Chapter

Manufacturing a Ceramic Water Filter Press for Use in Nigeria

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Abstract

A significant proportion of Nigerian households lack access to improved and safe drinking water supplies. This has resulted in high incidences of diarrhoeal-related deaths in the country, especially among young children. Several studies have shown that point-of-use water treatment options such as ceramic filtration are effective in reducing the occurrence of water-borne diseases; however, its use in Nigeria has been significantly low. There is a need to build entrepreneurial capacity among local potters and potteries to drive the scale up of ceramic water filter production across the nation in order to create demand for the filters, seeing that huge potential for its sales abounds. However, the high cost of acquisition of the ceramic water filter press, which is the most essential equipment in the production of the water filters, is a major limitation to the scale up of ceramic water filter production in the country. The goal of the study was to manufacture a ceramic water filter press, by adapting an existing design, using locally sourced materials and manpower, to achieve lower cost. The resulting filter press cost approximately $1000, proving the viability and cost efficiency of the local manufacture of ceramic water filter presses in Nigeria.

Keywords: ceramic water filters, filter press design, household water treatment, manufacturing, Nigeria

1. Introduction

Water is most essential for sustaining life and enhancing the quality of life, but it can transmit diseases. When adequate access to clean, safe water is lacking, incidences of waterborne diseases become rampant [1, 2]. Unsafe drinking water is one of the major causes of diarrhoeal diseases, which are known to be a leading cause of mortality globally especially in children aged five and below [3]. The 2015 WHO/UNICEF Joint Monitoring Programme (JMP) update reports that 69% of Nigeria's population use improved drinking water sources, which are presumed to be safe [4]. However, due to non-functionality, unsustainability, and lack of proper maintenance of most improved water sources, they are often of non-satisfactory quality [1, 5]. Therefore, the reality is that a lesser percentage of Nigerians than presented actually have access to safe drinking water. Furthermore, even where there is access to safe water, because most of these water sources are not located on premises or piped directly into the houses, there is the risk of contamination in the process of collection, transportation, and storage, thereby leaving the initially safe water unsafe at the point of consumption [2, 6]. It is therefore essential to ensure water is safe for drinking at the point of consumption. Point-of-use water treatment implies any water treatment system that purifies water at the point of consumption and it involves effective treatment and safe storage. It has been identified as an important public health intervention which serves to reduce the faecal-oral transmission of diarrhoeal diseases [7].

Recent studies on point-of-use household water treatment systems, suggest that ceramic water filters are the most sustainable and lowest cost options for water purification in developing countries [8]. The essential raw materials, basically clay and combustible bio-wastes, required to make this technology available and accessible in Nigeria are locally available in large quantities. However, there is a wide knowledge gap in the exploration and development of the technology of manufacturing ceramic water filters in the country. As much as there exists a need for household water treatment method such as the ceramic water filters, not many manufacturers engage in the production of ceramic filters. The springing forth of many peri-urban settlements in many Nigerian cities like Akure leaves the nation fraught with an urgent need to explore innovative solutions to put an end in sight to the prevalent water-related health challenges.

While household water treatment and safe storage systems have been considered as effective, low-cost alternatives and a reliable means of achieving safe water at point of use, having shown to significantly reduce diarrhoeal prevalence [6, 7, 9]; very few potters engage in the making of the ceramic water filters. In Nigeria, there are two factories that currently produce ceramic water filters, although production is fraught with many challenges such as understanding the technology behind the working of the filtration system. The major challenge however, to the establishment of a ceramic water filter production facility is the acquisition of the filter press machine.

The ceramic filter press machine is the priority piece of equipment required in the production process of ceramic water filters [10, 11]. The filter press machine, which is mostly hydraulic operated, is used to form the filters into its shape by the application of pressure to the clay mixture in-between a set of moulds. This method of forming is most suitable for making ceramic water filters because a non-plastic material mix is desired and therefore can be only formed successfully by semi-dry pressing techniques. This all-important equipment for the production of ceramic water filters is quite expensive to purchase, with very high shipping and importation costs and tariffs.

Personal communications in a pilot study with operators of ceramic water filter factories in Nigeria reveals that the cost of acquisition of a piece of filter press machine with its corresponding aluminium moulds ranged from $3000 to $3500 (USD). This is also confirmed by other researchers [10], stating that the cost of this press is estimated at over $3000 and therefore is considered a fundamental limiting factor to production of ceramic water filters to meet demands in areas where it is needed. While the Resource Development International - Cambodia (RDIC) approximated the cost at $2300, excluding shipping and handling costs [12]. This is too high an investment cost for a start-up ceramic/pottery business to bear considering the economic conditions in the country. Therefore the only feasible option to the making of ceramic water filters in Nigeria, to improve access to safe drinking water at the point-of-use, is to resort to the design and fabrication of a filter press machine using locally available materials.

The Potters Without borders (PWB) is one of the organizations that have carried out research on ceramic water filters and design of hydraulic filter press machine [10].

The PWB filter press machine design was adopted for this study, whose objective was to design and fabricate a hydraulic filter press unit using locally sourced materials with a view to promote the affordability and availability of this technology for the manufacture of ceramic water filters, consequently increasing access to safe drinking water in Nigeria.

2. Previous works on ceramic water filter press design

At its inception by Fernando Mazariegos, the ceramic pot water filter was shaped by hand on the potters' wheel. But in the 1980s, the Central American Institute of Industrial Research and Technology (ICAITI) introduced the use of hydraulic presses in the shaping of ceramic water filters resulting in more efficient ceramic water filter production and performance [10]. However, other literature [13] reports that the first press and the first set of moulds were developed to standardize the shape of the ceramic water filter (see **Figure 1**).

While the Potters Without Borders (PWB) press design is the most commonly used, other attempts have been made to explore different press designs to improve the workings and efficiency of the presses in the production of ceramic water filters and to meet the specific socio-economic needs of varying localities. The PWB filter press design operates with a 20-ton hydraulic jack and a hand lever for lifting and lowering the H-slide to which the male mould is attached. It produces the flat-bottomed ceramic water filters, using a set of aluminium moulds.

A recent study [14] on a multi-component water treatment, reported that they created a simple plastic press mould to shape the ceramic component of their water filtration system with the aim to improve efficiency and allow for easy replication. (see **Figure 2**).

Another study [10] designed a low-cost filter press with the goal of less than $200 in cost, less manpower requirement and shorter manufacture time. Their work concentrated on designing and prototyping a low-cost, filter press using

Figure 1.
Ron Rivera working on the first ceramic filter press [13].

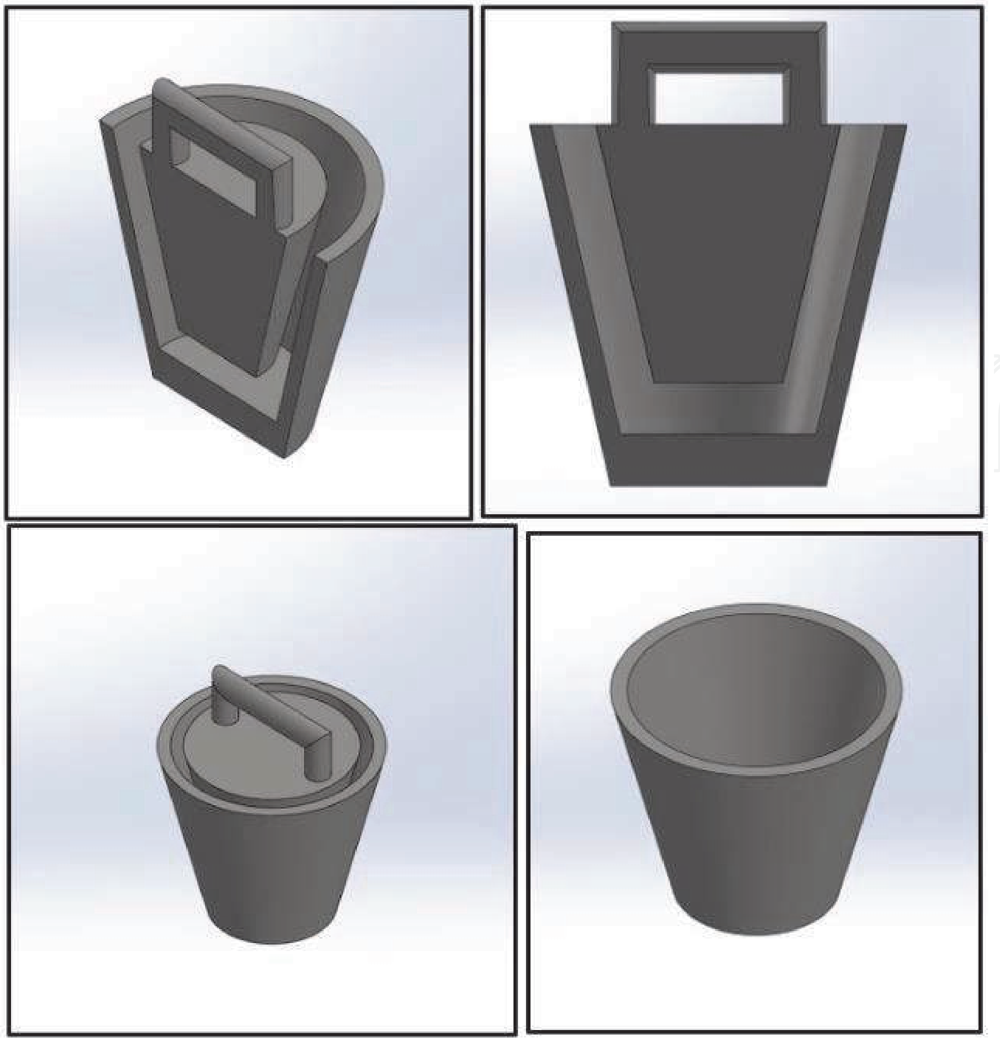


Figure 2.
Modelled diagram of the press mould and product [14].

locally-sourced materials. They attempted to achieve a lower filter formation pressure as a key requirement to reducing the cost, considering that using a 2-ton car jack instead of the 20-ton hydraulic jack used by PWB would greatly reduce cost. The press was designed for the round-bottom filters and adopted an inverted design in which the car jack was mounted to the frame headstock and the female mould was suspended on the underside of the jack elevator while the male mould sat on the base [10]. For the moulds, they improvised with the use of inexpensive aluminium bowls (see **Figure 3**).

A group of researchers [11] in their study described the use of a 30-ton manually operated hydraulic press developed and manufactured by MEC Ltd., India. The press makes use of a screw system to lower and lift the male mould which is attached to the die screw connector plate, while the female mould sits on a base plate which is attached to the hydraulic jack (see **Figure 4**). This press produces the flat-bottomed, frustum shaped filters of 23 cm height with 25.5 cm base diameter.

The Ceramic Filter Manufacturing Manual [15] developed by Pure Home Water, reported two types of press designs for shaping ceramic water filters; the Potters for Peace (PfP) press and the Mani press. The PfP press design as described in the text is a portable press that uses a 20-ton hydraulic jack with a removable female mould while the male mould is attached to a moveable shaft on the frame. It operates a crankshaft system which allows for the lifting and lowering of the shaft that holds

Figure 3.
A low-cost filter press prototype [10].

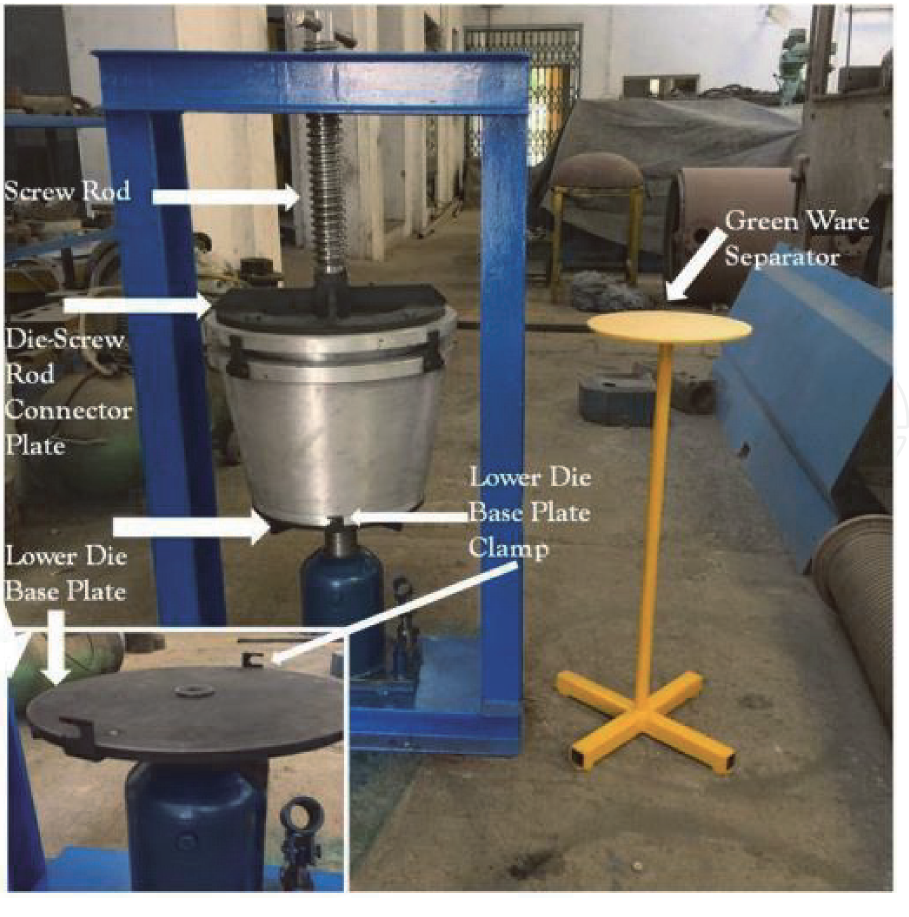


Figure 4.
Filter press operated with screw and hydraulic system [11].

Figure 5.
Operating the portable PfP press with crank system [15].

the male mould. The hydraulic jack is positioned above the male mould after it has been lowered into the female mould which contains the clay (see **Figure 5**).

The Mani press has both its male and female moulds attached; while the male mould is attached to an extendable table, the female mould is attached to the press

Figure 6.
The Mani press [15].

frame. It uses an 8-ton hydraulic jack and works with a pulley system that operates with a hand crank for lifting and lowering the female mould (see **Figure 6**).

The mould in the PfP press described in the Ceramic Filter Manufacturing Manual [15] is made of nylon while the material used to make the Mani press moulds was not stated in their report but can be made of concrete or metal. It, however, concluded that the Mani press delivered greater advantage and ease in use than the portable PfP press. The RDIC manual [12] describes a fully automated hydraulic system-operated ceramic water filter press. It uses a set of metal moulds, most likely aluminium. The male mould is attached to the frame headstock while the female mould is attached to a moveable shaft which is controlled by the hydraulic system which works with the use of an electric motor (see **Figure 7**). This action controls the press and the release of the clay filter mix in between the moulds.

The features of the various designs of ceramic water filter presses reviewed in the course of this study are presented in **Table 1**.

After a review of the designs of ceramic water filter presses as discussed hitherto, the PWB ceramic water filter press design was adopted based on the following considerations:

A non-electrically operated press was desired to overcome the challenge of poor electricity supply within the country;

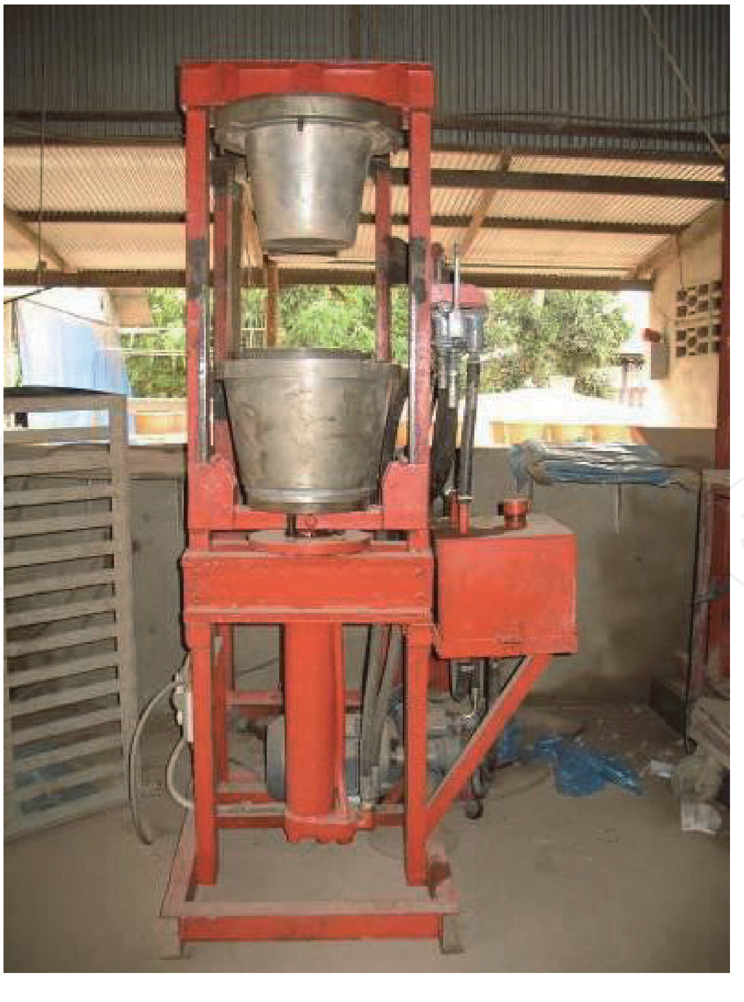


Figure 7.
An electric motor driven hydraulic press [12].

Ref. no	Description	Type of filters	Position of moulds	Mould material	Mould moving mechanism	Mode of operation
14	Hand press mould	Ceramic filter component	—	Plastic	—	Hand/ manual
10	Low-cost filter press	Round bottom	Inverted; female above	Aluminium bowls	—	2-ton hydraulic car jack
11	MEC India manufactured press	Flat bottom	Upright; male above	—	Hand-operated screw system	30-ton hydraulic jack
15	PfP portable press	Flat bottom	Upright; removable female mould positioned below	Nylon	Hand-operated crank system	20-ton hydraulic jack
15	Mani press	Round bottom	Inverted; male attached to extendable surface	—	Crank-operated pulley system	8-ton hydraulic jack
12	RDI-C	Flat bottom	Upright; male above	Metal	—	Automated hydraulic system
10	PWB	Flat bottom	Upright; male above	Aluminium	Hand-operated lever	20-ton hydraulic jack

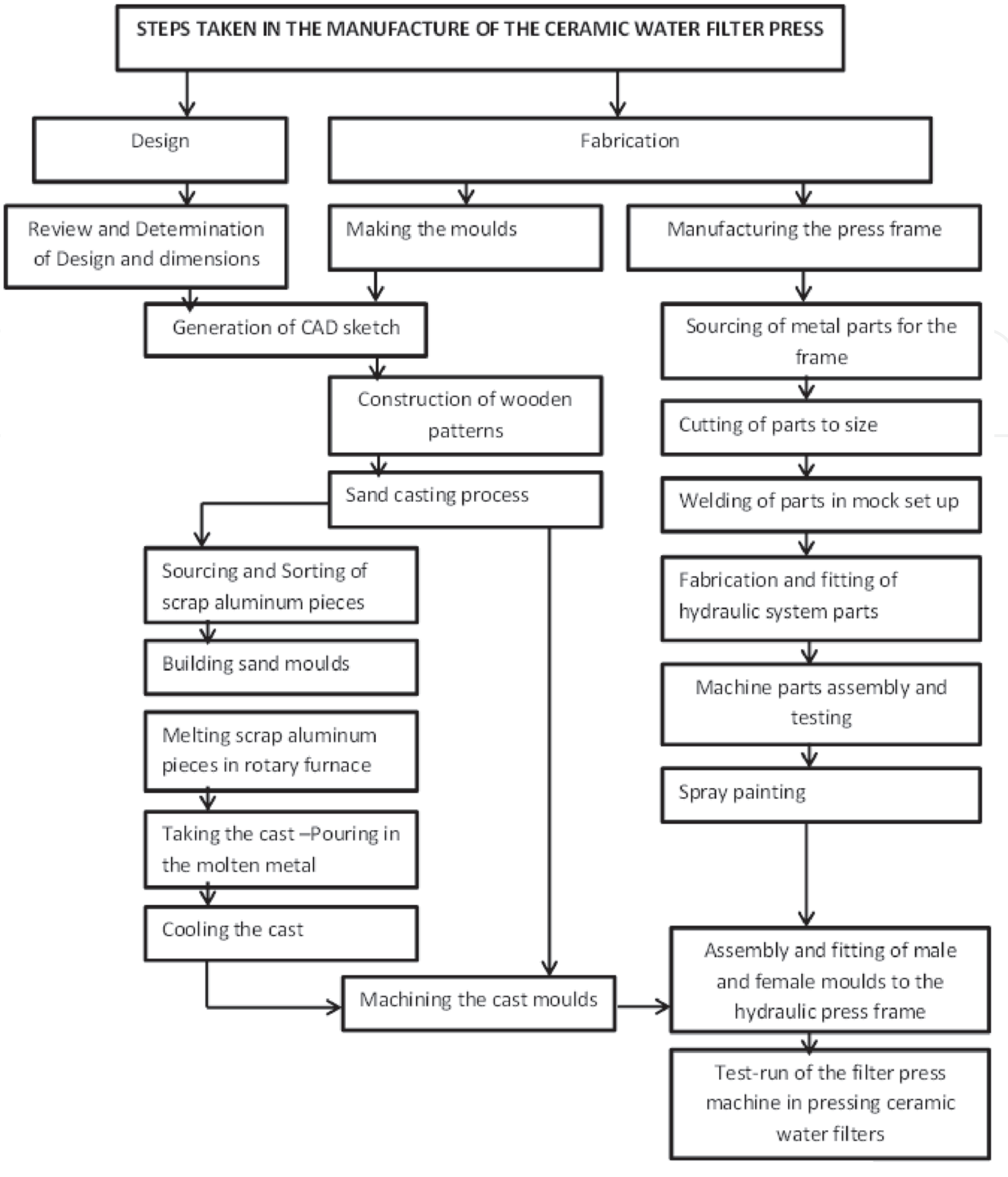
Table 1.
Features of the various types of ceramic water filter presses reviewed in this study.

The use of a fully manual system was also not desirable because it will increase the time taken to press one filter; therefore a hydraulic press mechanism was desired;

A lever was preferred for the lowering and lifting of the moulds, to the crank (as in the portable PfP press [15]) and the screw (as in [11]) because it makes the filter pressing more cumbersome and time consuming;

The moulds were preferred fitted to the press frame to overcome the challenge of misalignment of moulds, possible in removable moulds, and as well, the inconvenience and health hazard of lifting heavy moulds in each process of filter pressing (as in the portable PfP press [15]).

Based on these specific requirements, the Potters Without Borders (PWB) ceramic water filter press design was adapted for manufacture in Akure, Nigeria. The PWB ceramic water filter press is said to have several benefits with respect to design and operation. Its high-strength (20-ton) design allows the pressing of flat-bottom filters [10] while creating stability and preventing deformation in the shaped filters. The flat-bottom filters are said to provide more surface area and therefore higher flow rates [10]. Some of the adjustments made to the PWB filter press design, included the replacement of the hydraulic car jack with a locally fabricated industrial hydraulic jack, as well as the design and manufacture of the press mould to fit locally available wide-rimmed plastic containers to meet the water needs in larger households.



Flow chart of steps taken in fabricating the ceramic water filter press.

3. Fabricating the hydraulic press machine

It became expedient to fabricate a hydraulic press machine to facilitate the shaping of the ceramic water filters by the press cast method. This is the most suitable method of forming the ceramic filters because the mix is highly non-plastic and hence cannot withstand other ceramic forming techniques besides slip casting which is not very feasible at the desired dimensions of ceramic water filters.

For this study to ensure the economic feasibility, sustainability and hence the scalability of the manufacture of the ceramic water filter press in Nigeria, it was important to set a cost limit for fabricating the press; and this was set at 350000 naira (approximately $1000). This was done considering the issue of low access to capital for start-ups, which is common in the country. This study, however, intends to encourage local potters to venture into the production of ceramic water filters by alleviating some of the cost-related challenges of setting up a filter production unit.

All the materials and manpower used in fabricating this press were sourced from within the country. The hydraulic press machine typically consists of two parts; the moulds and the frame which holds the moulds and the hydraulic component. The procedures engaged in the making of both parts are discussed further.

3.1 Making of the filter moulds

The mould for the filter press machine was designed and made using aluminium as material, which was shaped using the sand casting method. The processes involved in the making of the filter mould include; generating a CAD drawing (see **Figure 8**), detailing the dimensions of the moulds; and the making of a wooden mould patterns (see **Figures 9** and **10**) from which sand moulds were derived.

The mould design was generated during the course of the study using dimensions which were estimated by the researcher to produce a ceramic water filter that would fit into commonly available wide-rimmed large plastic containers. The size of the container was used as mark up for the determination of the dimensions of the moulds. The core and drag mould components were designed to give a pressed ceramic filter product of 30 mm thickness all round; this is to accommodate the high shrinkage possible in most plastic ball clays available for use in South West Nigeria; as well as to allow for longer contact time with silver for the inactivation of pathogens in water and greater possibility of trapping the pathogens as they travel through the filter walls. With this design sketch, a wooden pattern made of cut out pieces of 2-inch plywood held together with resin bond, was derived. The pattern is highly essential to the process because the sand moulds which was used for casting the metal form is taken from it. So it is important to ensure correctness of dimensions and form in the wooden pattern.

The process of making of the sand moulds included filling up firmly, a square-shaped wooden frame in which the wooden pattern has been placed with fine sand (see **Figure 11**); after which the pattern is taken out and the sand is smoothened out

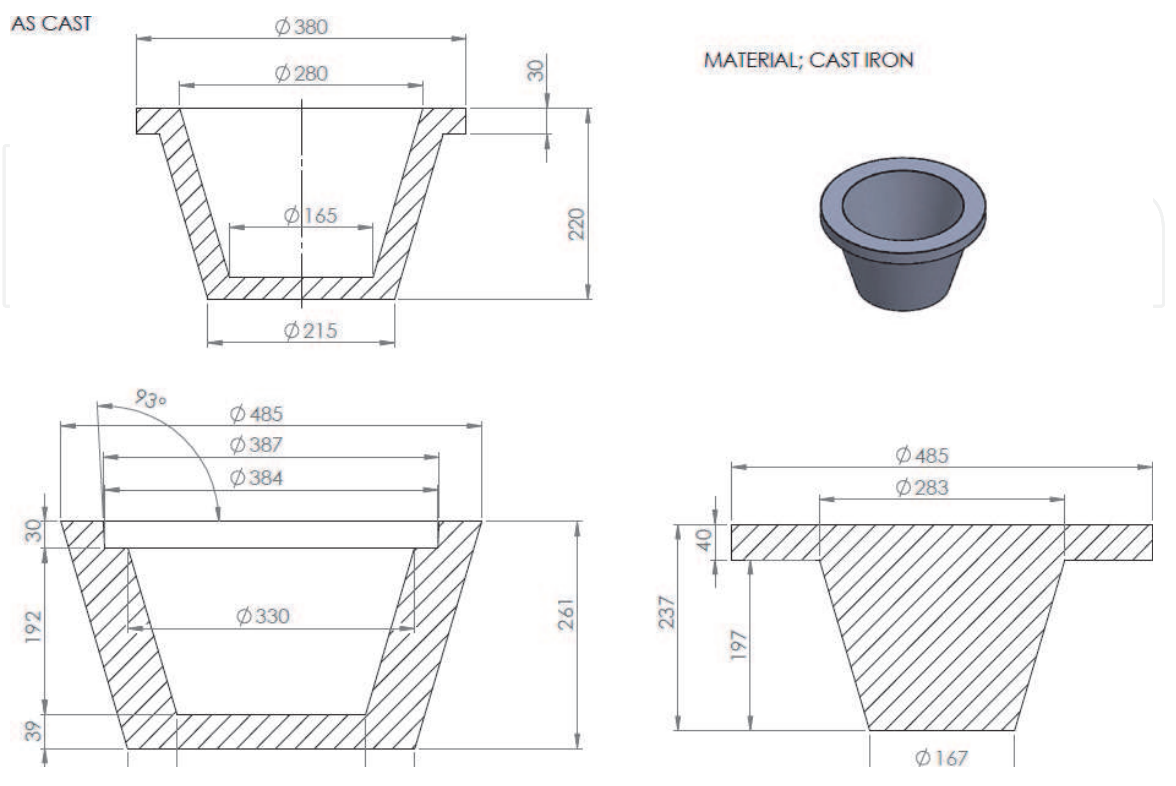


Figure 8.
CAD drawing for moulds (material: Aluminium).

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Figure 9.
Wooden patterns for the mould.

Figure 10.
Top view of wooden patterns for the mould.

using a metal spoon (see **Figures 12–14**). The metal cast was then taken from the prepared sand mould.

Pieces of waste aluminium collected from the local scrap market were charged into the rotary furnace and melted (see **Figure 15**) at temperatures between 600 and 700°C. The crucible bearing the molten aluminium was removed from the

Figure 11.
Filling the frame with sand.

Figure 12.
Pattern taken out.

furnace using a pair of furnace tongs (see **Figure 16**) and the crucible holding the molten metal was set in a 2-man carrier rod (see **Figure 17**).

It is important to remove dross and check for unmolten particles of other metals before casting (see **Figure 18**). The molten metal is then poured into the sand moulds by means of crucible tongs and carrier rod (see **Figures 19** and **20**).

In the process of pouring in the molten material, it is important to poke at it using a metal rod to aid the removal of any air bubbles that may have been trapped in while pouring (see **Figure 21**). The metal cast is afterwards left to cool for about 24 hours before it is removed from the mould (see **Figure 22**). The surface finish of the cast aluminium mould is mostly dull, lacks lustre and sometimes presents tiny holes as seen in **Figure 23**. Polishing the metal is therefore important to give a more usable finish to the cast aluminium moulds (see **Figure 24**).

The last phase in the making of the mould was the machining and polishing of the cast. Aluminium was the material used to make the moulds in this study. This is because aluminium is a non-rust metal and it is more affordable than stainless steel and can easily be machined because it is a relatively soft metal. Aluminium is also a very available material in most scrap markets across the country, and hence easy to access for this purpose. The machining or polishing of the moulds was carried out using a horizontal lathe machine in a privately-owned engineering workshop.

Figure 13.
Smoothening the sand mould.

Figure 14.
Finished sand mould.

Figure 15.
Process of melting the scrap aluminium in a rotary furnace.

Figure 16.
Removing molten aluminium from the furnace using a pair of tongs.

Figure 17.
Crucible set in the carrier rod in readiness for casting.

Figure 18.
Stoking the molten metal to remove dross and other particles.

Figure 19.
Pouring in the molten metal into the sand mould using furnace tongs.

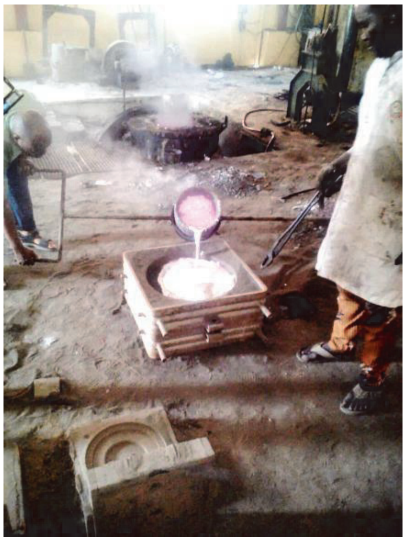

Figure 20.
Casting process using the crucible carrier.

Figure 21.
Poking the poured-in metal to remove trapped air.

Figure 22.
Cooling.

Figure 23.
Cast aluminium moulds.

Figure 24.
Polished aluminium mould.

3.2 Making of the hydraulic press frame

The frame of the hydraulic press machine was made from cast iron and steel parts. The design for the frame was adapted from the Potters Without borders (PWB) ceramic water filter press design (see **Figure 25**). The PWB filter press design incorporates the use of a removable car jack as its hydraulic mechanism. The design for this study has incorporated a hydraulic controller system which is comprised of a box, an industrial jack to drive the pressing mechanism which is expected to be more durable than the car jack over time and continued use; and a pressure gauge to measure the pressure applied in the pressing of each filter to enhance consistency in production.

The metal parts for the frame were sourced from Akure and Ibadan in Southwest Nigeria. Cast iron was the major material from which the parts of the frame were made. Some parts were also of made of steel. The long metal parts were cut into dimensions (see **Figures 26** and **27**) and holes were drilled through them to enable assembly of the frame using nuts and bolts. Bolting was preferred to welding in the assembly of the machine parts, to allow room for adjustments and for easy movement and transportation of the machine. The cutting and welding of the frame

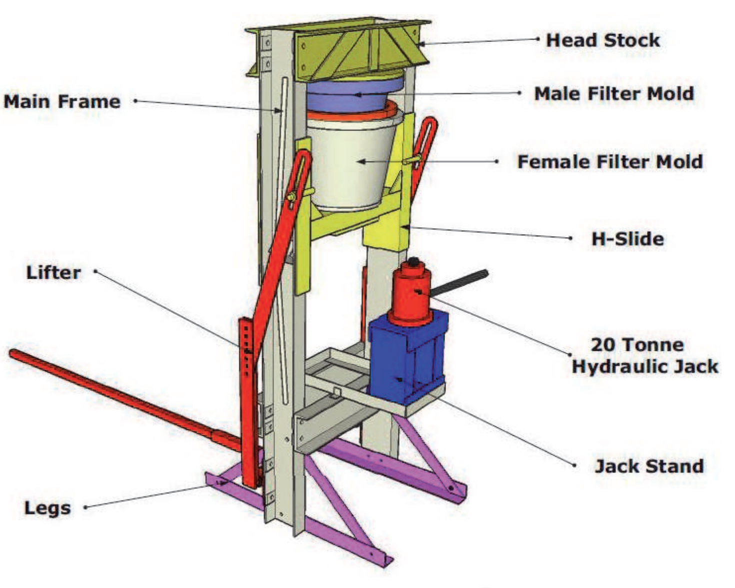

Figure 25.
PWB design of press machine [10].

Figure 26.
Cut out metal parts for the frame.

Figure 27.
Metal parts of frame in mock assembly.

Figure 28.
Press frame with moulds mounted.

Figure 29.
Installation of the lever mechanism.

Figure 30.
Testing the installed lever and jack.

Figure 31.
Press with hydraulic system installed.

Figure 32.
Finished ceramic water filter press.

was followed by the mounting of the moulds. The male component of the mould was bolted onto a metal plate which is welded to the headstock of the frame, and the female component was fitted via bolting onto the moveable H-slide (see **Figure 28**). The lever system which is used to control the lifting of the H-slide bearing the female mould during pressing and release of the moulds, was subsequently fixed in place (see **Figure 29**) and test run to assess the mould alignment (see **Figure 30**). The hydraulic jack was thereafter installed and tested in operation with the lever as shown in **Figure 31**. Finally, the hydraulic control box was installed and connected to the jack and the entire frame was sprayed with paint to improve its aesthetic and prevent rusting (see **Figure 32**). The making of the frame and the hydraulic control box, as well as the assembly of the moulds was done at Danzaki Engineering Services, a privately-owned mechanical engineering workshop in Akure, Nigeria.

4. Results and discussion

The outcome of the study showed the local availability of the required skills and material resources to locally manufacture a ceramic water filter hydraulic press machine in Nigeria. The total cost of the local production of the press though slightly above the set target, is approximated at $1000 USD and is about one-thirds of the cost of acquiring a press of similar specifications of foreign origin without the attending shipping and clearing costs.

The manufactured ceramic water filter press was effective in the shaping of ceramic water filters as indicated in the evenness in form and thickness of the filters pressed during a test run of the filter press (see **Figure 33**).

The technical specifications of the ceramic water filters produced from the manufactured filter press are outlined as having an inner height of 15 cm and inner diameter of 28.5 cm; with an estimated volume capacity of 12 L. This is specified to fit into a 30-L capacity bucket with a rim diameter of 30 cm. Shrinkage allowance of 10% was estimated and factored into the design to ensure the resulting filters fit onto the desired bucket.

However, there were a few limitations to the study as outlined thus: At the size required for the set of moulds, it was difficult to find a lathe machine of a size that could hold the cast moulds for machining. Therefore, alternative materials may be explored besides aluminium, especially such materials as would not require

Figure 33.
Freshly pressed ceramic water filter using the fabricated press.

machining/polishing. Also, there were issues surrounding the dimensions presented in the CAD sketch as generated by a draughtsman, this resulted in error in the moulds cast. This was, however, corrected by altering the dimensions of the mould during the process of machining in order to achieve even thickness around the product; and this action reduced the size of the mould and hence the resulting filter is shorter than other filters available.

5. Conclusions

This book chapter documents the procedure and results obtained in a study carried out to explore the local manufacturing of a ceramic filter press in order to prove the viability and cost efficiency of producing it locally as compared with the cost of acquiring the imported presses. This is in a view to encourage the set-up of more ceramic water filter producing factories in Nigeria, thereby bringing closer home the technology that would make clean, safe water more accessible and available to communities and households across the country.

The study indicates that ceramic water filter presses with hydraulic components as well as its corresponding set of moulds can be successfully and inexpensively manufactured in Nigeria, using all materials and skills sourced locally from within the country.

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Conflict of interest

We would like to declare that there is no conflict of interest.

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