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DESIGN AND CONSTRUCTION OF A CLAY CERAMIC FILTER FOR HOUSEHOLD WATER TREATMENT TECHNOLOGY

Fannah Aliyu Kyari, F[1], Alfred N Jones[2] and Falmata Abba Kyari[3]
[1&3]Department of Civil Engineering Technology, Ramat Polytechnic Maiduguri, Bornu State
[2]Department. of Civil and Water Resources Engineering, University of Maiduguri. Nigeria

Abstract: *In some communities' women and school-age children trek long distances to fetch water sometimes of poor quality and most often of limited quantity. The alarming state of safe water deprivation among rural communities in Nigeria is well recognized to be requiring urgent attention. Therefore, this study designed and produced Ceramic Water Filters (CWF) as point-of-use (POU) water treatment technology. The CWFs were produced from locally available combustible materials such as maize husk with clay and grog. The clay sample was evaluated and tested for plasticity, linear shrinkage, firing shrinkage, total shrinkage and water absorption. The results show that the clay was not too plastic to warp or crack as it fell within the limit for linear shrinkage of 12.3 % (<15 %). Combustible material (maize husk) and grog (burnt broken pots) having a moisture content of 2.2 %, do not have significant moisture to affect the final mix. A successful mix of 75 % clay and 25% combustible material and grog at a ratio of (6:1:1) was achieved while another mix ratio of above 25% slumped. A filtering test was out on each of the 650 ℃ and 900 ℃ pots. The pots sintered at 900 ℃ proved to be the most effective in turbidity and microbial contaminant removal.*

Keywords: *Ceramic, Filter Water Technology and Maize Husks*

INTRODUCTION

Ceramic water filters (CWFs) have become instrumental in purifying water, particularly in countries with limited access to safe drinking water, (Komba *et al,* 2022). These filters have been of benefit during natural disasters. As part of the response to flooding in the Dominican Republic in 2003, Oxfam GB distributed CWFs to 7 affected communities (Clasen & Boisson, 2006). CWFs are used in the form of intervention. Reportedly, over 30 filter factories across the globe, examples of such factories can be found in Cambodia, Vietnam, India, Ghana, Nigeria, Kenya, to name a few. Almost all are operating on similar principles and methods (Agbo *et al*, 2015). Thus, manufacturing methods employed must meet local circumstances and locally available materials. WHO, UNESCO and other

NGOs have committed themselves to making sure a greater number of people who live in areas with limited access to potable water benefit from such intervention.

In the literature, CWF has been defined by several authors. For instance, according to Anan (2016), a ceramic Water Filter is a process that makes use of a porous ceramic (fired clay) medium to filter microbes or other contaminants from water. In addition, Sobsey *et al* (2002) define CWF as the process that makes use of a porous ceramic (fired clay) medium to filter microbes or other contaminants from water. Furthermore, a simple bucket-shaped clay vessel is made from a mix (by weight) of local terra-cotta clay and sawdust or other combustibles such as rice husk, where the filters are formed using a press (Pottersforpeace.org).

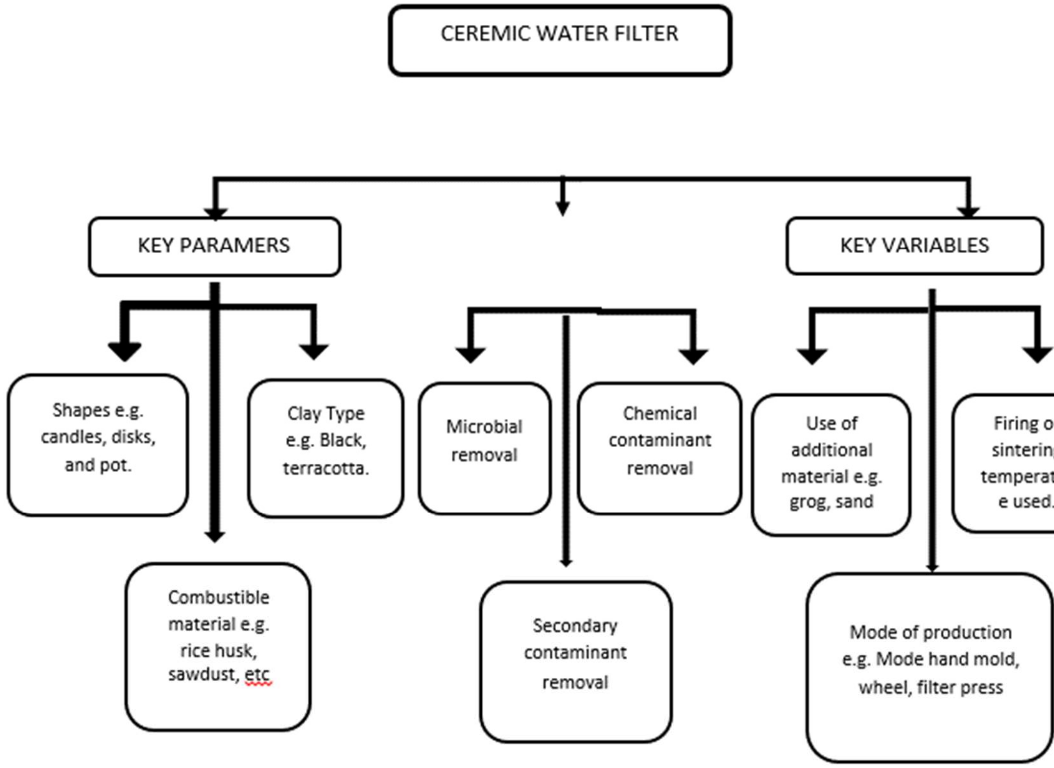
METHODOLOGY AND MATERIALS

Production of Ceramic Water Filter

Several types of both industrially made and locally produced CWFs are currently available in the market and being promoted (Grema *et al*, 2021). Examples of such factories can be found in the Dominican Republic, Guatemala, Colombia, Kenya, Ghana, and Nigeria. Filter production starts with raw materials acquisition evaluation to know their characteristics and behaviour. Plasticity, shrinkage rates (dry, firing & total shrinkage), and the firing temperature of clay (using total shrinkage and per cent porosity) was the recommended test for clay. (Ceramics Manufacturing Group, 2011). There are three main types of filters: disk, candle, and pot filters with many differences to each other. A disk filter consists of a removal CWF sandwiched between two containers. Candle filters consist of one or more candle-shaped ceramic filters and two chambers, while pot filters consist of only one plastic or ceramic receptacle (Aliyu *et al,* 2019). Ceramic water filters are easily assembled. The ceramic pot filter is assembled as one complete unit, unlike that of disk and candle filters. A ceramic pot water filter is the easiest of all because it can be produced locally using local knowledge and local materials (Aliyu *et. al*, 2019).

Clay is the cementing and skeleton element of CWF, therefore, its characteristics and quality affect the quality of the final finished CWF pot (Haiyan et. al, 2020). Factors such as the availability of clay source, its plasticity, shrinkage, porosity, and the leachability of heavy metals are some keys to be considered for clay selection (Ceramic Manufacturing Group, 2011). Details for clay source test, selection and handling can be obtained from The Ceramic Manufacturing Working Group,(2011).

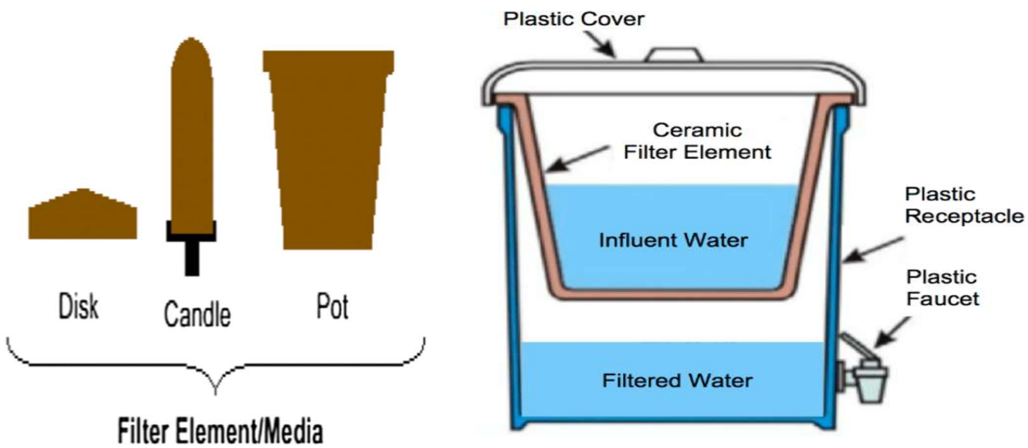
Clay alone cannot form the pores, thus in a study it has been observed that mixing sand and clay gives better porosity (Davies *et al*, 2011). The diameter of pore size and how many pores the CWF has is dependent on the ratio of the burnout material, the greater the proportion of the burnout material the more the CWF to have more pores and larger diameter.



RESULTS AND DISCUSSIONS

Among the criteria for CWFs production include accessibility and availability, it was observed in most literature (Grema *et al* 2021; Perez-Vidal *et al*, 2021; Aliyu, *et al*, 2019) rice husks and sawdust are more frequently used as a burnout material, regardless of the factory the CWFs are made, the procedure and method for the manufacture remain almost the same.

Detailed procedure for the CWF is given by the Ceramic Manufacturing Group, 2011



: Ceramic Water Filter System and Filter Element/Media

(Courtesy: Alemu and Geremew, 2019 &McBean et al, 2018)

Firing Chart for Ceramic Pots

Firing Temperature (°C)	Stages	Events	Firing Time
20 -120	Water Smoking Stage	Pore water remaining due to Atm. Humidity turns to steam. Temperature should be raised slowly to boiling point (100°C) to avoid cracking	2-4Hours depending on the filter wall thickness and humidity
120-350	Decomposition	It is safer to raise the temperature from 120 -350 ones the water smoking stage is complete. Expansion can occur but there is no risk of crack/breakage. At 200 vegetable matter in the clay the breaks.	100 per Hour
350-450	Combustion of BOM	The volatile in the BOM will burnout creating smoke. Controlling temperature at this point is difficult due to the additional temperature created by the BOM which can cause crack.	Depending on the volatile carbon ratio of the BOM.
350-700	Ceramic Change	Clay becomes ceramic. Chemically bond water will leave the filter, water and vapor will escape.	100/Hour to 700
At Around 573	Dunting Stage	Quartz in the clay rearrange itself called the quartz in version, this result in sudden expansion during firing and contraction during cooling causing cracking.	100 per Hour will accommodate the changes
Between 550-575		Both cooling and firing should be gradual at this stage. Firing should be monitored and heat spike should be avoided.	
Around 600	Dull Red Range	Clay particles are sintered together resulting in very slight shrinkage. After 600 there is no	

		risk of filter damage due to temperature variation.	
700-800	Burning-out called Oxidation	Carbon and sulphur in the clay burn-out. It starts at 700 and reaches its peak at 800	
800-870		To ensure this stage is thoroughly completed temperature should be held at this stage temperature should be present otherwise a black core/black iron oxide will remain in the filter walls.	
At 800	Vitrification Stage	Vitrification starts at this stage for most clays i.e when sodium and potassium flux with free silica during which the clay body contracts and welded with glass proving strength.	
At 900		Most of the carbon most have burn-out at this stage. At this stage filter won't change size.	1-3 Hours. This may vary depending on the carbon in the clay and the type of burn-out material.
	Cooling	During cooling the clay contracts at regular rate except during quartz inversion	

Source: Ceramic Manufacturing Group, 2011

Benefits and Limitations of CWF

To understand the function of CWF, it is essential to identify it benefits and limitations. Therefore, the main strengths and weaknesses of CWF are listed in Table 2.3. It is of paramount importance to consider all of the points (in Table 2.3) prior to designing any filter

General Benefits and Limitations of Ceramic Water Filters

Adapted from (Akuemaho *et al*, 2016)

S/N	Benefits	Limitations
1	Ceramic water filters are natural filter media that don't add anything to water or remove healthy minerals while it filter it.	Limited removal of viruses, heavy metals, and pesticides.
2	If designed and used properly can remove up to 99% of indicator organisms and reduce turbidity to below WHO guideline values.	The effective lifespan of the filter is unknown.
3	Take advantage of local materials (sawdust, clay, rice husk, etc.) and existing local knowledge.	Filter maintenance and reliability depend on the user-herein lies many non-technical issues.
4	Simple to use and maintain	Filter quality can vary by region or brand.
5	Relatively cheap to manufacture and produce.	Breakage during distribution or use can be a problem since ceramic filters are often fragile.
6	Proven effectiveness in removing bacteria and protozoa resulting in a reduction of diarrhoea by 60-70%.	It is difficult to maintain consistency (quality control is an issue).
7		Slow filtration ratios (typically ranging between 0.5-4L/H for non-turbid water)

Virus removal remains a challenge; due to its minute size it can easily pass through some pores into the effluent water (Ceramic Manufacturing Working Group, 2011)

CONCLUSION

Ceramic water filters can be categorized according to various key parameters such as shape, type of clay or combustible material used, function(s) for which the filter was designed, as well as key variables, e.g., firing temperature, mode of production, additional materials used can also influence the properties of the filter.

Ceramic water filters have demonstrated immeasurable uses in addressing water-related problems in developing countries in Nigeria. It has substantial economic and social benefits apart from addressing water-related issues as a reliable water filter avenue.

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