Feasibility Study of the Use of Recycled Crushed Glass to Remove Arsenic from Solution

Sultana Kudrati Khoda[1], Andrew Cundy[1], Marie Harder[1], Imamul Huq[2]

Abstract
Arsenic contamination in ground waters is a worldwide environmental hazard affecting millions of people. A significant number of people in Bangladesh currently suffer from arsenic poisoning. In the present study crushed recycled glass has been used to investigate the applicability of waste glass filtration in the removal of arsenic from contaminated water. Three colors of glass and two different sizes of crushed glass (2-4 mm, and 0.5-1 mm) were examined. Batch experiments were performed using glass which had been prepared by two different processes - imploding and grinding. An Optical Stereo Microscope (OSM) was used to study the surface properties of the different glasses. Preliminary results showed that ground glass of size 0.5-1 mm was the most effective at removing arsenic from solution. Given the promising initial results, further work is aimed at evaluating the practicability of waste glass media for point of use water treatment applications in Bangladesh.

Keywords
Arsenic; waste glass; Bangladesh; water filtration.

1. Introduction
Arsenic (As) is a highly toxic naturally occurring element which is found in the atmosphere, soils, rocks, natural waters and organisms (see review by Thomas, *et. al*., 2007). In Bangladesh millions of people are potentially at risk from consumption of As-bearing groundwater containing arsenic concentrations above the 0.05 mg/L maximum contamination level (MCL) (see review by Smedley and Kinniburgh 2003).

Symptoms of acute As poisoning usually occur within 30 min of ingestion and may result in gastrointestinal discomfort, vomiting, coma, and sometimes death while chronic poisoning can result in anemia, leucopoenia, skin cancer and other internal cancers (Source: http://www.un-igrac.org/publications/301).

Source:
http://www.who.int/bulletin/archives/78(9)1093.pdf

Figure 1. Cancer on foot caused by Arsenic poisoning

[1] Faculty of Science and Engineering, University of Brighton, Lewes Road, Brighton BN2 4GJ, United Kingdom. Corresponding Author: sultanakhoda@yahoo.co.uk

[2] Departments of Soil, Water and Environment, University of Dhaka, Bangladesh.

Numerous technologies have been developed to remove arsenic from water. These technologies include ion-exchange, adsorption, coagulation-filtration, membrane filtration, lime softening, electro dialysis, reverse osmosis, bio-filtration etc (see review in Mohan and Pittman 2007 and references therein). These technologies are frequently expensive and require skilled operation or application at large centralized treatment facilities. The As crisis in Bangladesh however requires point of use, low cost technologies which are easy to operate by rural communities.

1.1 Use of waste glass as a water treatment tool

In recent years, much research has been conducted to identify low-cost and low-technology systems for waste water treatment. Crushed glass is an amorphous (non-crystalline), angular surfaced material and has no grain boundaries, which gives glass more resistance to breakdown through filtration backwashing cycles (Source: www.wrap.org.uk). Echosmarte have produced a universal crushed glass media that is used for pool, industrial, and environmental filtration. The Echosmarte glass provides a direct replacement for sand or zeolite in both freshwater and saltwater pools (Source:www.ecosmarte.com/). Clean Washington Center (CWC) has also investigated crushed glass as a filter medium for wastewater treatment. CWC compared two biological filters using a) state standard C-33 sand as the treatment medium, and b) crushed recycled glass. The results of their research found that glass has much higher infiltration capacity, pore space and cleanliness than sand (Source: http://www.cwc.org/glass/gl972rpt.pdf). Crushed glasses are used in filters for swimming pools, reed-bed waste water filtration, as a flux for bricks, fiberglass insulation and grit blasting (Source: www.wrap.org.uk). Horan and Lowe (2007) trialled the use of recycled glass as a tertiary filtration medium for wastewater treatment. The results indicated that recycled glass provided a 10% reduction in the amount of media required compared to sand.

In Bangladesh, while a number of filter media have been shown to be potentially useful for As remediation, there are still cost and other drawbacks which limit their sustainable implementation. This research examines the applicability of recycled glass as a medium for the removal of arsenic from arsenic contaminated ground waters. Developing this technology could provide an integrated low cost and effective solution to arsenic contamination and would be particularly useful in the case of Bangladesh.

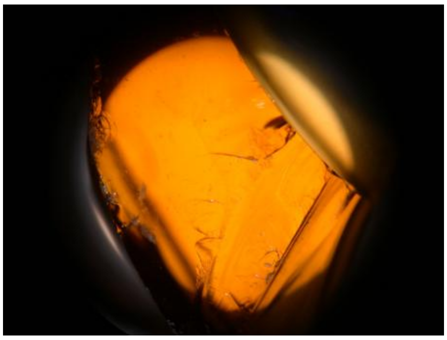
2. Materials and Methods

Recycled glass bottles were collected from local outlets and imploded using a Krystaline GP1 Imploder or ground using a Glen Creston Cross Beater Mill, Model 16-151. The glass granules were sieved using sieves of 4 mm, 2 mm, 1mm and 0.5mm mesh size. The sieved glasses were then separated for subsequent experiments. Arsenic solution was prepared by dissolving As_2O_3 (Arsenic Trioxide) in distilled water and diluted to the necessary test concentration. Batch adsorption experiments were performed in the laboratory of Brighton University using a standard shaker. Samples of supernatant were analyzed using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The physical properties (angularity and roughness) of crushed glass were studied using an Optical Stereo Microscope (OSM).

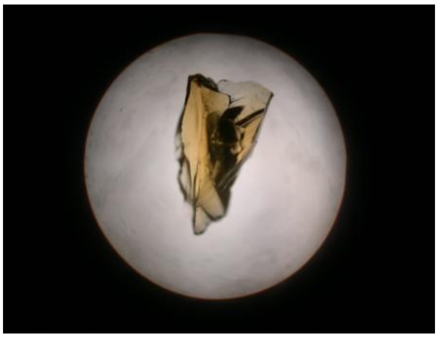
3. Results and discussion

3.1 Study of Physical properties of glass under Optical Stereo Microscopy (OSM)

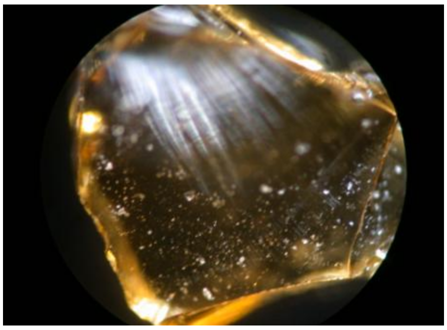
As the glass was size-reduced by two different methods - implosion and grinding- it was assumed that the different preparation processes would contribute some properties to the resulting crushed glass surface. Three colors of recycled crushed glass bottles were prepared (Green, Brown and Clear) and examined under OSM (4X). The images seen under OSM of brown and green glass, along with the bulk material, are shown in Figure 2-3. In all OSM images the glass surface showed some roughness and angular projections, which may increase the active surface area of the particles. There was no significant visual difference however between the surfaces of imploded and ground glass.



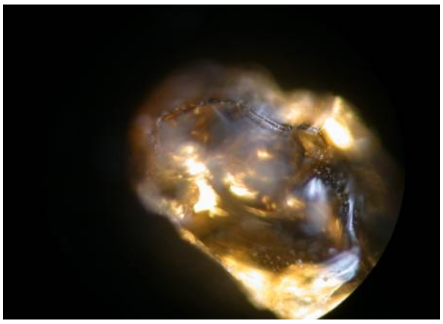
2a. Ground Brown (2-4mm)



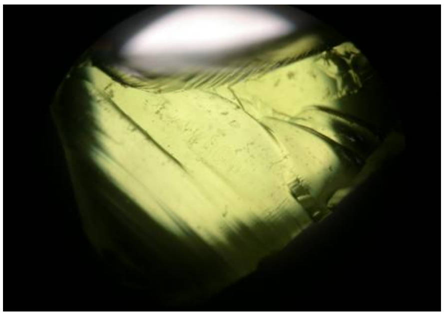
2b. Ground Brown (0.5-1mm)



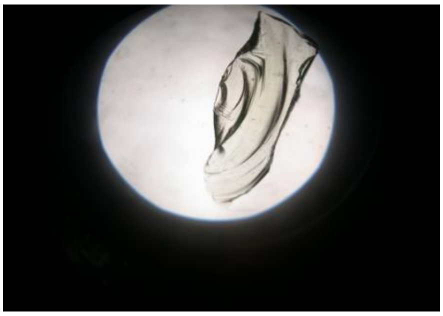
2c. Imploded Brown (2-4mm)



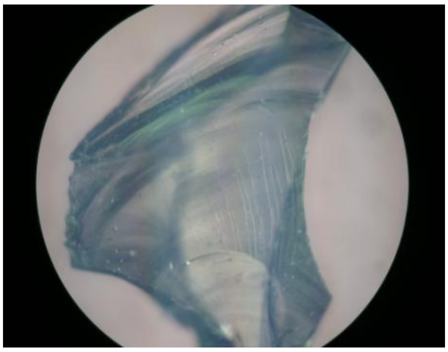
2d. Imploded Brown (0.5-1mm)



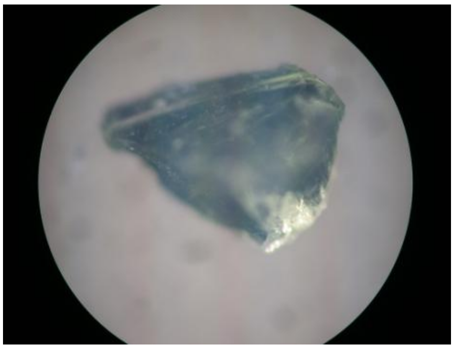
3e. Ground Green (2-4mm)



3f. Ground Green (0.5-1mm)



3g. Imploded Green (2-4mm)



3h. Imploded Green (0.5-1mm)

Figure 2-3. OSM images of size reduced brown and green recycled glass, prepared by grinding and implosion.

3.2 Effect of glass size in Arsenic removal

The feasibility of using glass granules for As adsorption was examined using batch uptake experiments. A preliminary investigation was set up with imploded glass of 2-4mm and 0.5-1 mm glass granule size. The results are presented in figures 4 and 5. 150 ml synthetic arsenic solution (3ppm) was shaken in a 250 ml flask with three colors of 150g imploded glass from each batch. One flask was shaken with 150 ml As solution only as a control with every batch experiment. The shaking was performed at room temperature for 5 hours, after which samples were withdrawn. The residual As in the supernatant was analyzed using ICP-OES and mean values are plotted in figures 4 and 5. No detectable adsorption occurred on glass of 2-4mm size (Figure 4) but some As was removed using glass of 0.5-1mm (Figure 5). Blue imploded glass (0.5-1mm size) removed more arsenic than brown glass of the same size. These results indicate increased adsorption onto smaller glass particle sizes, which is probably a result of their increased surface area.

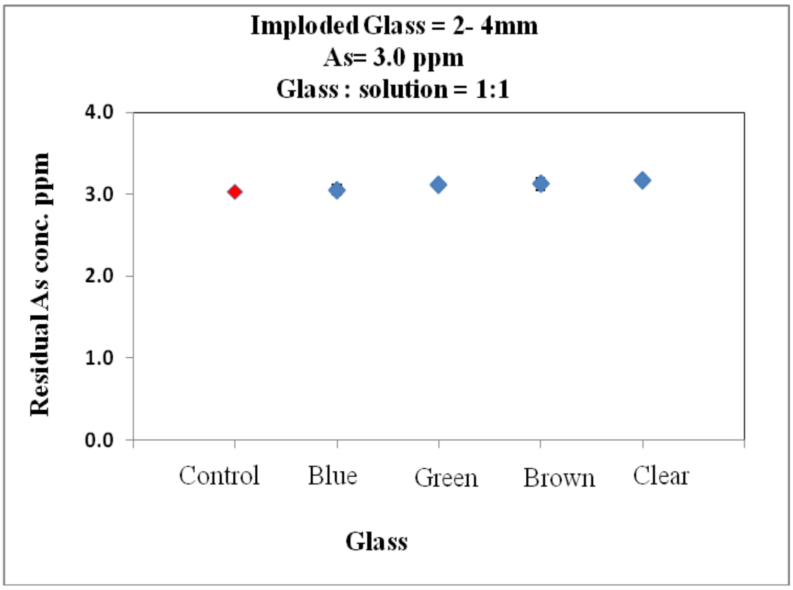


Figure 4. Arsenic removal with different colored imploded glass (2-4mm granule size)

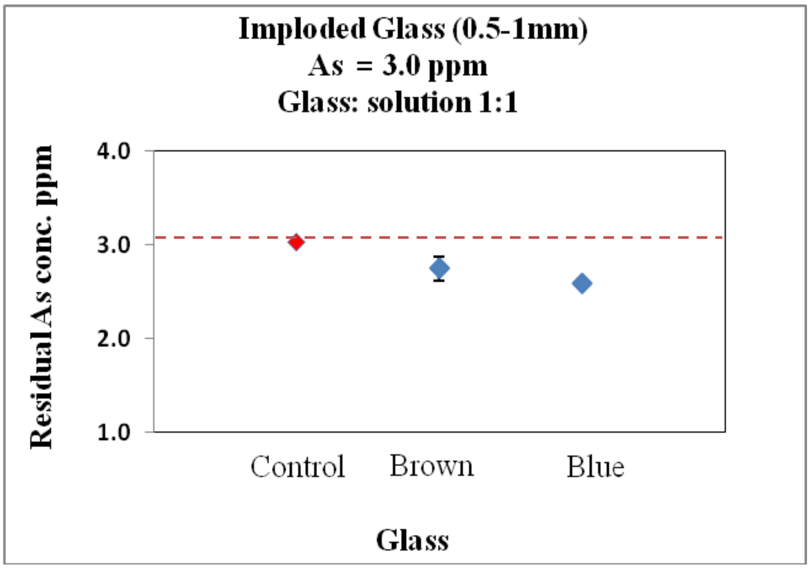


Figure 5. Arsenic removal with different colored imploded glass (0.5-1mm granule size)

To compare the adsorptive properties of imploded glass and ground glass, a batch of shaking experiments were set up with ground glass of 0.5-1mm. Green, Brown and Clear glass was shaken with As solution under the same conditions as previously and analyzed accordingly. The results indicated that clear ground glass performed better in As removal (50%) followed by brown (45%) and green glass (figure 6). The performance of ground vs. imploded glass is plotted in figure 7, and shows better performance of ground brown glass than imploded brown glass of the same particle size.

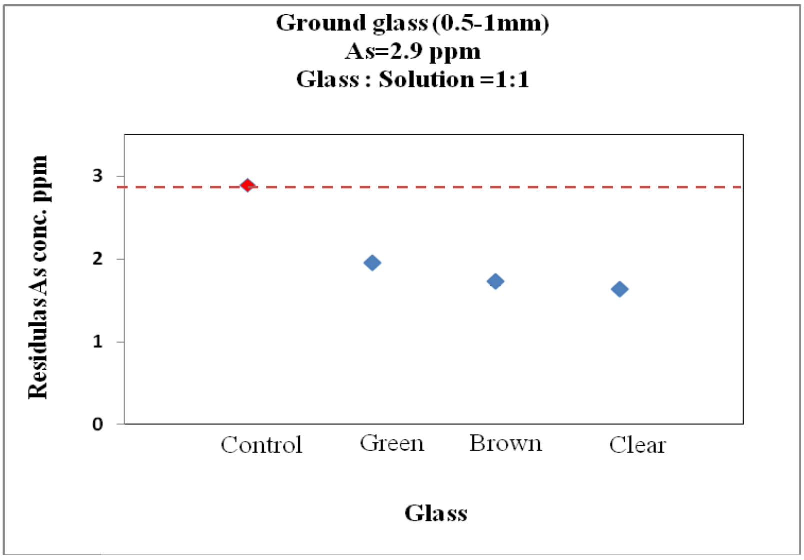


Figure 6. Arsenic removal with different colored ground glass (0.5-1mm granule size)

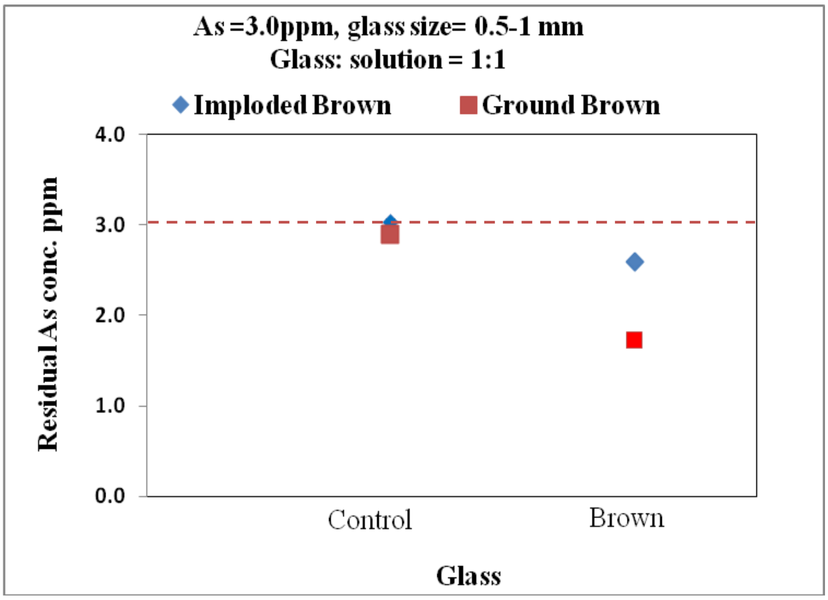


Figure 7: Difference between ground and imploded glass in arsenic removal from solution

The above experiments indicate that the smaller size of glass (0.5-1 mm) shows improved As removal and that ground glass has superior performance over imploded glass.

4. Conclusion:

Although OSM analysis showed some surface angularity on the glass granules, it did not indicate any physical differences between ground and imploded glass which might contribute to differences in adsorptive capacity. Batch experiments showed that glass granules have some potential for arsenic removal, at a smaller particle size of 0.5-1 mm (possibly due to greater surface area of these particles). Further investigation is needed to determine the optimal ratio of glass media and total volume of arsenic solution treated, and optimal particle size (given that smaller particles will show denser packing and lower through-flow rates when used as a filter medium). In ground water in Bangladesh As is present with a number of other metals i.e. Fe, P, Mn, Ni etc., and the concentration of As is usually lower than was used in these experiments. Further study thus requires experiments to be performed under field conditions that will indicate the efficiency of glass in As removal from more commonly found ground water. It is also necessary to determine the As removal efficiency under different flow conditions and configurations, and varying As speciation, to determine if waste glass will be useful at house hold scale for water purification. Such investigations also need to consider the filter design, the size of the filter media and maintenance issues.

5. References

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