Skyhydrant

Membrane filtration

Project in cooperation with

Norplan

And

Ministry of Rural Rehabilitation Department

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Summary

Fetching water from rivers, springs and ponds are common by the rural population in Afghanistan. The quality range and a polluted water source is an emerging problem leading to frequent exposure towards waterborne diseases.

This report focus on the performance of a membrane filtration unit, Skyhydrant, and how the turbidity affect the filtration rate (Output). The experiment was conducted from the 3rd - 12th of May 2015. The raw water tank was kept at a constant level maintaining a differential pressure of 2.5 meters. Manual cleaning was performed daily and when changing raw water. Measurements on total coliforms (faecal coliforms) and E.coli were conducted on the raw water, directly from the filter and from the fresh water tank. Turbidity and output was hourly measured.

The output ranged from 360 l/h to 690 l/h, depending on the turbidity, hours of filtration and the frequency of backwashing. Results revealed that the filtrated water had a turbidity of 0 NTU and was free from total coliforms and E.coli. However, one sample taken from the freshwater tank reviled presence of total coliforms (Faecal coliforms).

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Introduction

In the rural areas of Afghanistan, 61 % of the people lack access to potable drinking water (1). Most of them fetch water from rivers, springs, ponds and wells that are highly polluted (2). As a result water borne diseases is a common problem among the population, claiming the lives of 85 000 children yearly (1), where diarrhoea, dysentery and cholera are the main illnesses (3). Pollution of surface water and groundwater is an emerging problem where physical, biological and chemical pollutants are the main objects, and as much as 90 % of the streams and wells in Afghanistan are contaminated (4). The surface water consist of mainly five river basins and they cover 90 % of the land (5). Estimates shows that the country has 75 billion cubic meters (BCM) of water, where 57 BCM are surface water (6).

Surface water is exposed to various hazards and often require treatment when used for drinking purposes. Physical, chemical and biological pollutants are the three main groups (7) and they cause among others, - colour and taste, and the presence of particles and pathogens are common (8). They originate from sediments, storm runoff, direct discharge from industries and sewer systems, air contaminates, agriculture, and generally human pollution (9). However, there are the natural chemicals, originated from rocks and sediments that are the cause of most of the health problems (10). Turbidity of the water is one of the main indicators when evaluating the suitability of a water source used for drinking purposes (11).

In order to meet the challenges related to drinking water it is essential to come up with sustainable technical solutions with the potential to produce safe drinking water. Membrane filtration is a physical barrier preventing materials up to a certain size to pass the filter, depending on the pore size of the filter. There are four different types of membranes; Ultrafiltration (UF), reverse osmosis (RO), nanofiltration (NF) and microfiltration (MF), depending on what degree of purification needed (12).

Due to high levels of turbidity and colour in surface water in the central areas of Afghanistan, a UF membrane filter was selected for investigations for this project. This study has focused on how the raw water quality affect the frequency of backwashing the filter, water produced, and the treatment efficiency with respect to suspended solids (turbidity) and total coliforms (faecal coliforms) and E.coli of the filtrated water.

Methodology

The skyhydrant is a gravity fed ultra-filtration unit with a nominal membrane pore size of 0.04 µm. The filter has a height of 1430 millimetres, width of 180 mm and a length of 250 mm. The approximated weight is 12 kilogram when the filter is dry and 27 kg when the filter is operating. The nominal capacity is set to be 400 to 1000 l/h, depending on the raw water quality and pressure. The maximum recommended turbidity of the raw water is 500 NTU. The pressure requirements is set to be between 0.5 – 4.0 meters. All the outlets use 20 mm (3/4") connectors.

A 20 mm water hose distributed the raw water to the filter, connector T1 (Figure 1). The raw water was filtered from downstream to upstream the filter where the filtrated water was discharged from T3 (Figure 1). A 20 mm water hose was thereby connected to T3 (Figure 1) and to the drinking water tank, having a volume of 1 m^3. Cleaning of the filter was performed by rotating the cleaning handles (Figure 1), and the backwash water was discharged out through T_2 (Figure 1).

The skyhydrant is designed to remove turbidity, bacteria, protozoa, cysts and to significantly reduce the level of viruses (13). For further instructions, regarding manual cleaning and additional technical specifications visit http://www.skyjuice.com.au/skyhydrant.htm

Figure 1: Skyhydrant (13)

Experimental setup

The function has been assessed by evaluating the quantity of filtrated water (Output) without backwashing the filter, by having a stable pressure of 2.5 metres. Primary data was collected from 3rd to 12th of May, and turbidity, Output, total coliforms (faecal coliforms) and E.coli levels were registered, together with the frequency of manual cleaning. The raw water was pumped from the tanker truck and to the raw water tank. The pump was continuously pumping the raw water to the tank keeping the water level constant, and the overflow was circulated back into the tanker. The water was continually flowing through the system, and the filter was kept saturated when not in use.

Water with different turbidity was fetched from the Lalander and Gulbagh River where the turbidity ranged from 15 to 331 NTU. The output was measured every hour using a bucket, and a 10 l and a 1 l cup measured the quantity. The measurement was taken directly from the filter, connector T3 (Figure 1). Tests regarding turbidity, total coliforms (faecal coliforms) and E.coli were performed daily on the MRRD lab. Hourly measurements on the turbidity was performed, using a turbidity meter, Hanna instruments HI 93703, with unit NTU. Measurements on Coliforms bacteria and E.coli were measured on both the raw water and the filtrated water, using the Readycult Water Check method and a Dehydrated Culture Media (Membrane Lauryl Sulphate Broth) provided by Avonchem. The incubator temperature was 37° for total coliforms (faecal coliforms) and 44° for E.coli. The Veterinarian lab in Kabul city performed a analyse on the turbidity, suspended solids, total coliforms (Faecal coliforms) and E.coli on the river water sampled the 9th – 10th of May. A duplicate was tested in the MRRD lab for quality control.

The water pump was of the brand Dulf Water Pump, model QDXL 1.5-17-0.37 and had an effect of 0.37 kW (0.5HP). The Q rate of the pump was 1500 l/h.

Results

On the 3rd of May the raw water contained an initial turbidity of 140 NTU. After three hours of operating, the output decreased from 660 l/h to 600 l/h (Table 1). The filtrated water had a turbidity of 0 NTU.

Table 1: Output and turbidity 3rd of May

Date: 03.05.2015	**Name:**	**Lalander River**	
Hour	**Output (l/h)**	**Manual cleaning**	**Turbidity (NTU)**
0	660		**140**
1	642		
2	618		
3	600	Yes	

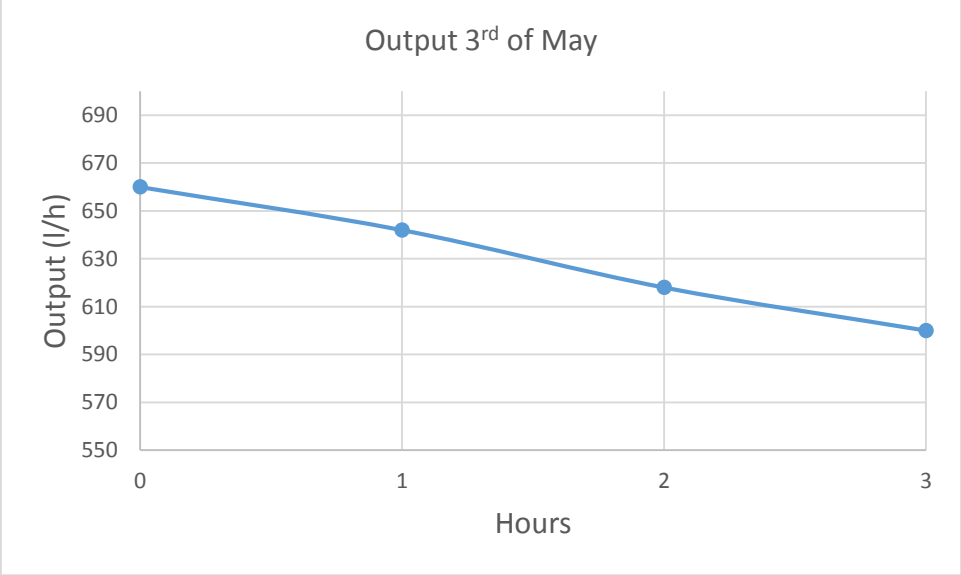

Figure 2: Output on the 3rd of May

On the 4th of May the raw water contained an initial turbidity of 31 NTU. After filtration, the turbidity was reduced to 0 NTU. The initially output was 690 l/h (Table 2) and this was decreased by 132 l/h after 6 hours of operating.

Table 2: Output and turbidity (NTU) 4th of May

Date: 04.05.2015	**Name:**	**Lalander River**	
Hour	**Output (l/h)**	**Manual cleaning**	**Turbidity (NTU)**
0	690		**31**
1	642		
2	624		
3	594		
4	552		
5	570		
6	558	Yes	

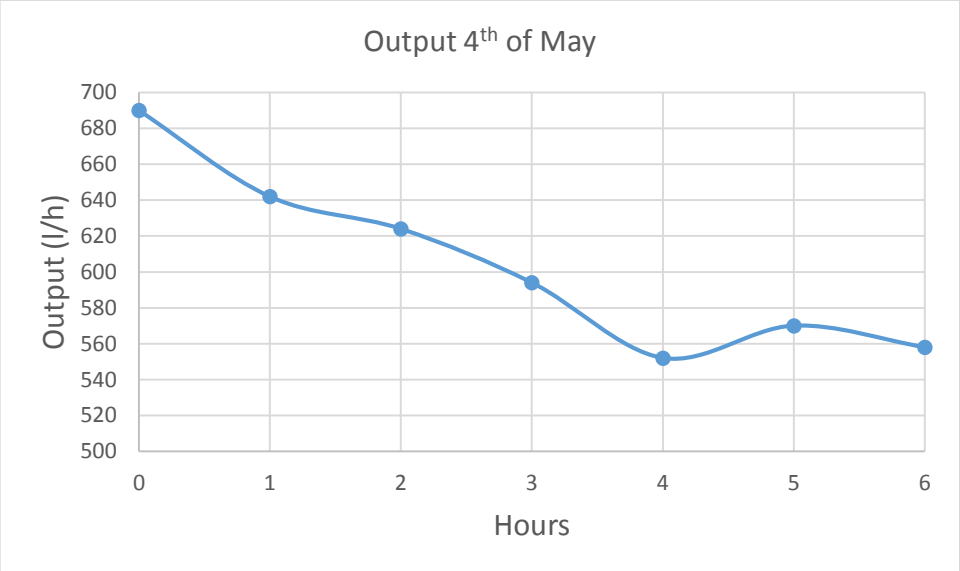

Figure 3: Output on the 4th of May

On the 5th and 6th of May the initial turbidity of the raw water was 176 NTU, and the total amount of hours measured were 10 hours. The output decreased from 654 l/h to 438 l/h, while the turbidity ranged from 176 to 47 NTU.

Table 3: Output (l/h) and Turbidity 5th and 6th of May

Date: 05-06.05.2015	Name:	Gulbagh river	
Hour	**Output (l/h)**	**Manual cleaning**	**Turbidity (NTU)**
0	654		176
1	630		106
2	570		107
3	546		52
4	528		82
5	534		47
6	516		48
7	492		
8	474		53
9	456		60
10	438	Yes	64

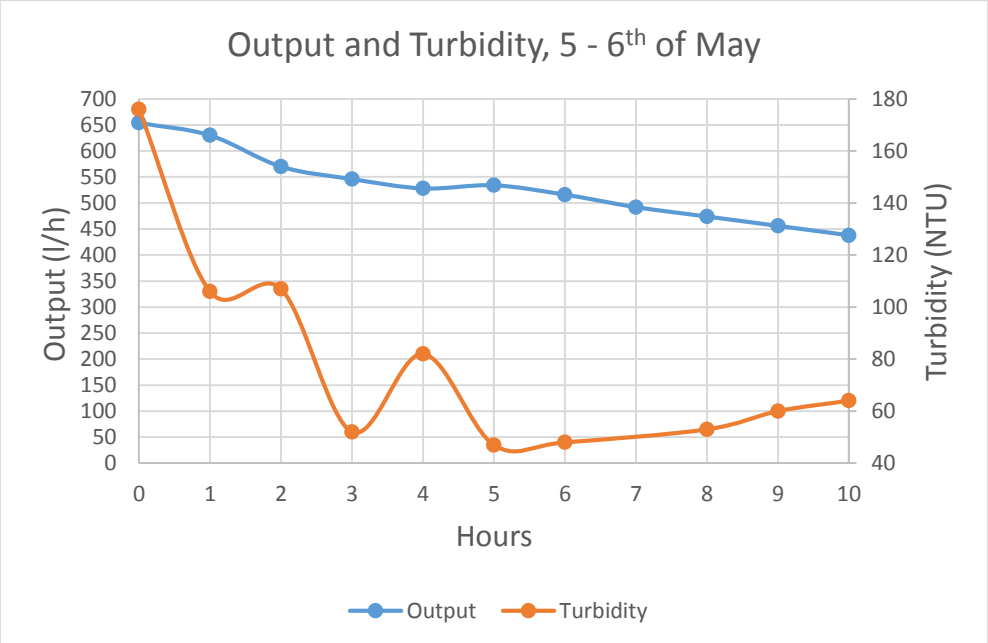

Figure 4: Output (l/h) and turbidity (NTU) on the 5th and 6th of May.

On the 9th and 10th of May the turbidity ranged from 331 to 80 NTU (Table 4). The output was at its highest at hour zero, of 654 l/h, and had its lowest flow after 10 hours of filtration, 360 l/h. A backwash was performed during the 10th and 11th hour, which resulted in an increase in output.

Table 4: Output (l/h) and Turbidity 9th and 10th of May

Date: 09-10.05.2015	**Name:**	**Gulbagh river**	
Hour	**Output (l/h)**	**Manual cleaning**	**Turbidity (NTU)**
0	654		273
1	612		331
2	576		324
3	534		318
4	492		258
5	468		262
6	456		129
7	408		107
8	402		113
9	384		101
10	360		109
11	582	Yes	89
12	522		90
13	504	Yes	80

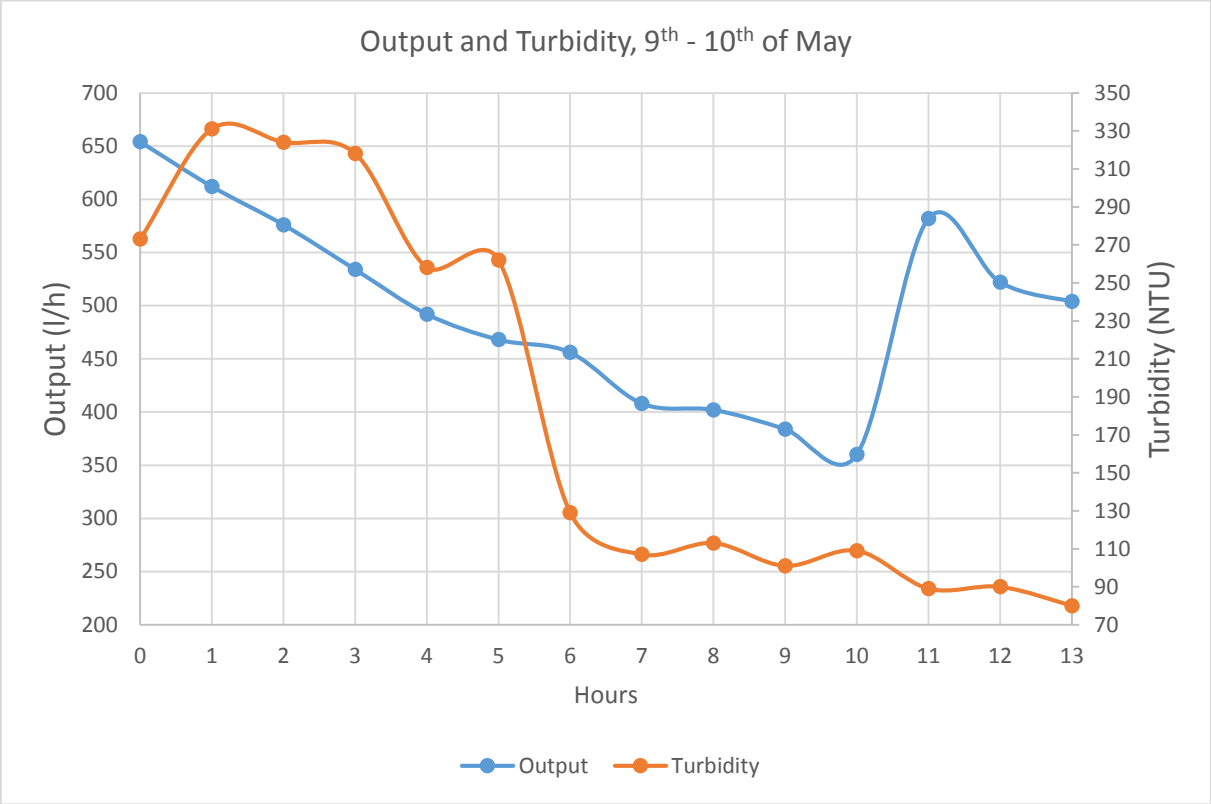

Figure 5: Output (l/h) and turbidity (NTU) on the 9th and 10th of May.

The output was reduced from 540 l/h to 468 l/h on the 11th and 12th of May. There was conducted a backwash during the 5th and 6th hour of filtration that increased the output to 552 l/h. The turbidity ranged from 98 to 15 NTU.

Table 5: Output (l/h) and Turbidity 11th and 12th of May

Date: 11-12.05.2015	Name:	Mixed Gulbagh river and borehole water	
Hour	**Output (l/h)**	**Manual cleaning**	**Turbidity (NTU)**
0	540		93
1	516		94
2	510		83
3	498		76
4	480		84
5	468		98
6	552	Yes	48
7	528		46
8	522		65
9	522		19
10	504		32
11	498		30
12	498	Yes	15

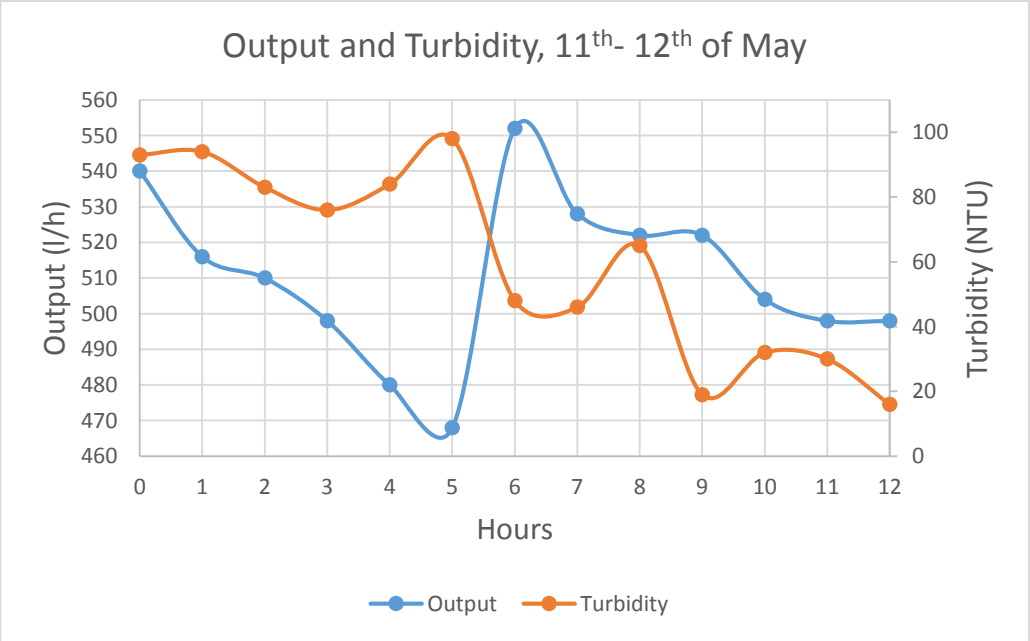

Figure 6: Output (l/h) and turbidity (NTU) on the 11th and 12th of May.

The microbiological tests showed positive for Coliform bacteria (Faecal coliform) and E.coli in the raw water. Samples taken directly from the filter (named After filtration) tested negative for Total coliforms (Faecal coliforms) and E.coli. However, water sampled from the fresh water tank (named Freshwater tank) tested positive for Total coliforms (Faecal Coliforms) on the 6th of May. After chlorination of the tank on the 9th of May, the sample was negative.

Table 6: Showing Microbiological tests in form of Total coliforms and E.coli.

Sample code	Date	Before filtration / after filtration / freshwater tank	Volume filtrated (ml)	No. of colonies E.coli	No. of colonies Total Coliforms (faecal coliforms)
132	04.05.2015	Before filtration	25	67	72
133	04.05.2015	After filtration	100	0	0
135	05-06.05.2015	Before filtration	25	80	101
136	05-06.05.2015	After filtration	100	0	0
137	05-06.05.2015	Freshwater tank	100	0	30
149	09-10.05.2015	Before Filtration	5	61	198 (+- 10)**
155	9-10.05.2015	Freshwater tank	100	0	0
164	11.05.2015	Before filtration	5	13	66
165	11.05.2015	After filtration	100	0	0
164*	11.05.2015	Before filtration	100	Positive	Positive
165*	11.05.20155	After filtration	100	Negative	Negative

*Water quality tested in the Veterinary laboratory, Kabul.

** Estimated number

Total Suspended solids (TSS)

Sample 164 (Raw water):

Turbidity: 138 NTU

Weight filter: 76.2 mg

Weigh filter+ residue: 81.8 mg

Calculation for TSS: 81.8 – 76.2 x 10 = 56.0 mg/l

1 L 56 mg

13 h of filtration

Average flow 497 l /h on the 9th and 10th of May

$\frac{56 \; x \; 497 \; x \; 13}{1000}$ = 361 g

Estimations suggest that after 13 hours of filtrating water with a turbidity 138 NTU the amount suspended solids in the filter is 361 g.

Sample 165 (Filtrated water):

Turbidity: 0 NTU

Weight filter: 75.5 mg

Weigh filter+ residue: 77.0 mg

Calculation for TSS: 77.0 – 75.5 x 10 = 15.0 mg/l

Discussion

The results show that the output ranges from 360 l/h to 690 l/h depending on the turbidity of the water. The output decreased with an increase in turbidity and out the operating period when not backwashing.

A turbidity of 31 NTU showed a decrease in output of 96 and 132 l after 3 and 6 hours of filtration. The average hourly decline was 22 l/h after 6 hours of operating with a turbidity of 31 NTU. Raw-water with the turbidity of 176 and 331 NTU slowed the filtration rate by 108 and 122 litres respectively after 3 hours, and 138 l and 198 l after 6 hours of filtration. With the initial turbidity of 93 NTU the output decreased by 42 l after 3 hours of operating and 72 l after 5 hours of operating.

On the 5th and 6th of May the turbidity ranged from 47 to 176 NTU where the highest output was during the start-up hour, of 654 l/h. After 10 hour of operating, the output decreased to 438 l/h, resulting in an hourly average decrease of 21.5 l/h.

On the 9th and 10th of May the turbidity ranged from 80 to 331 NTU having the highest output at the start up hour, 654 l/h. The output decreased to 360 l/h after 10 hours of filtration, resulting in an hourly average decrease of 29.5 l/h. Performing an backwash during the 11th hour resulted in an increase in output to 582 l/h.

The turbidity ranged from 15 to 98 NTU on the 11th and 12th of May having the highest outputs in the start-up hour and hour 6, 540 l/h and 552 l/h respectively. The output was decreased by 72 l/h after 6 hours of operating. A backwash conducted between the 6th and 7th hour increased the output to 84l l/h. During the 7th and 12th hour the output decreased by 54 l, resulting in an hourly average decrease of 7.7 l/h.

The raw-water tested positive for both total coliforms (faecal coliforms) and E.coli. Samples taken directly from the filter showed negative values, which indicates that the filter removes all bacteria as indicated. One sampled tested positive for total coliforms (faecal coliforms) in the fresh water tank, which indicates that the water can be contaminated after leaving the filter. After chlorination of the freshwater tank, the test was negative.

The turbidity levels in the raw-water decreased due to settling in the tanker truck. The manual cleaning was easily preformed, however some leakages was observed from the cleaning handles during performance.

Conclusion

The results reveal that the output ranges from 360 l/h to 690 l/h having a stable pressure of 2.5 m. In this experiment, the output depended on the turbidity of the water and the frequency of backwashing. However, it is assumed that a change in pressure will also have an effect on output. The raw water had a turbidity that ranged between 31 to 331 NTU, which contained both Total coliforms (faecal coliforms) and E.coli. Tests showed that the output had a turbidity of 0 NTU, and was free from bacterial contamination. However, one sample tested positive for total coliforms in the fresh water tank.

The set-up, manual cleaning and chlorination of the unit was quick and easily performed. The use and maintenance of the filter is assumed suitable for local peoples to perform, independent on level of education. However, proper guidance and training of the people is required.

This membrane filter is as a good fit in areas where people fetch drinking water from surface water containing high turbidity and bacterial contaminations. The membrane provides a water free from both particles and bacteria, while it also provides a satisfactory output.

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Pictures

Picture 1: Skyhydrant

Picture 2: Chlorination of freshwater tank

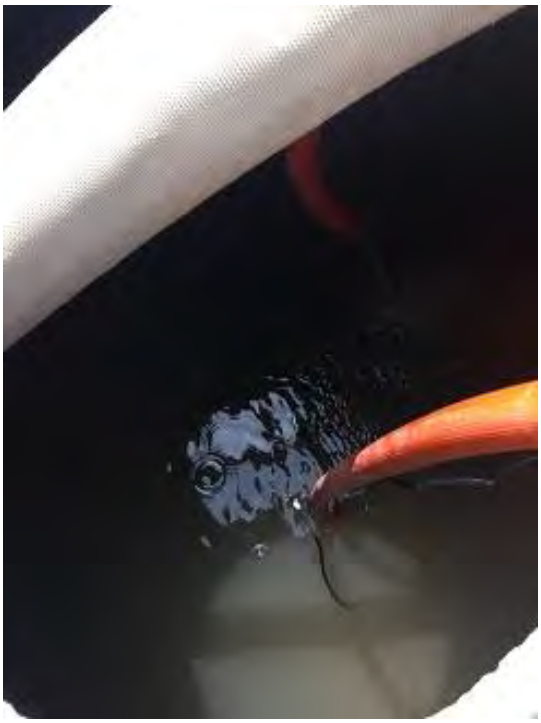
Picture 3: Colonies of total coliforms in the raw water (left and directly from filter (right)

Picture 4: Filtrated water in the centre of the picture and raw water samples gathered around

Picture 6: High team effort assembling the tanks

Picture 5: Measurement of output

Picture 8: Water sampling



Picture 7: Raw water inside tanker truck

Picture 12: Overview Skyhydrant

Picture 11: Overview Skyhydrant

Picture 10: Overview Skyhydrant

Picture 9: Overview Skyhydrant