# Arsenic removal for ceramic water filters

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**ABSTRACT:** *Arsenic in drinking water is a hazard to human health and is a known carcinogen (Mass 1992). Resource Development International – Cambodia (RDIC) has researched, developed, and manufactured simple ceramic water filters (CWF) which have proved to be extremely effective in removing pathogens from water. These filters however, do not remove arsenic from water, which exists in the source water at levels above the World Health Organisation (WHO) guideline of 10µg/L. The aims of this literature based study were to investigate conventional and non-conventional arsenic removal processes, and to discuss the options for applying an arsenic removal technology to the CWFs produced by RDIC. It was found that conventional arsenic removal technologies are difficult to implement in the context of household water treatment in a developing country. This study suggested that non-conventional arsenic removal technologies shall be more effective and that field studies must be undertaken to verify the success of such methods.*

**KEYWORDS:** Ceramic, filter, arsenic, removal, household.

## 1 INTRODUCTION

Over 137 million people suffer from arsenic related problems each year (WHO, 2001). Arsenic is a metalloid, which is a known carcinogen to humans if consumed in small doses, over a long period. The water which is consumed by CWF users exceeds the WHO international guideline of 10 µg/L.

The WHO has identified that the best method for obtaining safe drinking water and reducing the affliction of waterborne diseases in developing countries is household water treatment. Of the various household water treatment technologies, CWFs have proven to be extremely effective in removing disease causing pathogens. Resource Development International – Cambodia (RDIC) has developed and manufactured CWFs which are able to remove 99.99% of pathogens which cause disease. However, this filter is not capable of removing arsenic, and thus options are considered and evaluated to extend the capabilities of these filters.

An independent study (Van Halem, 2006) which evaluated the effectiveness of CWF reported that the filters leached arsenic into water in the first 2-4 weeks of use. It is in the scope of this study to research and provide recommendations to reduce the possibility of excess arsenic being consumed by the water filter user.

Undoubtedly, there is no single solution of removing arsenic from water which is appropriate for all areas affected. There are many variables such as the concentration of arsenic in source water and the socio-economic status of the area which has a direct relation to the most effective and efficient solution. Thus, further research needs to be undertaken, focusing on individual areas which include data gathering, methodology proposal, experimental procedures, results testing and analysis before the implementation of any solution can occur. This study aims to accelerate this process by assessing various arsenic removal technologies and identifying which methods would be more applicable to CWFs.

## 2 ARSENIC REMOVAL TECHNOLOGIES

### 2.1 Conventional

Membrane technologies are a method of arsenic removal which use microscopic pores which allows certain constituents through while rejecting others. Due to the dense nature of the material used, a force is required to assist the movement of molecules through the membrane. An effective method of providing this force is to have a potential difference on either side of the membrane.

The greatest difficulty with applying membrane technologies to CWFs is to provide the pressure required to pass the source water through the dense membrane. Traditionally, this requires power, which is not readily available in rural areas of developing countries. Another disadvantage of membrane technology is the small amount of raw water (10-15%), which passes through the membrane as permeate. This means that more than one membrane needs to be connected in series to ensure higher recovery rates (80-90%) are achieved (Nguyen et al, 2009). This also constitutes to a higher source water requirement, which is not readily available in rural contexts throughout the year.

Although membrane technologies are capable of treating arsenic to excellent standards, conventional methods have a high water and energy cost, as well as a high sensitivity to other contaminants, which endow it unsuitable for the context of CWFs in developing countries.

Adsorption/ion exchange technologies utilises the natural charge of arsenic causing the attraction of arsenic to an added material, which is added to the water. The added material can be of various forms and needs to be regenerated, and, or replaced regularly.

It is the nature of this method to remove only charged ions, which means arsenite, which has a neutral charge, is not removed. Since the source water in developing countries has a high variability, it is difficult to know the charge of the arsenic, and hence whether or not it has been removed. This technology requires the regular regeneration and replacement of the material in order to continue absorbing arsenic. It has also been found that sulfate, which is also present in the source water, is more attracted to the added material than arsenic, making it difficult to monitor at a household level the efficiency of arsenic removal.

The major variance in source water, namely the amount of arsenic and sulfate, combined with the responsibility of regeneration and replacement, which is transferred to the end user, makes these technologies apidly. The coagulant can add a positive force, which reduces the overall negative charge of the arsenic incldifficult to implement with CWFs.

Coagulation/filtration technologies consist of destabilising the contaminant by introducing a coagulant and mixing ruded in water. This allows particles to collide, forming larger particles (Choong et al, 2007). This process is followed by flocculation, where larger particles clump together.

Coagulation and filtration technologies for arsenic removal have been used effectively around the world in both laboratories and in the field. Currently, they operate as stand alone systems, in which chemicals are added to water and stirred, followed by sedimentation and filtration. Further research and experimentation is required to investigate the best coagulant that can be used with CWFs. The application of this method can be adapted into CWFs by adding chemicals to the pot and manually mixing as required. This can be left for natural sedimentation before using the current water filter for microbial filtration. The disadvantage with such technologies is the level of effort required to operate such a system at a household level. This includes the addition of coagulants, mixing as required, and removal of flocs regularly to ensure the arsenic removal mechanisms can work effectively. Field studies were evaluated in a study in Bangladesh (Karim, 2000), which found that the amount of operational effort required was one of the key reasons for rejections of a technolog.

## 2.2 Non-conventional

Based on the different context in which developing countries operate, it is necessary to consider non-conventional methods of arsenic removal. These are new innovative ways which arsenic can be removed with a focus on specific objectives such as reduced cost, sustainable, low energy requirements and using materials that are locally available. The following technologies have been identified to have great potential to remove arsenic from water, and can be combined with the current actions of CWFs:

- 'Plastic bottle' solution (Tongesayi, 2011): this technology involves using pieces of plastic bottles coated with a commonly available amino acid to remove arsenic. At a laboratory scale, this method has proven to effectively reduce the amount of arsenic in drinking water from concentrations of 20 µg/L to 2 µg/L. This technology can easily be implemented with CWFs by adding the amino acid coated plastic into the filter pot. The major benefits of this method are the use of locally available waste products and the simple to use technologies of coating the plastic.
- Idaho National Laboratory scientists have engineered a new Nano-Composite Arsenic Sorbent (N-CAS), which is specifically designed to remove arsenic from water. "N-CAS is a compound that can remove arsenic contamination from drinking water over eight times as effective than any other method to date, for a fraction of the cost" (Mower, 2011). This breakthrough technology uses a special polymer, which is highly porous with an iron oxide to trap arsenic. Due to its small particle like shape, a small amount of the sorbent has a large surface area, making it extremely practical and requiring much less effort that conventional adsorption methods.
- A study (Malik et al, 2009) was conducted to investigate the potential of low cost adsorbents to remove arsenic from water. This technology uses local waste products from agricultural and industrial processes such as rice husks, slag, fly ash and red mud as adsorbents. This modification of the conventional adsorption method reduces the initial and ongoing operational cost and can potentially be implemented with CWF.

These non-conventional methods were found to be much more appropriate than conventional methods for developing countries. The key differences were in the cost and simplicity of the technologies, which would help the acceptance of such methods by communities. Of the non-conventional technologies identified, most were in laboratory testing phase and require further research and development to create a product with which the arsenic removal technology can be developed. The CWF developed by RDIC can be used to deliver the arsenic removal capabilities of these upcoming technologies.

## 3 INITIAL RINSING TO REDUCE ARSENIC

A recent study (Archer et al, 2011) was conducted to address the issue of the significant arsenic leaching from CWFs in the first 2-3 weeks of use. The study investigated the effects of initial rinsing on 50 water filters which were tested between January 2010 and March 2011. This study provided conclusive data on the effectiveness of current practices adopted at a CWF production facility in Guatemala. The following process describes the method which was used to ensure the significant spike in arsenic isn't exposed to the CWF user:

1. A new, unused, and dry CWF that had not been wetted since firing was placed in a bucket that had been rinsed with tap water and dried.
2. The CWF was filled with tap water and allowed to filter for approximately 2 hours.
3. The volume of filtered water was measured, and a sample was collected for arsenic analysis.
4. The CWF was periodically refilled over a 24 hour period, and the volume of filtered water was measured.
5. At the end of the 24 hour period, the CWF was emptied, refilled, and allowed to filter water for approximately 1 hour. The filtered water volume was recorded, and a sample was analysed for arsenic.
6. Step number 5 was repeated 3 more times, so that the total number of samples collected for arsenic analysis was 5 for each CWF evaluated in January, and 10 for the March CWFs. Step 5 was repeated 4 times, so that a total of six arsenic analyses were performed for ten of the CWFs evaluated in March.

The results of this study clearly indicated that initial rinsing using approximately 15 L of water reduced the arsenic concentration from levels of up to 240 µg/L to less than 20 µg/L. It is therefore recommended that RDIC follow a similar process before the distribution of their ceramic water filters.

## 4 CONCLUSIONS

To improve the capacity of CWFs to provide clean and safe water to its users, this research investigated arsenic, its contamination and options which could be explored for suitable arsenic removal from drinking water. This literature based research was aimed at identifying which technologies would be most appropriate to research and develop, so that arsenic removal could also be a function of the CWF. The key findings of this research have been summarised below:

- Harmful amounts of arsenic (up to 240 µg/L) leached from the CWF into the effluent in the first 2-3 weeks of use. This reduces to a significantly lower concentration (approximately 17 µg/L), which is still greater than the WHO guideline of 10 µg/L (Van Halem, 2006).
- The long term effects of consuming water with an arsenic concentration of 17 µg/L has shown to have significant detrimental health effects.
- Rinsing the filters following the method provided is an effective way to ensure the initial spike of arsenic is not exposed to the users of the CWF (Archer et al, 2011).
- It is not appropriate to implement the same conventional technologies that are used in developed countries in developing countries. This is due to large differences in water, economic and social contexts.
- Non-conventional arsenic removal processes have great potential to combine with CWF and increase its ability to remove arsenic.
- Further research and development is required in a particular technology to specifically collaborate with the CWF.

These key findings are important to the development of a specific technology, which can be implemented for the CWFs that have been developed by RDIC. To accelerate the development of a method to remove arsenic from water for CWFs, it is recommended to:

- Identify the key factors and priorities for the design of the arsenic removal technology. This will help focus research and engineering on the most important objectives.
- Explore non-conventional arsenic removal technologies and provide specific data where required to scientists, researches and engineers to assist the development of their technologies.
- Collaborate with laboratory researchers to conduct in-field testing to verify results of laboratory tests and upscale technologies.

The reduction of arsenic from drinking water has numerous benefits and will have significant improvements in the lives of all users.

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