# 7
# Conclusion and Scope of Future Work

## 7.1 CONCLUDING REMARKS

The present development of G filters in India is observed as a viable household water filtration technology using the gravity-based ceramic materials [Gupta *et al*., 2018]. The technology has propagated to different parts of India with potter communities showing interest to learn this traditionally aligned technique of ceramic manufacturing [Iqbal, 2017;Banerji, 2016]. With this spread of technology to different parts of India (especially Tamil Nadu, and Bihar) also came the question of the ability of the clay ceramic material (G Filter) to remove specific impurities such as Arsenic asunder from microbial water contamination [Satankar., 2018].

Therefore, developmental research on low-cost materials to enhance the properties of clay ceramic device needs to be undertaken due to this specificity of contaminants at different locations. The thesis proffers an initial study of the association between physical properties, microstructure and mechanical characteristics of the porous clay ceramics (basic G filter material).

Potter traditionally uses long time experience to gain abilities to manufacture ceramics, test its quality in traditional ways. When a potter is requested to select the best artifact from a set of fired clay products, he does use visual appearance and sound as a way to assess the quality of his products. Visual appearance basically refers to the surface color, surface texture and surface roughness. Therefore, this thesis first utilized the surface properties of equal volume fraction composition of G Filter ceramic material to correlate its mechanical strength and other related physical properties.

A family of ceramics with distinct clay and sawdust volume fraction capable of submicron level water contaminant removal have been characterized for its surface properties. A qualitative correlation of surface properties and physical properties is quantified. Fired ceramics were siliceous in nature. Further, presence of fluxing compounds (such as $K_2O$, $Na_2O$ and $Fe_2O_3$) in them contributed to densification of clay ceramics. The clayey soil was characterized by the presence of high amounts of $Na_2O$, $K_2O$, CaO, and MgO in the ceramics.

Efficient filtration characteristics of these ceramics were attributed to the orthogonality of pores. Tomography based investigation revealed large densities of orthogonally orientated pores of sub-micron sizes in samples with 50 percent organic fraction. This result confirmed the sustenance of use of this ceramic material for separation processes during gravity-based water filtration.

The degree of the surface roughness accentuated proportionally with pore fraction. A polynomial decrement in compressive strength as a function of increasing surface roughness of ceramics is observed. These ceramics showcased a linear decrease in $K_{IC}$ with increasing surface roughness. Further, $K_{IC}$ of the ceramics also follows a logarithmic relationship with the organic volume fraction used as a raw material for manufacturing the ceramics.

During one of the workshop for the G Filter, an organization Sehgal Foundation showed interest in transferring the technology for potters in Bihar. Potters from three villages of Samastipur, Bihar questioned whether the G filter is capable to separate arsenic from water? The groundwater aquifers in Bihar are getting alarmingly contaminated with arsenic due to leaching from the rocks [Ghosh, 2007]. This diverted attention to the search for low cost methods to contain arsenic in water using distinct material modifications to the G Filter material. The machine shop which manufactures the G Filter press faced problems in disposing of fine particle of milled or machined Fe [Gupta *et al*., 2018]. Iron is known as an important material that showcased exemplary properties in binding with arsenic in water [Castro *et al.,* 2018; Ngai, 2002]. There is abundance of iron in ore form (hematite in Bhagalpur and Magnetite in Gaya are some of the examples) and processing units in Bihar which could be locally used to solve the arsenic contamination in the region thus proffering local solution to Bihar potters (IMY, 2013).

The sintered iron mixed clay mixtures have been used for efficient water treatment [Ezzatahmadi *et al.*, 2017]. The porous clay ceramic composition (50O or G-filter composition) was modified by a limited addition of Fe to the raw materials. This modified ceramic was named FCC. FCC, a new adsorbent, was developed for arsenic removal from water media. The FCC adsorbent showed several advantages, such as an inexpensive and simple manufacturing process using reutilization of ferrous mill waste and locally available clay and sawdust materials, an ability to remove ~99% arsenic at 6.5±1 pH. The arsenic adsorption was found to be pH-dependent, and exhibited strong adsorption at pH 3-7. The adsorption process followed a pseudo second-order expression. The arsenic rejection from the FCC media reduced with the increasing initial concentration of the solution. The adsorption data fitted well with both the empirical Freundlich and Langmuir isotherm models.Addition of ferrous material removed the E.coli bacteria from effluent with a ~99% efficiency. The strength of the ceramic filtration media increased nearly two fold with the addition of ferrous waste.

The thesis investigated Arsenic removal potential of low-cost materials available in Western Rajasthan. It was observed during the earlier study in Chapter 4 that clay of this region contains high fluxing oxides [Gopal and Bhargava, 198]. Further, this region is internationally known for its limestone mines [Shah., 2017]. Fuhrman *et al.*, (2004) established the Bauxsol technology which uses calcium brine saturated red mud to adsorb arsenic. Therefore, the presence of clay and marble slurry can be jointly used to prepare material similar to those proposed by Fuhrman *et al.*, (2004). Here, the basic 50O ceramic composition used to manufacture filtration ceramics is modified using marble slurry without disturbing the basic volume ratios. Incorporation of marble slurry into the ceramic composition enhanced the rate of arsenic removal from the effluent. The addition of marble into the filter composition has raised the antimicrobial properties of the filters. The marble utilization will reduce the cost of the filter unit, as no colloidal silver coating would be required. The structural integrity of the ceramics was greatly enhanced through the addition of marble.

The implication of this work paves the way for scale-up of the materials investigated and designed here for large scale applications in water treatment [Wei *et al.*, 2011]. Constructed wetland used for water treatment may use such ceramics to filter organic materials as well as separate inorganic contaminants in dissolved forms [Gupta *et al.*, 2015; Singh *et al.*, 2015; Wei *et al.*, 2012].

## 7.2 SUGGESTIONS FOR FUTURE WORK

To extend the work presented in this dissertation, the following possible future directions are suggested:

1. The clay used in this dissertation is the local clayey soil from Western Rajasthan. Future work should investigate the effect of clays from different parts of neighboring states on the filtration efficiencies and mechanical properties of ceramics. The effect of different ratios of region-specific local solid wastes on the contaminant removal should be studied. Future generations of filters may also be made by other processing techniques such as high-pressure compaction or sol-gel processing.

2. The mechanical properties of the filters presented in this dissertation were obtained in the dry condition. However, the future research should investigate the strengths of the porous clay-based ceramics under long-term (≥ 2 years) hydrated conditions. The fatigue and creep effects should also be studied at different levels of saturation and compared to the results obtained from this dissertation.

3. Though the mechanical properties of clay ceramics were improved by the addition of locally available wastes. More efforts should be made to reduce the brittle characteristics of such ceramics by making clay-based composites from a mixture of clay and cement material and/or metals.

4. The applicability of FCC and MCC filters for removal of other heavy metals should be investigated. The effect of ferrous mill waste and marble slurry on the filtration and leaching characteristics of the filters should be elucidated. The water should be tested for the potential (short and long term) effects on human health if any.

5. The batch operations are useful only for the treatment of small quantities of contaminated water. In future, the feasibility of arsenic removal from aqueous solution when operated in column mode should be analyzed.

6. It is recommended that the new material formulations of FCC and MCC developed in this thesis should be transformed to frustum shaped ceramic water filters. The filters thus developed should be experimented on the field to assess its role in the prevention of waterborne diseases [Morris *et al*., 2018, Plappally *et al*., 2011]