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ARSENIC REMOVAL BY NANOFILTER TECHNOLOGY FOR THE RURAL AREAS OF BANGLADESH

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Abstract Arsenic in ground water is posing a serious threat to the rural people of Bangladesh. In 59 out of 64 districts of Bangladesh, arsenic level in the groundwater exceeds the threshold level 0.05 mg/l. A variety of treatment processes have been used for arsenic removal from water. The most commonly used technologies include co-precipitation and adsorption on to coagulated floc, lime softening, sulfide precipitation, adsorption on to activated carbon, activated alumina, ion exchange and membrane process such as reverse osmosis. This paper deals with the arsenic removal by the method of nanofilter. In the nanofilter units, water is passed through the filter with necessary pressure. Basic problem in the use of nanofilter in the rural context of Bangladesh is the availability of a suitable source of power required to generate the water pressure. Bicycle unit mounted nanofilter arsenic removal unit was developed for use in the rural areas of Bangladesh. In most of the rural areas of Bangladesh where electricity is not available – manual energy is the most reliable source that has been exploited in the operation of the unit to generate the necessary pressure. This makes the unit one of the most suitable options for removal of arsenic from extracted groundwater. Arsenic As(III) is not removed by the nanofilter but arsenate As(V) is successfully removed by the unit. Removal efficiency of As(V) of the unit is about 95% to 100%.

INTRODUCTION

The provision of safe drinking water remains the prime target for all countries all over the whole world. By far the greatest water quality problem especially in developing countries is the prevalence of water borne diseases. Such problem comes out from poor quality water sources, inadequate installation and poor hygiene. Bangladesh has achieved a commendable success among the developing countries in provision of drinking water supply through hand tube-well. But in recent time arsenic in ground water has come as a threat to the rural water supply. In this situation the immediate concern is to find a safe source of drinking water. There are two options:

- Finding a new safe source when unsafe arsenic contamination is identified in an area the immediate action should be to find a safe alternate source of drinking water which is arsenic free as well as microbiologically safe. It would be a serious mistake to revert back to unsafe use of surface water source.

- Removing arsenic from the contaminated source or at least reducing the arsenic contamination below the harmful level: sometimes it is observed in some areas that the arsenic contaminated water is abundant but arsenic free sources are scarce or polluted with other compound. In these cases it would be most efficient to remove arsenic or at least reduce the contamination to the safe level . it should be recalled that health effects of arsenic are dose dependent, and a partial solution is better than no solution.

There are so many options to remove arsenic from water. This paper only reviews nanofilter technique to remove Arsenic from drinking and cooking water. Quantity of treated water of the treatment unit is an important issue in considering the treatment method. Also the technology should be sustainable and should not have any adverse effect on the environment. The operational safety must also be ensured. The technology should be acceptable in economic as well as gender aspect. Other wise the technique will not be socially acceptable.

NANOFILTER UNIT

Nanofilter membrane was developed in the early 1980's. The pore size of the membrane is one nano-meter and so it is named nanofilter. Membrane

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processes can be used to remove a wide variety of materials of water ranging from suspended particles to ions. The membrane process used in a given application, depends on the raw water quality and the finished water treatment objective. Nanofilter membrane can be described as 'loose' reverse osmosis membranes and are not as effective at rejecting small, mono-valent ion such as sodium and chloride, but removes larger ions effectively such as Arsenic.

Membrane Geometry

Nanofilter membranes are constructed in different geometries. The two primary types are *hollow fine fibers* and *spiral wound*. Hollow fine fibers are produced as long capillary tubes with the diameters approximately of a human hair. Feed water is applied on the outside of the tubes with the permeate flow collected from the inner capillary. The wall of the tube is thick relative to the inside diameter to allow the membrane to operate under high pressure. These membrane tubes are arranged as a bundle of short loops tightly packed inside a cylindrical pressure vessel and sealed on both ends with a thick epoxy cap. One end seal is then partially cut to allow permeate water to flow out of the pressure vessel and produce water to be collected. Spiral wound membranes are made from flat sheet of membranes that are placed on each side of a sheet of porous material. The layers are then glued on three edges allowing water to permeate through the membrane and be collected in the porous material located between the membrane sheet. The fourth side is then attached to a perforated pipe which acts as collector for product water. From 2 to 26 membrane leaves are attached to the central pipe. A feed water channel spacer made of a mesh screen is then inserted between the leaves. This allows feed water to pass over the membranes and any remaining flow to be discharged as concentrate. The leaves and spacers are made of a mesh screen and then rolled to form a compact cylinder.

Basic working principle

Nanofiltration membranes are a pressure driven device. At pH 7 the membranes are negatively charged. As it is negatively charged it will repulse other negatively charged ions. This is the basic principle of nanofilter. When the feed water carrying negatively charged particle comes towards the membranes with a pressure, the negatively charged particles are repulsed and come outwards as concentrate and the ion free water is extracted throughout the other path as permeate. At

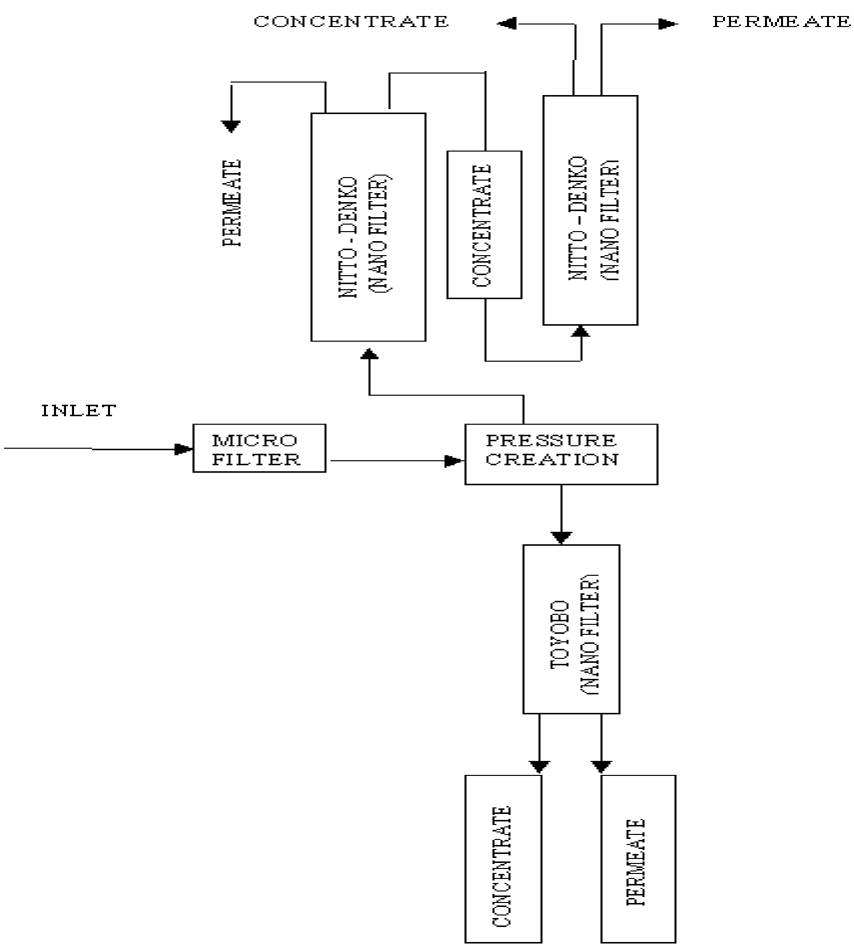

Fig. 1 Flow diagram of water flow in the nanofilter membrane unit

neutral pH arsenite As(III) is zero valent whereas arsenate As(V) is negatively charged. At high pH like 9 to 10, As(III) is negatively charged. But the membrane is effective at pH 7. So it does not work at pH 9 to 10. As arsenic (III) is zero valent at pH 7 , it is impossible to remove As(III) by the membrane. The membrane can only remove negatively charged ions, so only arsenate As(V) could be removed by the machine. The repulsed ions with a huge amount of water comes outward through the concentrate outlet and ion free small amount of water is extracted through the permeate path. NITTODENKO and TOYOBO belonging to two different types of geometry. Flow diagram of the machine is given in the fig.1. Initially the water is passed through a micro filter where suspended particles are removed. Then water is driven through nanofilter by

RESULTS

The experiments were performed by a nanofilter kit. There are two units in the kit with the brand name of creating pressure manually.

All the experiments were performed with a given dose of arsenic(V). The performance of the machine with different doses of Arsenic at different operating pressure are as in Table 1 and 2.

Table 1 Arsenic removal performance of Nitto-denko nanofilter

SAMPLE NO	INITIAL As CONCEN.	OPERATING PRESSURE	FINAL As CONCEN.	% REMOVED
	(ppm)	(atm)	(ppm)	
1a	0.1	6	nil	100
1b	0.1	6	nil	100
2a	0.1	7	nil	100
2b	0.1	7	nil	100
3a	0.1	8	0.0042	95.8
3b	0.1	8	nil	100
4a	0.2	6	0.0072	96.4
4b	0.2	6	nil	100
5a	0.2	7	nil	100
5b	0.2	7	nil	100
6a	0.2	8	0.0062	96.9
6b	0.2	8	0.002	99
7a	0.3	6	nil	100
7b	0.3	6	nil	100
8a	0.3	7	0.0052	98.2
8b	0.3	7	0.0012	99.6
9a	0.3	8	nil	100
9b	0.3	8	nil	100

Table 2 Arsenic removal performance of Toyobo nanofilter

Sample no	Initial As concen. (ppm)	Operating Pressure (atm)	Final As concen. (ppm)	% Removed
1	0.1	6	nil	100
2	0.1	7	nil	100
3	0.1	8	nil	100
4	0.2	6	0.0048	97.6
5	0.2	7	0.005	97.5
6	0.2	8	0.008	96
7	0.3	6	nil	100
8	0.3	7	0.009	97
9	0.3	8	0.0112	96.2

Table 1 Arsenic removal performance of Nitto-denko nanofilter

Table 2 Arsenic removal performance of Toyobo nanofilter

From the above results it has been observed that arsenic(V) removal efficiency is almost 100%. Water with different arsenic(III) doses have also been experimented by the units for removal of arsenic but efficiency was found to be zero.

It was also observed that higher operating pressure results a higher rate of output. But for manual operation a higher operating pressure is not always possible. The optimum operating pressure for a man is 5-6 atm. For one liter of output , time required is 90 second for both Nitto-denko and Toyobo units. It was also observed that a man can operate the machine 8 to 10 minutes successfully at a stretch. From this statistics it has been observed that the arsenic free water production rate is low. The rest of the water comes out through the path of concentrate. This water is also usable. 20 liters of raw water of 0.2ppm arsenic concentration were taken to the machine at a pressure of 6 atm. After operating the machine, reduced concentration of As contaminated water obtained were nearly 2.5 liters and its As concentration was 0.0072ppm. Volume of concentrate was 17.5 liters with As concentration of 0.227ppm which is not so high from 0.2ppm. This 17.5 liters water with or without dilution may also be used in other household purpose and 2.5 liters water should be used for drinking purpose only.

CONCLUSION

The studies conducted on the various issue of arsenic contamination of groundwater in Bangladesh led to the following conclusions:

1. The unit can remove only arsenate. In groundwater both arsenite and arsenate are present. By aeration major portion of arsenite is converted into arsenate which can be successfully removed by the unit. So the machine may be used to remove the arsenic of groundwater in the affected areas.

2. Both male and female are able to operate the machine and without electric power it can be operated. The unit is suitable for use at the remote zone of Bangladesh where electric power supply is not available.

3. The output rate of arsenic free water is not so high. But from the result it has been observed that the concentration of As in the permeate flow is almost nil. According to WHO guideline 0.1ppm of As is allowable in drinking water. So the raw water may be mixed with the As free water to the limit. By operating the machine about 10 minutes a man can collect about 7 litres of As free water. If the raw water As concentration is 0.3 ppm then 3.5 litres of raw water be safely mixed with the 7 litres of As free water to get the final As concentration of 0.1ppm. so a man can get 10.5 litre of drinkable water. By operating the machine another 20 minutes a man can collect the total drinking water for his family for a day.

4. The machine would be able to supply water irrespect of season. It also creates no sludge like some other options, which is a problem for disposal and environmental pollution.

5. At last community based attempt would be feasible to install the machine on economic aspect.

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