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A Module Design–Arsenic Removal Filter for Rural Community

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ABSTRACT

The problem of arsenic intoxication by contaminated drinking water emerged in the past two decades, when surface water an ground water from open dug Wells and tube well formerly used to cover the drinking water supply in rural areas of many tropical regions. Chronic arsenic exposure can lead to severe health problems such as hyperkeratosis, melanosis, skin cancer and cancer of internal organs. Arsenic pollution of ground water has been recognised in the Ganga region of Bihar. The ground water of numerous households in this region is not only contaminated by arsenic but it also contains high iron concentration. Arsenic removal is necessary in urban and communal water as well as in areas pumping ground water through family based tube well. Therefore I have investigated the arsenic removal household filter for rural communities. The arsenic bio-sand filter (ABF) comprises of two removal unit- A) the arsenic removal unit consists of the metal diffuser box, citrus sinensis skin powder and a polyester cloth, B) the pathogen removal unit consists of sand and gravel layers. Arsenic removal is governed by the precipitation of iron hydroxides, which forms a coating on the sand's surface. Arsenic then adsorb to the iron hydroxide and forms complex compound with citrus sinensis skin which forms a coating on polyester cloth filter and also sand surface. The arsenic removal efficiency of (ABF) filters was examined from 10 samples collected from 10 sampling stations. Arsenics removal efficiency of 80% was achieved in ground water containing 10-21(ppb) and iron 0.75 to 3.50 mg L^{-1}. High iron concentration clearly enhances arsenic removal. ABF filters use locally available materials and are operated without chemicals can treat a reasonable amount of ground water within a short time and can easily replicate by the affected communities.

Keywords: Adsorption, ABF, Arsenicosis, removal.

INTRODUCTION

The problem of arsenic intoxication by the contaminated drinking water emerged in the past two decades [1,2]. When surface water and ground water from open dug wells and tube wells formerly used to cover the drinking water supply in the rural areas of many tropical regions, the presence of arsenic in ground water is due to anoxic dissolution iron hydroxides and release of previously adsorbed arsenic. Arsenic is released from the sulphide minerals (arsenopyrite) in the shallow aquifer due to oxidation. Mountain erosion leads to a release of rock forming minerals and arsenic into the hydrosphere. Eroded iron turns to rust iron hydroxide and forms particles as well as coating on the surface of silt. Surface suspended particles with iron hydroxide coating and adsorbed arsenic are washed into rivers and transported into down streams.

Arsenic removal is highly dependent on the iron concentration, i.e., if more iron is initially present larger surface areas are formed and more oxidant are produced for arsenic oxidation. Iron concentrations greater than 5 mg L^{-1}. Convey a bad taste to the ground water, which is described as "fishy" smell. Phosphates and other anions behave in a similar way as arsenic species (oxyanions). Phosphates have the highest adsorption capacity to iron hydroxides surface and is a key factor governing arsenic removal.

Health problems caused by chronic arsenic poisoning (arsenicosis):- Arsenic concentration of 50 µg L^{-1} of water can cause chronic health problems. If such water is consumed over a period of 5-10 years. Development of the disease is strongly dependent on exposure time and arsenic accumulation in the body, but age, nutritional habit and life style of the exposed person may also have an influence on the occurrence of the health problems. Skin ailments are generally the first symptoms which develop after a few years of continued arsenic ingestion i.e., hypo pigmentation (white spot on skin), hyperpigmentation (dark spot on skin) and keratosis (break up the skin on hands and feet). More serious health affection such as skin cancer or cardiovascular and nervous affection are known to appear with a latency of 10 or more years of exposure.

MATERIALS AND METHODS

Arsenic Bio-sand Filter (ABF): The ABF is an integration of two removal units, the arsenic removal unit and the pathogen removal unit. The arsenic removal unit consists of the metal diffuser box, citrus sinensis skin, and a polyester cloth. The pathogen removal unit consists of sand and gravel layers. The cross-sectional diagram are given below –

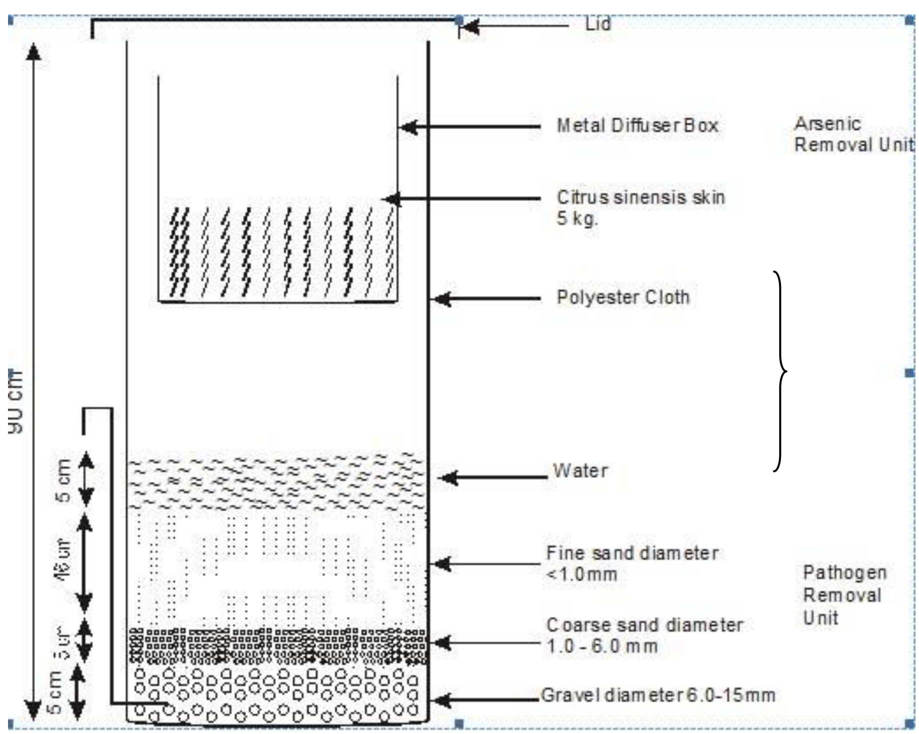

Fig. Cross-section of the Arsenic Bio sand Filter Design

Numerous studies on bioadsorbent have shown that citrus sinensis skin is an excellent adsorbent for arsenic. A surface complexation reaction occurs when aqueous arsenic species come into contact with citrus sinensis skin. Both species of arsenic found in water (arsenite and arsenate) are effectively and tightly bound to the citrus sinensis skin [3-4].

When arsenic - contaminated water is poured into the ABF, the arsenic is adsorbed on to the surface of the citrus sinensis skin. Some of the arsenic loaded citrus sinensis skin particles are trapped by the polyester cloth, but most of the particles are flushed past the polyester cloth, onto the underlying fine sand layer. Because of the very small pore space of the fine sand layer, almost citrus sinensis skin containing arsenic will settle on top of the fine sand layer. Since most of the arsenic in the water is already adsorbed onto the citrus sinensis skin, and this citrus sinensis skin trapped on top of the fine sand layer, as a result, arsenic is effectively removed from the water. The arsenic particles are found on to adsorbent and resulting molecules are filtered by the top layer of the fine sand.

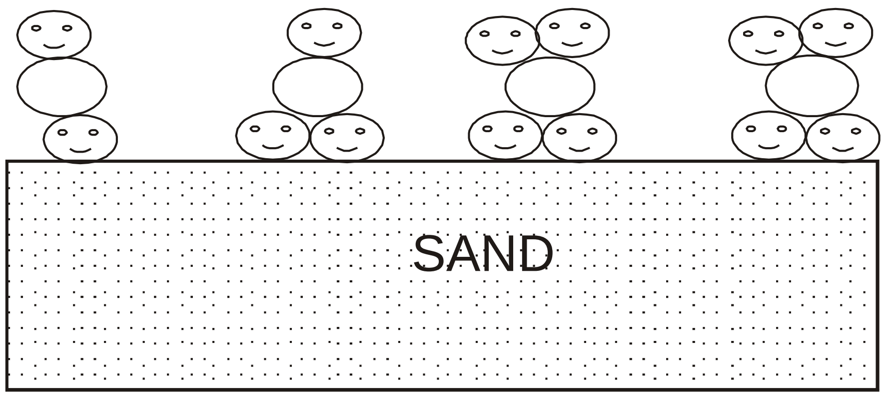

Fig. A simplified illustration of the Arsenic removal mechanisms

The arsenic particles are bound on to adsorbent and resulting molecules are filtered by the top layer of the fine sand.

Pathogen Removal: The process of pathogens removal in microbially contaminated source water is not yet will understand. It is currently believed that pathogens in an ABF can be removed primarily by two mechanisms: Physical-chemical and biological [5, 6, 7]. A simplified explanation of these processes is discussed below -

Physical-chemical Mechanism: Of the many physical-chemical processes associated with filtration, surface straining and inter-particle attraction are probably the most important process responsible for pathogen removal in an ABF. Surface straining refers to the trapping of foreign particles on top of the filtered of sand grains can capture particle about 5% of the grain diameter. For example, sand with a diameter of 0.1 mm will strain out particle that are 5μm or larger [8]. This is substantially larger than many particles to be removed from surface water such as cysts (1-20 μm) and bacteria (0.1 to 10μm) [9]. Viruses are much less than 1 mm and must, therefore, by removed by other means [10] such as biological mechanism.

Interparticle attraction refers to the process with which the foreign particles are adsorbed to the filter medium (i.e. sand). This process is affected by a variety of chemical interactions between microbial cells and porous media including hydrophobicity (i.e. polarity) and surface charge [11,12].

Biological Mechanism: Foreign particles such as dust, dirt, organic substances will begin to settle on top of the fine sand layer as a filter cake. Arsenic water is poured into the ABF, dissolved organic carbon, dissolved oxygen and nutrients present in the influent water will support elevated biological populations within the filter cake and in the top few cm of the fine sand [13]. This diverse biological population is known as the biofilm. It is consists of algae, bacteria, protozoa, and small invertebrates [14].

The ABF is designed in such a way that there is always about 5 cm of standing water above the fine sand layer. The 5 cm height was reportedly to be the optimum height for pathogen removal. If the water level is two shallow, the biofilm layer can be easily disturbed and subsequently damaged by the force of the incoming water. On the other hand, if the water level is two deep, an insufficient amount of oxygen diffuses to the biofilm resulting in suffocation of the micro-organism in the biofilm layer [15]. In addition to the 5cm protective water layer, the diffuser box above the fine sand layers serves an important purpose to reduce the force of input water from disturbing the top layer of sand [16]. When microbially contaminated water is poured into the ABF, predator organisms that reside in the biofilm layer will consume the incoming pathogens [17]. Recent studies and experiments conclude that this process can be a significant cause of bacterial removal in slow sand filters [18].

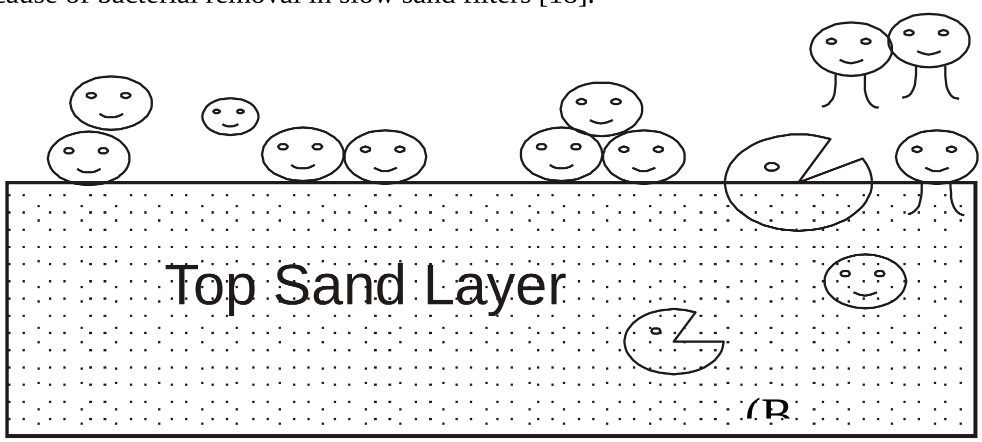

Figure: A simplified Illustration of the Pathogen Removal Mechanism

Physical removal by surface straining is illustrated in (A) Bacteria are two large to pass through the sand layer. Biological removal by predation is illustrated in (B). The microorganisms living in the biofilm consume incoming bacteria.

Biofilm Ripening: When an ABF is newly installed, or when the biofilm layer is damaged (i.e. during the filter cleaning), time is needed for the biofilm to grow to maturity. This is called the ripening period. The ripening period can be as short as a day and can go up to several weeks, depending on the water temperature and chemistry 1920. For example - high concentration of organic substances in the influent water may encourage biofilm growth [21]. During the ripening period, the filter does not remove bacteria effectively because only physical-chemical mechanism is at work remove bacteria. A study by Bellamy et. al. concluded that a new sand bed could remove 85% of the coliform bacteria in the influent. As the sand bed matures biologically, the percent removal improves to more than 99% for coliform bacteria [22]. Accuracy of ABF is measured by experiment with ten samples collected from different sampling stations. For this work ten sampling station of Bidupur block has been selected named as –s1 s2 s3 s4 s5 s6 s7 s8 s9 s10 respectively.

Table 1: Areas of Bidupur Block of Vaishalli district (Bihar) used for sampling

1.	Khajwati (hand pump)	S 1
2.	Khajwatti (well)	S 2
3.	Chandpur Saidabad (Hand pump) 155 ft.	S 3
4.	Mohanpur (Hand pump)	S 4
5.	Khajautta (Well)	S 5
6.	Keshavpur Pakri (Hand pump 155 ft.)	S 6
7.	Chandpur Saidabad (Well)	S 7
8.	Khajautta (Hand pump)	S 8
9.	Kutubpur (Hand Pump)	S 9
10.	Vajeetpur (Hand pump)	S 10

Table – 2

Sample	Arsenic conc before treatment mv/l	Iron conc	Arsenic conc after Treatment ttb	Removal %
S 1	12	2.37	O.37	80%
S 2	18	2.4	5.04	72%
S 3	13	1.29	3.38	74%
S 4	17	0.60	6.12	64%
S 5	19	0.75	5.89	69%
S 6	10	3.50	4.50	53%
S7	11	2.87	1.42	78%
S8	21	0.75	17.14	66%
S9	14	0.42	9.38	33%
S10	15	0.42	8.35	71%

APPLICATIONS

This arsenic bio sand filter is very useful for rural community because it can be available easily at low cost and is eco-friendly.

CONCLUSIONS

The investigated areas reveal of an extremely heterogeneous arsenic levels. The water of different villages may exhibit arsenic levels of significantly above the drinking water threshold. This unpredictable variability requires not only simple and efficient arsenic removal technology on a house hold level but also an effective monitoring programme to decide on the design and application of mitigation measures. The removal efficiency of ABF were analysed from the given table-2. Maximum efficiency of removal is 80% and minimum is 33%.

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