

## Efficiency of DHR as a Biosorption of Arsenic

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### Abstract

Arsenic contamination in water possesses severe health problems all over the world. It was first noticed in West Bengal, India in 1983. Instead of decreasing very soon it become a serious problem all over the India. At present arsenic pollution has been reported from more than seventy countries on six continents so far. The present study successfully evaluate dried powdered root of water hyacinth (*Eichhornia crassipes* (Mart.) Solms), referred as dried hyacinth root (DHR), for biosorption of arsenic as a low cost technique. Results from ICP suggest that 0.75 g of DHR removes 89 percent of 2 ppm As (III) in 120 hours whereas 50 g DHR removes 99.5 percent in 48 hours and 91.5 percent within 12 hours. Further study reveals that 50g of DHR removes 99.98 percent of 50 ppm or 50000 ppb As (III) in 48 hours. It is concluded that by increasing the mass of DHR, it is possible to increase the removal efficiency of As (III) in short span of time.

**Keyword:** Arsenic, DHR, water hyacinth, biosorption.

### Introduction

Arsenic poisoning or Arsenicosis is reported to cause melanosis, keratosis, skin cancer and well-known black-foot disease<sup>1</sup>. Arsenic, a metalloid element, is a natural part of the earth's crust. The natural occurrence is usually associated with sedimentary rocks of marine origin, weathered volcanic rocks, geothermal areas and fossil fuels. Arsenic exists in natural water in both organic and inorganic forms. The inorganic forms of arsenic are more toxic than its inorganic form. Inorganic arsenic exists in natural water in two oxidation states: arsenite and arsenate. As (III) is dominant in more reduced condition whereas As (V) is dominant in an oxidizing environment<sup>2</sup>. Excessive amount of arsenic can cause acute gastrointestinal

(GI) and cardiac damage. Chronic doses can cause vascular disorders such as Blackfoot disease and epidemiological studies have linked arsenic to skin and lung cancer<sup>3</sup>. The problem of arsenic contamination was first come in notice in 1983 in West Bengal (India) and soon it becomes a serious water contaminant. There are immense conventional techniques available for the removal of arsenic from drinking water based on oxidation and sedimentation; coagulation and filtration; Sorptive filtration and Membrane filtration. But the major disadvantages of these technologies is that either they are very expensive or cause environmental problems as a side effect. Moreover these technologies required skilled manpower and so they are not sustainable.

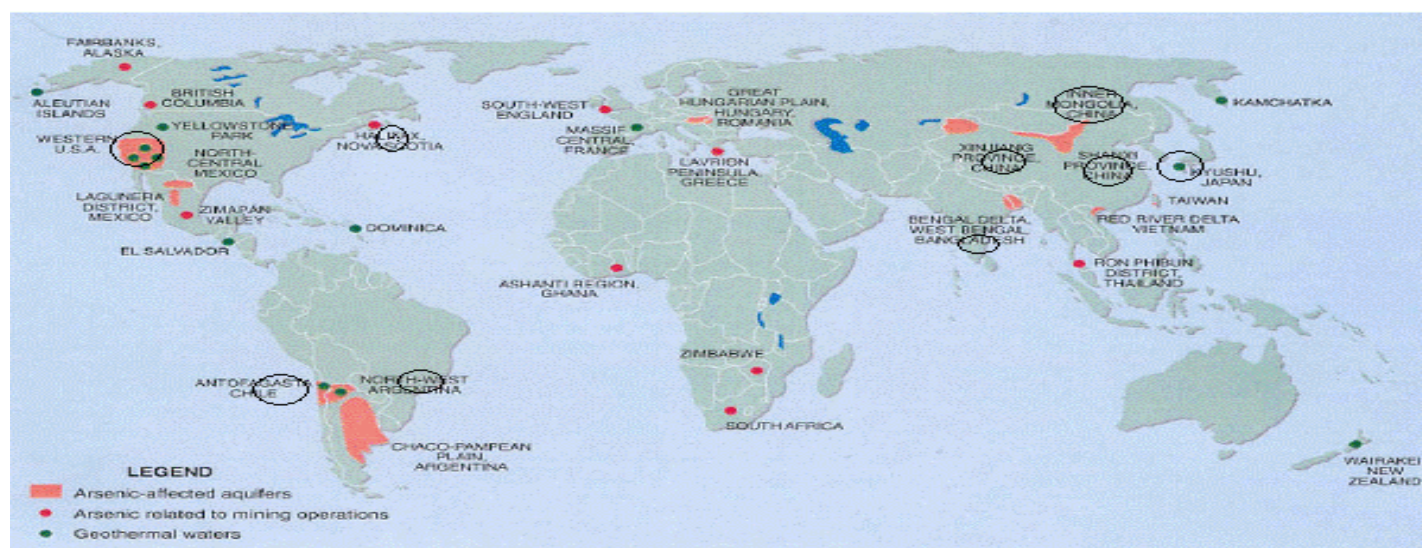


Figure-1(A)  
Map illustrating arsenic – affected place

To overcome these shortcomings many alternative and cost-effective techniques were studied. Biosorption appears to be one of the effective principles in removing arsenic from drinking water. Biosorption (or bioadsorption) is a passive immobilization of metals by biomass<sup>4</sup>. The mechanism of cell surface sorption is independent of cell metabolism; they are based upon physicochemical interactions between metal and functional groups of cell wall. The microorganism's cell wall mainly consists of polysaccharides, lipids and proteins, which have many binding sites for metals. This process is independent of the metabolism and metal binding is fast<sup>5</sup>. Sag<sup>6</sup> reported that metal uptake by dead cells takes place by the passive mode. Living cells employ both active and passive modes for heavy metal uptake.

Biosorption and bioaccumulation differ in kinetics and activation energies ( $E_a \sim 21$  kJ/mol for biosorption, which is in agreement with the physical nature of the process and  $E_a \sim 63$  kJ/mol for bioaccumulation corresponding to biochemical process) reported by Raraz<sup>7</sup>; Kadukova and Vircikova<sup>5</sup>. The biosorption of arsenate was found to be highly pH dependent. At the optimum treatment condition of pH 4, temperature 25°C, contact time 90 minutes, and adsorbent dose 4 g/l, 85.70 percent removal of arsenate reported by Kamsonlian, Majumder, and Chand<sup>8</sup>.

Water hyacinth (*Eichhornia crassipes*) a wild fern belonging to the family Pontederaceae, is a submerged aquatic plant, found abundantly throughout the year; it is common in India<sup>9,10</sup>. It was investigated that non-living water hyacinth roots have the ability of sorption of Uranium from aqueous solution<sup>11</sup>. It has been shown that more than 93 percent of arsenite (As III) and 95 percent (As V) were removed from a solution containing 200 µg/l or 0.2 ppm within 60 minutes of exposure to a powder produced from dried roots<sup>12</sup>. Haris and Harington<sup>13</sup> repeated the same experiment and come up with the same result. Shekar, Donald and Rock<sup>14</sup> reported that a concentration of 20 g/l dried hyacinth root was found adequate for greater than 90 percent arsenic removal in the batch test. However, in these studies it is not indicated that how much quantity of dried hyacinth root would be sufficient to make a filter bed of DHR (dried hyacinth root) in order to remove 2 ppm or 2000 ppb of arsenite from drinking water. The present study was developed to determine the quantity of DHR required mitigating the arsenic concentration up to 100 ppm or 100000 ppb in drinking water in order to optimize DHR for arsenic mitigation.

## Material and Methods

**Biosorbent preparation:** For the present investigation, water hyacinth collected from pond situated at Chinhat, Lucknow was used for the experiment. The water hyacinth root was converted into powdered form and used it as biosorbent.

**Preparation of DHR powder:** Water hyacinths were collected from pond situated at Chinhat, Lucknow. It was initially washed in tap water and then all roots were cut using scissor. These

roots were then soaked in a bucket with 10 liter capacity for removal of tannins and pigments with regular mixing with hand. This step was repeated five to seven times in fresh tap water and was then allowed to soak in freshwater overnight at 4°C in a refrigerator. After 24 hours, water was drained out and the washing was repeated nearly 3-4 times to achieve clear washout water. The roots were then allowed to air-dry at room temperature for 96 hours. (Time for air-dry depends on sunshine. If its winter it will take 7-8 days and if its summer it will take 4-5 days).

The dry roots were then stored in selected polythene (Zip lock) bags at room temperature. The dried roots were ground at 12000 rpm in a waving commercial blender using a 4 liter stainless steel jar within a well-ventilated area and were again stored at room temperature in sealed polythene bags. Approximately 1 kg of water hyacinth provides 99.7 gram or 100 gram (approximately) of root powder. For this experiment total 10 kg of water hyacinth were collected from pond which provide approximately 1000 gram of root powder.

**Preparation of standards, and reagent:** Distilled deionised water was used for the preparation of 1 N of 1000 ppm arsenic (Analytical grade chemicals- Sodium arsenite 'Excel R' NaAsO<sub>2</sub> (Mol. Wt.129.91) and Sodium arsenate 'Excel R' Na<sub>2</sub>HAsO<sub>4</sub> (Mol. Wt. 312.01) stock solution. Out of which working solution of 2 ppm, 10 ppm, 50 ppm, 75 ppm and 100 ppm was prepared.

100 ml of each working solution was added to each of the plastic beakers containing different mass at room temperature. The mixture was shaken for 120 minutes on a magnetic stirrer. At different time intervals roots were removed by filtration to obtain a supernatant solution, which was analysed in ICP for arsenic presence. The filter was stored in conical tube with a screw cap in room temperature. The experimental beakers were covered with thermoplastic self-sealing laboratory film to prevent evaporative loss and volume change in the reaction mixture.

**Removal percentage:** Biosorption is one of the latest techniques used for the removal of heavy metals from aqueous solution. The percentage removal of arsenic ions was calculated as per Wei et al<sup>15</sup>;

Biosorption Percentage (%) =  $\frac{C_i - C_f}{C_i} \times 100$

Where  $C_i$  and  $C_f$  are the initial and final concentration of arsenic ions present in the biosorption studies.

## Results and Discussion

In the present study, DHR was found to be effective in removing As (III) from drinking water. The effect of contact time on removal of arsenic onto DHR biomass surface was investigated. The results presented in figure 1 indicate that 0.75 g of DHR removes 89 percent of 2 ppm arsenic in 120 hours whereas 50 g removes 91.5 percent of arsenic within 12 hours and 99.5 percent in 48 hours.

Increasing concentration of arsenic to 10 ppm shown in figure 2, illustrate 30 g DHR removes 99.3 percent in 120 hours and 50 g DHR removes 70 percent in 12 hours, 90 percent of arsenic within 48 hours and 99.9 percent in 120 hours.

Further raising concentration of arsenic to 50 ppm or 50000 ppb illustrated in figure 3, reveals that 50 g DHR removes 99.98 percent in 48 hours and 71.9 percent in 12 hours.

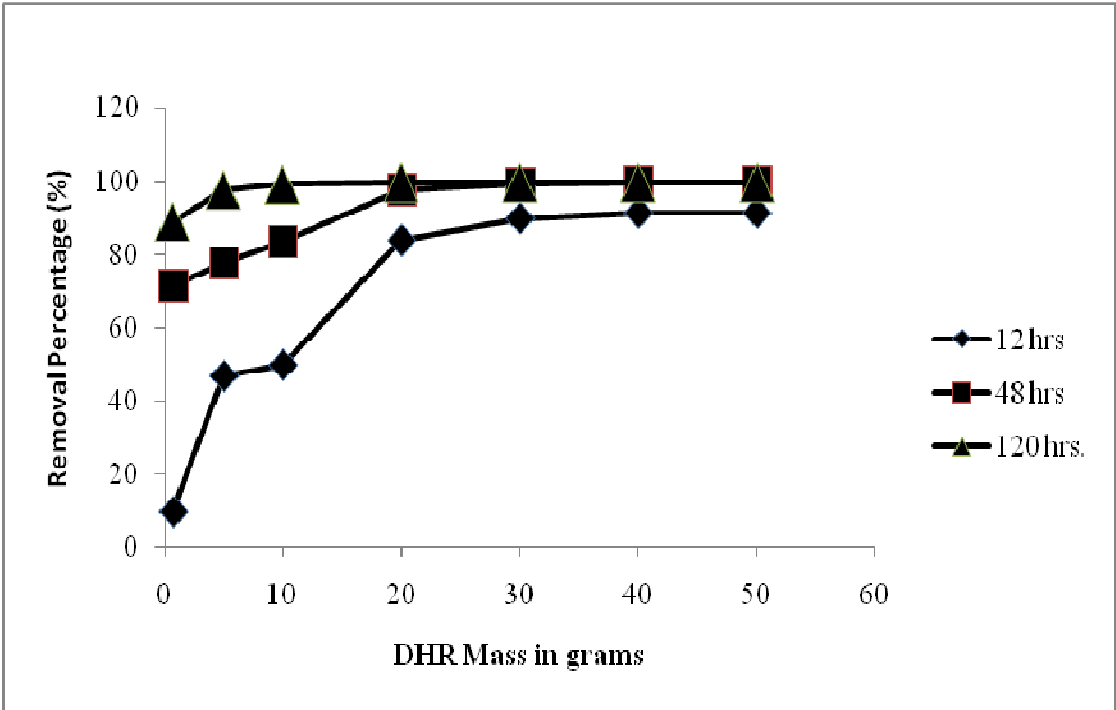


Figure-1

Different mass of DHR in 2 ppm of arsenic indicates that removal percentage increases from 20 gm DHR onwards and it removes up to 99.5 percent within 48 hours and 91.5 percent within 12 hours using 50 gram of DHR

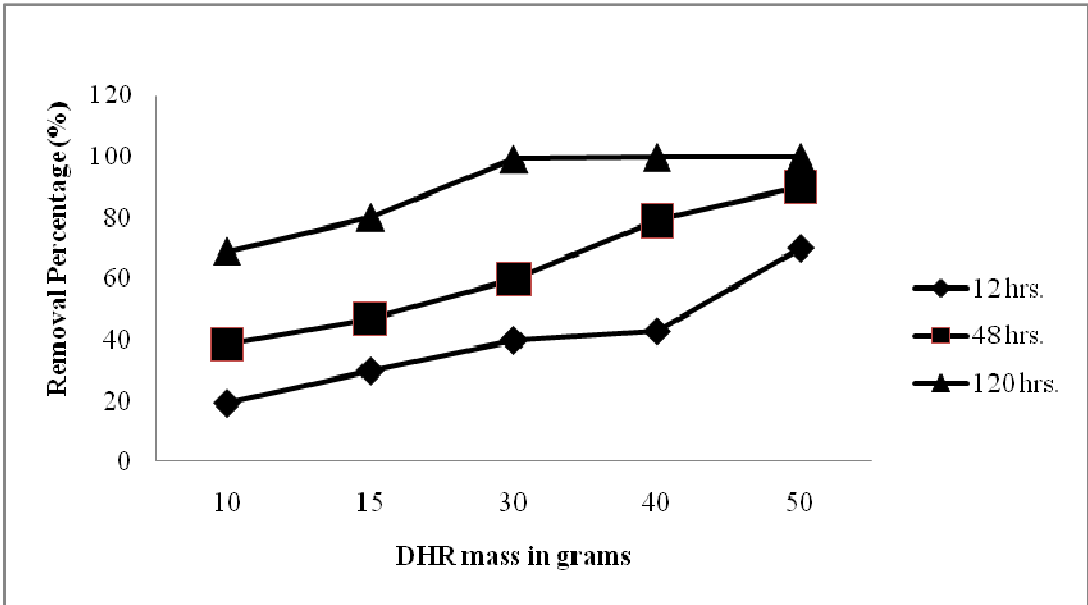


Figure-2

Different mass of DHR in 10 ppm arsenic indicates removal percentage increases from 30-40 grams onwards and at this high concentration it removes 99.9 percent within 120 hours and 90 percent within 48 hours

To optimize DHR arsenic concentration was again increases to 75 ppm or 75000 ppb shown in figure 4, removes 94 percent within 48 hours, 99.98 percent in 120 hours and 74.66 percent in 12 hours.

Further, figure 5 indicates the efficiency of DHR in removing 99.99 percent of 100 ppm or 100000 ppb of arsenic within 120 hours, 90.99 percent in 48 hours and 75.99 percent in 12 hours using 50g DHR. However, the concentration of arsenic was kept higher than the normal concentration found in drinking water in order to optimize DHR in removing arsenic.

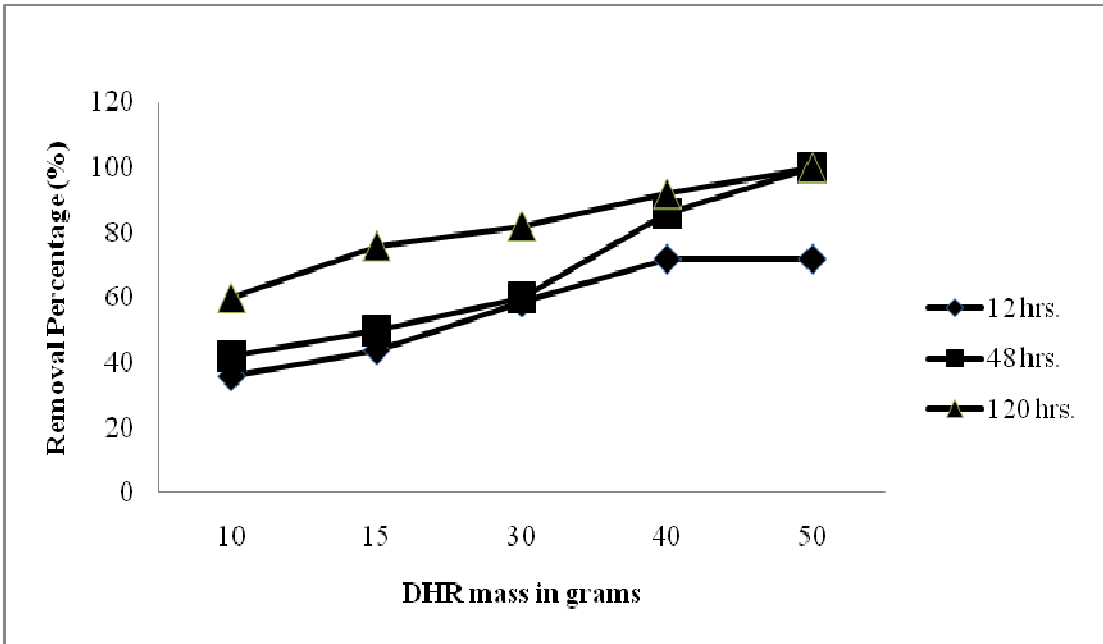


Figure-3

Different mass of DHR in 50 ppm arsenic shows removal percentage increases as the mass increases and it removes up to 99.9 percent within 48 hours using 50 grams of DHR

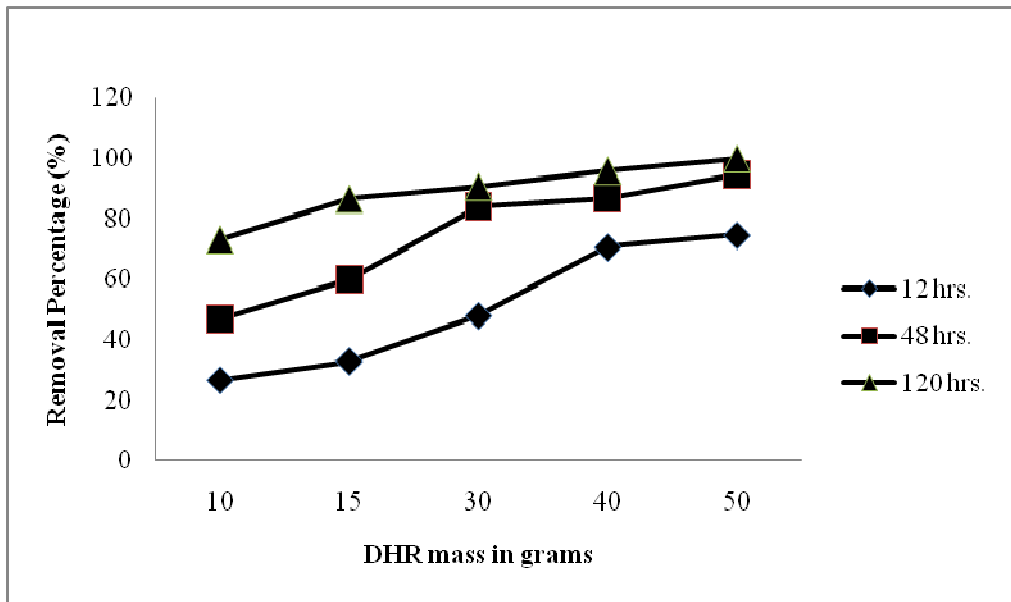


Figure-4

DHR in 40-50 grams successfully removes 75 ppm arsenic up to 99.5 percent which indicates that the removal percentage of arsenic increases with increase in mass of DHR.

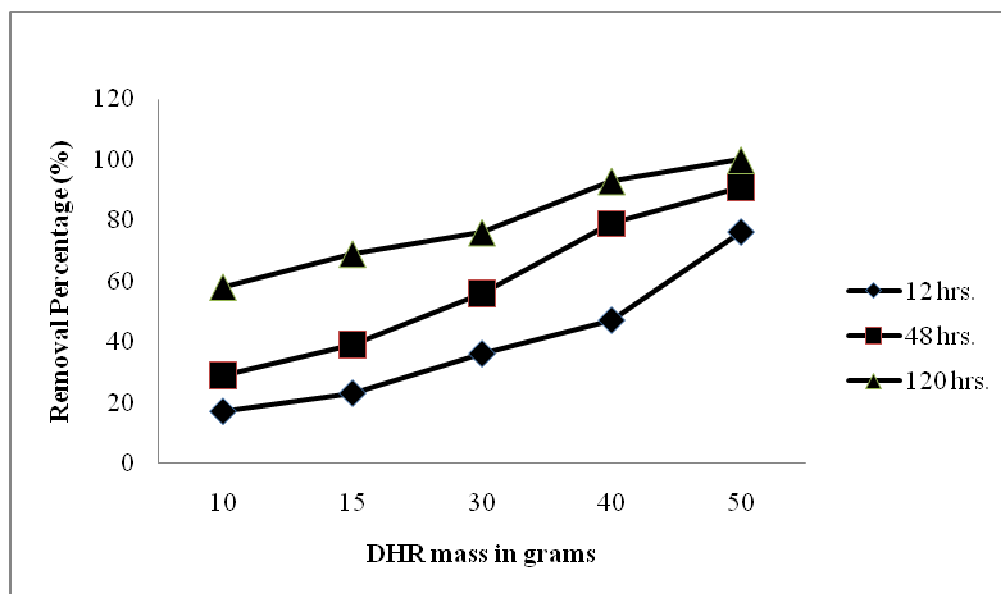


Figure-5

High concentration of arsenic that is 100 ppm can be effectively remove by 50 grams of DHR in 120 hours up to 99.9 percent and 90.99 percent within 48 hours which inferred that removal percentages increases with increase in mass of DHR

Al Ramalli et al.<sup>12</sup> demonstrated that more than 93 percent of arsenite and 95 percent of arsenate were removed from a solution containing 200 ppb or 0.2 ppm within 60 minutes of exposure to a powder produced from dried roots. It is inferred from our experiment that if the mass of DHR is increased up to 10 g, it is possible to remove 1 ppm or 1000 ppb of arsenic within 60 minutes. In this study, DHR was successfully examined at higher concentration of arsenic up to 100 ppm in order to establish that DHR could be used in developing suitable filter for arsenic mitigation at low cost. It is well known that hitherto, high concentration of arsenic in all over the world is noticed up to 1000 ppb or 1 ppm so far and in rare cases it goes beyond 1 ppm.

Water hyacinth is well-known for causing eutrophic condition in water bodies throughout many tropical and sub-tropical parts of the world. Wang, Fuerstenau, and Smith<sup>16</sup> reported that water hyacinth biomass can be produced at a rate of 160 to 1000 kg per hectare per day depending on the nutrient and temperature conditions. In this study, water hyacinth roots exposed to 100000 ppb or 100 ppm (figure 5) removed up to 90.99 percent with only 50 grams. This result supports the experiments demonstrated by Al Ramalli et al.<sup>12</sup> and Govindaswamy, Schupp and Rock<sup>14</sup>. Therefore, to treat 1000 liter of water containing 1ppm or 1000 ppb of arsenic, 10 kg of dried hyacinth roots (DHR) would be required. DHR could be used successfully in developing cheap and sustainable filter. It is also reported by Khan et al.<sup>17</sup> that dried hyacinth root powder could be used to produce cheap filters similar to the simple three-pitcher filtration method. This biomaterial is inexpensive and the raw material is widely available. It is economically, socially and

environmentally sustainable. This DHR technique could be used by the rural masses without the help of any technocrats.

## Conclusion

This study was conducted to determine the efficiency of DHR in removing arsenic. It was revealed that at high concentration of arsenic that is up to 100 ppm, DHR successfully removes arsenic up to 99.9 percent within 120 hours. However the high concentration found in drinking water is up to 1 ppm and in rare cases it goes beyond 1 ppm. Therefore, this experiment concludes that if DHR is used at low concentration of 200 ppb or 0.2 ppm, it could successfully reduce or completely remove As (III) from drinking water. Further, by increasing the mass of DHR it is possible to increase the removal efficiency of As (III) in short span of time and therefore, it could be used in filter as a low cost technique.

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