ABSTRACT

Bangladesh faces what the World Health Organization has called the "largest mass poisoning of a population in history." Forty-nine million people drink water contaminated with arsenic far exceeding the WHO guideline value for safe water. Arsenic, which is odorless, colorless and tasteless, and damages human health in a host of ways especially after extended exposure, has come to be known as a 'silent killer'. Regarding the scale of the problem not only in Bangladesh but in many other parts of the world the enormous amount of activities have been done so far in order to cope with it, still however millions of people are exposed to dangerous arsenic concentrations in drinking water, and no technology was found which could be economically affordable and technically effective in all arsenic contaminated areas.

Several community-based technologies were investigated between February and June 2009 to provide sufficient technical information in advance of the launch of the Clean Water Foundation's Arsenic Mitigation Project (list of technologies cf. table 1). The objective was to find a relatively simple, easily maintainable and affordable technology, which will produce enough of water for a local entrepreneur to earn a living by running a business that purveys water to his community. Most of the information was collected from the primary sources, through close cooperation with the proponents of these technologies, academics who have spent much of their careers devoted to solving the arsenic problem, international organizations and local institutions including UNICEF, WHO, the Bangladeshi Environmental Technology Verification Body and many others. From this research, it was found that the groundwater in Bangladesh is also manganese-rich in many places. In the southern districts of the country, people straggle with the problem of brackish water. Without any existing technology for ions removal there, and given that alternative drinking water sources are usually extremely polluted and thus require complex treatment before the consumption, they have little option but drink salty water.

Most of the technologies for arsenic removal are based on the adsorption on the media (cf. table 1). Unfortunately, due to the complex water matrix (including the presence of various dissolved components, particularly phosphates and silicates) it appears that most of these technologies have a much lower production capacity than it was initially assumed. This factor significantly increases their associated maintenance costs. As noted from experience on the ground, this condition has all but led to the abandonment of some these units in remote rural areas of Bangladesh. **Most of the adsorption-based technologies should not be used if arsenic concentration is very high, and accompanied by the presence of phosphates or silicates**.

Populations in Bangladesh with the misfortune of having groundwater contaminated with arsenic, fortunately have secret weapon in that same water: high concentrations of naturally occurring iron that after proper oxidation has the affinity to adsorb arsenic.

This phenomenon is used by some of the existing technologies. **However the oxidation-based technologies are highly dependent on the iron concentration and can be used only if its value is ten times that of the arsenic concentration.**

Finally the newly developed electro-membrane-based technology, FTC, opened an avenue for supplying clean water to Bangladeshi living in areas of high salinity, manganese, iron, arsenic and many other ions.

FTC is the only technology that can eliminate all the undesired chemical components present in the groundwater of Bangladesh.

The technologies recommended include:

AIRP 70-80 HH (for sparsely populated villages where the quantity of water production is not of a great importance and arsenic concentration is rather low and iron rather high); **TiPOT** (for fresh waters with high iron concentration); and **FTC** (definitely where TDS value indicates brackish water, and everywhere else where the other technologies cannot be applied). FTC is likely the most technically effective solution for supplying clean water in Bangladesh, however for the moment it is not the most economical one. Adsorption-based technologies are not recommended as they require the governmental approval for the use and are so much depended on the water matrix. **SIDKO** that was initially considered as a promising technology leads to negative month revenue. The main reason of it is the frequent necessity for changing the media, which after deeper analysis appeared to be in practice approximately 7 times more frequent than in theory. It leads to very high cost of consumables[1]. Thus Sidko can be only used in areas with very low arsenic concentrations and minimal levels of phosphates and silicates. Only then will its production capacity be higher and its operating time can be increased to sustain higher daily water production.

Calculation of the Total Cost of Ownership (TCO) is one of the models used for an objective comparison of the technologies (cf. table 1).

Table 1 presents the TCO of actual technologies (part above) as well as future models of FTC (part below). The assumptions stated in the table refer to all the technologies.

Table 1, Total cost of ownership for investigated technologies

ADSORPTION-BASED TEHNOLOGIES | OXIDATION-BASED TECHNOLOGIES | ELECTRO-MEMBRANE BASED TECHNOLOGY

TOTAL COST OF OWNERSHIP

Cost per year [$]	SIDKO 240 LPH	READ-F 240 LPH	READ-F 600 LPH	MAC TECHNOLOGY 900 LPH	SWN RAVI ARSENIC PLANT 500 LPH	AIRP 40-60 HH	AIRP 70-80 HH	TiPOT 4000 L/day	FTC (2008) 360 LPH IM.TAX 3%	FTC (2008) 360 LPH IM.TAX 25%
Purchase cost	$ 5 300,00	$ 5 000,00	$ 12 481,00	$ 3 066,00	$ 7 143,00	$ 1 100,00	$ 1 700,00	$ 3 000,00	$ 14 234,00	$ 17 275,00
Costs of consumables	$ 2 905,00	$ 1 650,00	$ 4 100,00	$ 11 932,00	$ 104,00	$ -	$ -	$ -	$ -	$ -
OPEX and maintenance costs	$ 151,00	$ 35,00	$ 40,00	$ 101,50	$ 66,00	$ 152,00	$ 228,00	$ 84,00	$ 199,00	$ 199,00
CapEx	$ 795,00	$ 750,00	$ 1 872,15	$ 459,90	$ 1 071,45	$ 165,00	$ 255,00	$ 450,00	$ 2 135,10	$ 2 591,25
Total	$3 851,00	$2 435,00	$6 012,15	$12 493,40	$1 241,45	$317,00	$483,00	$534,00	$2 334,10	$2 790,25
Produced water [m3 / year]	700	700	1752	2628	2190	547,5	821,3	1460	2628	2628
TCO/m3	$ 5,50	$ 3,48	$ 3,43	$ 4,75	$ 0,57	$ 0,58	$ 0,59	$ 0,37	$ 0,89	$ 1,06

ASSUMPTIONS	
Life expectancy [years]	10
Interest rate	5%
Depreciation	Linear

	FTC Q3 2009 IM. TAX 3 %	FTC Q3 2009 IM. TAX 25 %	FTC Q3 2010 IM. TAX 3 %	FTC Q3 2010 IM. TAX 25 %
Purchase cost	$ 7 731,00	9382	$ 3 203,00	3888
CapEX	$ 1 159,65	$ 1 407,30	$ 480,45	$ 583,20
Total	$ 1 358,65	$ 1 606,30	$ 679,45	$ 782,20
TCO/m3	$ 0,52	$ 0,61	$ 0,26	$ 0,30

[1] Cost of consumables (CoC)- total cost of the chemical consumable components of the system (media, disinfectants, reducing agents, coagulants etc.)