp. C.	Type R/T	Conduct. mS/m	Turbid. NTU	pH	F-Coli /100ml	TPC /ml	NORMAL TPC
1	301	HOME	1/12/86	2200	20.50	T	45.80	.30	7.03		140	
4	304	HOME	2/12/86		21.50	T	89.80	.23	6.81		480	
6	306	HOME	3/12/86	1945	21.50	T	67.50	.34	7.05		1000	
8	308	HOME	4/12/86			T	80.70	.32	7.64		980	
10	310	HOME	5/12/86	2100	23.00	T	65.80	.21			560	
12	312	HOME	6/12/86	1800	23.50	T	67.50	.35			460	
14	314	HOME	7/12/86	2200	18.00	T	60.20	.23			140	140
16	316	HOME	8/12/86	1700	19.50	T	41.00	.32			250	250
18	318	HOME	9/12/86	20	20.00	T	36.00	.53		32000	540	540
20	320	HOME	10/12/86	20	17.50	T	30.00	.56			170	170
22	322	HOME	11/12/86	2055	15.50	T	67.00	.36			60	60
24	324	HOME	12/12/86	2030	19.00	T	62.00	.21			200	200
26	326	HOME	13/12/86	2030	22.00	T	76.00	.27			50	50
28	328	HOME	14/12/86	19	23.00	T	54.00	.25			140	140
30	330	HOME	15/12/86	2045	24.00	T	76.00	.24			130	130
34	332	HOME	17/12/86	1830	17.00	T	67.00	.27			10	10
36	334	HOME	18/12/86	2130	19.50	T	74.00	.21			160	160
38	336	HOME	19/12/86	2020	19.00	T	36.00	11.00			220	220
41	338	HOME	20/12/86	2100	21.50	T	66.00	.52			80	80
43	340	HOME	21/12/86	2100	21.50	T	32.00	1.20			170	170
45	342	HOME	22/12/86	2100	22.50	T	74.00	.27			150	150
47	346	HOME	24/12/86	2000	19.50	T	90.00	.25			120	120
49	353	HOME	30/01/87	2100	20.00	T	79.00	.29		5000	2100	
51	355	HOME	01/02/87	2100	20.50	T	70.00	.23		2000	460	
53	358	HOME	04/02/87	2100	20.60	T	62.20	.24	7.55	500	8400	
55	360	HOME	05/02/87	2100	21.10	T	48.00	.28	7.75	1000	860	
57	362	HOME	06/02/87	2000	21.40	T	42.80	.25	7.74		800	
59	365	HOME	08/02/87	2100	19.80	T	47.40	.28	7.90		280	
61	368	HOME	12/02/87	2100	20.00	T	78.70	.19	7.76		10	
63	370	HOME	13/02/87	2000	22.60	T	81.70	.21	7.80		970	
64	371	HOME	19/02/87	2015	22.20	T	67.40	.23	7.33		190	
"	"	"	"	"		T					160	
"	373	HOME	26/02/87	1910	21.20	T	68.60	.29	7.57		1390	
68	375	HOME	16/03/87	800		T					1190	
"	"	"	"	"		T					1420	
"	"	"	"	"		T					1800	
70	377	HOME	17/03/87	0800		T				2000	1670	
		HOME	17/03/87	0800		T				2000	1320	
		HOME	17/03/87	0800		T					980	
73	381	HOME	23/04/87	2200		T		.25		1		
"	"	"	"	"		T				2		
"	"	"	"	"		T				0		
75	383	HOME	24/04/87	2200	16.40	T	53.20	.22	7.42	2		
77	385	HOME	25/04/87	2200	16.40	T	52.30	.22	7.26	2		
79	387	HOME	26/04/87	2200	16.10	T	53.50	.25	7.35	0		
81	389	HOME	28/04/87	2200	17.80	T	51.80	.31	7.74	5		
83	391	HOME	29/04/87	2200		T				2		
"	"	"	"	"		T				2		
85	393	HOME	30/04/87	2200		T				2		
"	"	"	"	"		T				1		
87	395	HOME	02/05/87	2200		T				2		
"	"	"	"	"		T				1		
89	397	HOME	03/05/87	2200	14.60	T	50.50	.22	7.84			
91	399	HOME	04/05/87	2200	13.75	T				1		
"	"	"	"	"		T				1		
93	401	HOME	13/05/87	2235	15.10	T	44.90	.31	7.71	32	138	
"	"	"	"	"		T				26	98	
95	403	HOME	15/05/87	2000	15.50	T	39.50	3.60	7.65	19	140	
"	"	"	"	"		T				27	210	
97	405	HOME	07/06/87	2230	8.20	T	44.20	.24	7.67	1		
"	"	"	"	"		T				5		
99	407	HOME	28/06/87	2000	11.00	T	45.50	.25		3		
"	"	"	"	"		T				1		
"	"	"	"	"		T				3		
101	409	HOME	01/07/87	2030	10.00	T	44.50	.25	7.00	0		
"	"	"	"	"		T				2		
"	"	"	"	"		T				2		
103	410	HOME	02/07/87	1800	10.50	T	45.90	.35	7.00	1		
"	"	"	"	"		T				1		
"	"	"	"	"		T				1		

NOTES					**		***
Count	43	42	43	22	30	43	1r
Mean	18.69	59.02	.38	7.48	4.88	716.19	161.86
Max	24.00	90.00	3.60	7.90	32.00	8400.00	540.00
Min	8.20	32.00	.19	6.81	.00	10.00	10.00
Std Dev.	3.80	15.44	.52	.32	6.53	1804.22	115.17
Variance	14.42	238.33	.27	.10	72.81		13265.23

Summer Mean	20.59	62.68	.32	7.49
Winter Mean	13.78	47.80	.54	7.46
Difference	6.81	15.08	-.22	.03

Reduction 4.650963

Appendix A.3 Complete raw water results

SMALL SCALE WATER TREATMENT PLANT L.J. Abrams

Raw water results

Item Number	Sample Number	Location	Date	Time	Temp. C.	Type R/T	Conduct. mS/m	Turbid. NTU	pH	F-Coli /100ml	TPC /ml
2	302	HOME	1/12/86	2200	16.00	R	58.60	15.00	7.14	393400	1060000
3	303	HOME	2/12/86		18.50	R	80.40	6.50	7.15	21000	3720000
5	305	HOME	3/12/86	1845	23.00	R	52.20	18.00	7.05	950000	8700000
7	307	HOME	4/12/86	1730	23.50	R	68.00	13.00	7.60	2400000	3100000
9	309	HOME	5/12/86	1745	25.00	R	59.50	9.50		620000	104000
11	311	HOME	6/12/86	1800	23.50	R	61.00	4.00		37000	103000
13	313	HOME	7/12/86	2130	19.00	R	21.20	20.00		102000	244000
15	315	HOME	8/12/86	1800	21.00	R	16.00	28.00		4000	7000
17	317	HOME	9/12/86	20	22.00	R	74.00	8.20		32000	460000
19	319	HOME	10/12/86	18	20.00	R	80.00	5.60		230000	1330000
21	321	HOME	11/12/86	2020	18.00	R	88.00	6.80		740000	201000
23	323	HOME	12/12'86	2030	21.00	R	74.00	7.20		1970000	840000
25	325	HOME	13/12/86	2030	22.00	R	76.00	5.60		130000	136000
27	327	HOME	14/12/86/	19	23.00	R	73.00	4.60		74000	162000
29	329	HOME	15/12/86	2045	22.00	R	74.00	4.50		52000	204000
33	331	HOME	17/12/86	1840	17.00	R	6.50	32.00		200000	147000
35	333	HOME	18/12/86	2100	21.00	R	80.00	5.40		54000	42000
37	335	HOME	19/12/86	2100	19.00	R	11.00	35.00		170000	225000
40	337	HOME	20/12/86	2100	21.00	R	86.00	4.10		47000	109000
42	339	HOME	21/12/86	2100	21.00	R	69.00	4.10		35000	42000
44	341	HOME	22/12/86	2100	22.50	R	96.00	4.40		61000	37000
46	345	HOME	24/12/86	2000	17.50	R	58.00	5.00		33000	15000
48	352	HOME	30/01/87	2130	20.00	R	77.00	3.40		70000	57000
50	354	HOME	01/02/87	2030	20.50	R	62.00	4.50		78000	116000
52	357	HOME	04/02/87	2100	20.70	R	41.40	6.70	7.91	280000	440000
54	359	HOME	05/02/87	2100	23.20	R	59.80	5.30	8.09	340000	1000000
56	361	HOME	06/02/87	2100	21.70	R	59.20	3.90	8.07	120000	215000
58	364	HOME	08/02/87	2000	22.60	R	105.20	9.70	7.89	170000	330000
60	367	HOME	12/02/87	2100	21.20	R	78.20	4.50	7.93	31000	28000
62	369	HOME	13/02/87	2100	23.90	R	73.80	4.40	8.14	20000	17000
65	372	HOME	26/02/87	1910	22.20	R	83.90	9.00	8.30	100000	148000
67	374	HOME	16/03/87	800		R					
69	376	HOME	17/03/87	0800		R				55000	
"	"	"	"	"		R				17000	
71	378	HOME	30/03/87	0800		R				150000	
"	"	"	"	"		R				60000	
"	"	"	"	"		R				80000	
72	380	HOME	23/04/87	2200		R		4.50		10000	
74	382	HOME	24/04/87	2200	16.60	R	47.40	4.20	7.24	3000	
76	384	HOME	25/04/87	2200	17.10	R	47.00	3.50	7.20	500	
78	386	HOME	26/04/87	2200	18.20	R	46.30	6.10	7.12	24000	
80	388	HOME	28/04/87	2200	18.30	R	57.90	3.50	7.82	1100	
82	390	HOME	29/04/87	2200		R				2800	
84	392	HOME	30/04/87	2200		R				6200	
86	394	HOME	02/05/87	2200		R				3400	
88	396	HOME	03/05/87	2200	15.70	R	50.20	2.80	7.65		
90	398	HOME	04/05/87	2200	16.20	R				1200	
"	"	"	"	"	"	R				600	
92	400	HOME	13/05/87	2235	16.60	R	37.90	42.00	8.30	26000	
94	402	HOME	15/05/87	2000	15.90	R	47.40	4.10	7.45	2900	166000
96	404	HOME	07/06/87	2230	8.40	R	43.60	2.00	7.88	1600	
"	"	"	"	"	"	R				200	
98	406	HOME	28/06/87	2000	10.50	R	43.10	5.10		11300	
100	408	HOME	01/07/87	2030	11.50	R	43.50	10.00	7.00	1500	
"	"	"	"	"	"	R				1200	
102	410	HOME	02/07/87	1800	12.00	R	36.00	22.00	7.00		

SMALL SCALE WATER TREATMENT PLANT L.J. Abrams

Count	43	42	43	21	53	32
Mean	19.29	59.60	9.48	7.62	189130.19	734531.25
Max	25.00	105.20	42.00	8.30	2400000.00	8700000.00
Min	8.40	6.50	2.00	7.00	200.00	7000.00
Std Dev.	3.73	22.01	9.21	.44	438751.64	1652610.72
Variance	13.93	484.23	84.83	.20		
Summer mean	21.05	64.61	9.61	7.75	2.757333e5	7.528710e5
Winter mean	14.75	45.48	9.15	7.47	5.735294e3	N.A.
Difference	6.30	19.13	.46	.29	4.807658e1	

Appendix A.4 Normal Treated Water Results

Normal Treated Water Results

Item Number	Sample Number	Location	Date	Time	Temp. C.	Type R/T	Conduct. mS/m	Turbid. NTU	pH	Treated F-Coli /100ml	Raw F-Coli /100ml
73	381	HOME	23/04/87	2200		T		.25		1	3000
"	"	"	"	"		T				2	500
"	"	"	"	"		T				0	24000
75	383	HOME	24/04/87	2200	16.40	T	53.20	.22	7.42	2	1100
77	385	HOME	25/04/87	2200	16.40	T	52.30	.22	7.26	2	2800
79	387	HOME	26/04/87	2200	16.10	T	53.50	.25	7.35	0	6200
81	389	HOME	28/04/87	2200	17.80	T	51.80	.31	7.74	5	3400
83	391	HOME	29/04/87	2200		T				2	
"	"	"	"	"		T				2	1200
85	393	HOME	30/04/87	2200		T				2	600
"	"	"	"	"		T				1	26000
87	395	HOME	02/05/87	2200		T				2	2900
"	"	"	"	"		T				1	1600
89	397	HOME	03/05/87	2200	14.60	T	50.50	.22	7.84		200
91	399	HOME	04/05/87	2200	13.75	T				1	11300
"	"	"	"	"		T				1	1500
97	405	HOME	07/06/87	2230	8.20	T	44.20	.24	7.67	1	1200
"	"	"	"	"		T				5	
99	407	HOME	28/06/87	2000	11.00	T	45.50	.25		3	
"	"	"	"	"		T				1	
"	"	"	"	"		T				3	
101	409	HOME	01/07/87	2030	10.00	T	44.50	.25	7.00	0	
"	"	"	"	"		T				2	
"	"	"	"	"		T				2	
103	410	HOME	02/07/87	1800	10.50	T	45.90	.35	7.00	1	
"	"	"	"	"		T				1	
"	"	"	"	"		T				1	
Count					10		9	10	8	26	1
Mean					13.48		49.04	.26	7.41	1.63	5468.75
Max					17.80		53.50	.35	7.84	5.00	26000.00
Min					8.20		44.20	.22	7.00	.00	200.00
Std Dev.					3.15		3.71	.04	.30	1.24	7850.06
Variance					9.89		13.78	.00	.09	1.55	

Reduction winter 3.3456e3
overall 1.1570e5

Appendix A.5 Dissolved Oxygen Results

Dissolved Oxygen Profiles

Elapsed time	1/2 hour	10 hour	4 hour	12 hour	24 hour
Date	23/12/86	24/12/86	6/1/87	7/1/87	7/1/87
Depths					
Raw	6.50	6.50	6.56		
SuperNat	3.75	3.75	6.56	3.75	3.75
50.00	2.55	2.35	3.25	.80	.15
100.00	.65	2.31	4.35	.90	.75
200.00	.60	2.11	.70	.60	.00
300.00	.00	.05	.00	.00	.00
400.00	.13	.00	.00	.00	.00
500.00	.45	.00	.00	.00	.00

Appendix B Field test results

Appendix B.1 Lekhema Field Test Results

Lekhema Field Plant

Item Number	Sample Number	Location	Date	Time	Temp. C.	Type R/T	Conduct. mS/m	Turbid. NTU	pH	F-Coli /100ml	TPC /ml
104	100	Lekhema	19/12/86	10h20	30.50	T	46.00	2.70		0	3000>
105	101	Lekhema	19/12/86	10h20	30.50	R	22.00	3.40		6000	83000
106	102	Lekhema	23/12/86	14h15	17.00	R	25.00	6.40		1000	1500
107	103	Lekhema	23/12/86	14h15	17.00	T	35.00	1.70		1000	1300
108	104	Lekhema	8/1/87			R	12.00	9.00		3000	112000
109	105	Lekhema	8/1/87			T	38.00	1.70		0	1030
110	107	Lekhema	29/1/87			R	26.00	6.50		11000	1190000
111	108	Lekhema	29/1/87			T	24.00	7.20		0	3000>

Appendix B.2 Mafefe field test results

SMALL SCALE WATER TREATMENT PLANT L.J. Abrams
Mafefe Field Pilot Plant

Sample Number	Location	Date	Time	Temp. C.	Type R/T	Conduct. mS/m	Turbid. NTU	pH	F-Coli /100ml
5	Mafefe	5/12/88	10h30	24.00	T	29.30		8.55	0
6	Mafefe	5/12/88	10h30	24.50	R	21.90		8.55	5700
7	Mafefe	5/12/88	10h30	24.50	R	21.90		8.55	TNTC
8	Mafefe	5/12/88	10h30	24.50	R	21.90		8.55	TNTC
19	Mafefe	5/12/88	16h30		T				1
23	Mafefe	6/12/88	09h00		T				0
24	Mafefe	6/12/88	09h00		R				700
25	Mafefe	6/12/88	09h00		R				TNTC
30	Mafefe	20/12/88	18h30	31.50	T				0
31	Mafefe	20/12/88	18h30	29.00	R				700
32	Mafefe	20/12/88	18h30	29.00	R				8500
35	Mafefe	21/12/88	09h00	27.50	T	28.00		8.50	0
36	Mafefe	21/12/88	09h00	27.50	T	28.00		8.50	0
37	Mafefe	21/12/88	09h00	29.90	R	30.70		8.53	6300
38	Mafefe	21/12/88	09h00	29.90	R	30.70		8.53	1200
88	Mafefe	9/03/89	17h45	21.00	R				2400
89	Mafefe	9/03/89	17h45	22.00	T				0
90	Mafefe	9/03/89	17h45	22.00	T				0
91	Mafefe	9/03/89	17h45	22.00	T				0
92	Mafefe	10/03/89	10h15	21.00	R				3500
93	Mafefe	10/03/89	10h15	21.00	T				0
94	Mafefe	10/03/89	10h15	21.00	T				0
95	Mafefe	10/03/89	10h15	21.00	T				0
96	Mafefe	10/03/89	16h45	21.00	R				2700
97	Mafefe	10/03/89	16h45	22.00	T		<		0
98	Mafefe	10/03/89	16h45	22.00	T		*<		0
99	Mafefe	10/03/89	16h45	22.00	T		<		0
100	Mafefe	11/03/89	8h30	22.00	R				3000
101	Mafefe	11/03/89	8h30	21.00	T		<		1
102	Mafefe	11/03/89	8h30	21.00	T		**<		4
103	Mafefe	11/03/89	8h30	21.00	T		<		4
104	Mafefe	11/03/89	15h00	23.00	R				2000
105	Mafefe	11/03/89	15h00	23.00	T		<		3
106	Mafefe	11/03/89	15h00	23.00	T		***<		2
107	Mafefe	11/03/89	15h00	23.00	T		<		5

Unless otherwise stated the filter flow rate was maintained at 0.15 l/min

* Flow rate = 0.667 l/s
** Flow rate = 2.0 l/s
*** Flow rate = 5.0 l/s

TNTC = Too Numerous To Count

Appendix C WHO water quality tables

Table 1. Microbiological and biological quality

Organism	Unit	Guideline value	Remarks
I. Microbiological quality			
A. Piped water supplies			
A.1. Treated water entering the distribution system			
faecal coliforms	number/100 ml	0	turbidity < 1 NTU, for disinfection with chlorine, pH preferably < 8.0, free chlorine residual 0.2–0.5 mg/litre following 30 minutes (minimum) contact
coliform organisms	number/100 ml	0	
A.2. Untreated water entering the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 98 % of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples
A.3. Water in the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 95 % of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples
B. Unpiped water supplies			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	10	should not occur repeatedly; if occurrence is frequent and if sanitary protection cannot be improved, an alternative source must be found if possible
C. Bottled drinking water			
faecal coliforms	number/100 ml	0	source should be free from faecal contamination
coliform organisms	number/100 ml	0	
D. Emergency water supplies			
faecal coliforms	number/100 ml	0	advise public to boil water in case of failure to meet guideline values
coliform organisms	number/100 ml	0	
Enteroviruses	—	no guideline value set	
II. Biological quality			
protozoa (pathogenic)	—	no guideline value set	
helminths (pathogenic)	—	no guideline value set	
free-living organisms (algae, others)	—	no guideline value set	

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