Development, Optimisation and Commercial Production of Locally-Sourced Ceramic Water Filters for Sustainable Potable Water Supply in Nigeria

Executive Summary

Access to safe drinking water in Nigeria remains among the lowest globally, with millions exposed daily to waterborne diseases such as cholera and typhoid due to contaminated sources. Large-scale infrastructural interventions have proven costly and unsustainable, highlighting the urgent need for affordable, community-based water treatment solutions.

This project aims to build on successful preliminary research, in which prototype ceramic pot filters (CPFs) were developed, tested, published, and patented. Evaluations in the Neke and Ikem communities of Isi-Uzo Local Government Area, Enugu State, Nigeria, where residents rely solely on the Ebonyi River, confirmed the filters' effectiveness in improving water quality.

The next phase will be to standardise production processes and establish a commercially viable manufacturing model using locally fabricated insulated refractory kilns (built with indigenous clays), large ceramic membrane containers for faster filtration rates, and production with hydraulic press machines to ensure uniformity and durability of products. Together, these innovations will enable cost-effective, scalable production of CPFs for widespread adoption

1.1 Background of the Study

One of the United Nations Sustainable Development Goals (SDG 6) is to ensure universal access to water and sanitation by 2030. However, this goal remains far from realization in many low- and middle-income countries. Globally, unsafe water, sanitation, and hygiene are responsible for an estimated 6–10% of the disease burden and cause between 1.8–2.2 million deaths annually—88% of which are preventable. The UNESCO 2021 World Water Development Report highlights that approximately 829,000 people die each year from diarrheal diseases linked to unsafe drinking water, sanitation, and hygiene, including nearly 300,000 children under five years of age, representing 5.3% of all deaths in this age group (Kristanti et al., 2022; WHO, 2023).

The World Health Organisation further reports that over 2.6 billion people globally lack access to safe water, contributing to about 2.2 million deaths each year, 1.4 million of which are children. In Nigeria, waterborne diseases remain a major public health challenge (WHO, 2023). Despite efforts by government and non-governmental actors, the majority of the population still lacks access to potable water and must depend on unsafe sources for their daily needs. Many households resort to any available water within their community, regardless of quality, compounded by limited knowledge on water treatment and safe storage practices (UNICEF/WHO, 2023: Agbo *et al*., 2025).

The situation in Isi-Uzo Local Government Area of Enugu State, Nigeria, epitomises this crisis. Isi-Uzo, an agrarian area located on the undulating lowlands of the state's north-eastern flank, comprises five major communities: Mbu, Neke, Umualor, Ikem, and Eha-Amufu. The primary water sources in these communities are the Amanyi and Ebenyi rivers, which serve as the only means of drinking and domestic water supply. These rivers become highly turbid during the rainy season, increasing health risks. Sachet water, widely consumed in other parts of the country, is largely inaccessible in Isi-Uzo due to poor road infrastructure that prevents tanker and supply vehicles from reaching the area. Consequently, residents face acute water insecurity, high exposure to waterborne diseases, and escalating public health concerns.

This background underscores the urgency of developing affordable, community-based, and scientifically proven water treatment technologies, such as ceramic pot filters, to bridge the gap in access to safe water in vulnerable Nigerian communities.

1.2 Statement of the Problem

The supply of safe, adequate, and aesthetically acceptable drinking water remains one of the most pressing challenges in Nigeria, particularly in rural communities. Potable water is indispensable for human health, yet millions of rural dwellers continue to rely on untreated and unsafe sources, exposing themselves to preventable diseases. Despite numerous interventions, access to safe water and sanitation in Nigeria is among the lowest globally, with drinking water being the primary source of exposure to microbial pathogens and chemical contaminants.

Conventional water treatment methods, such as chlorination and large-scale filtration, are not affordable or sustainable for many rural households, most of whom live below the poverty line. Moreover, chlorination is often associated with issues of taste, acceptability, and potential by-products, further limiting its adoption. Large-scale infrastructure projects such as dams, treatment facilities, and piped-water networks have equally failed to deliver lasting solutions, constrained by high costs, poor maintenance, and limited reach into rural areas.

situation has created a persistent public health crisis, with rural households forced to depend on contaminated surface waters, thereby increasing their vulnerability to diarrheal diseases, cholera, typhoid, and other waterborne illnesses. There is, therefore, an urgent need for a low-cost, efficient, and user-friendly water purification technology that can be adopted at the household and community levels. Ceramic water filters, produced from locally available clay, diatomite, and agricultural by-products such as sawdust, offer a viable solution. They are affordable, environmentally friendly, and durable, with an average lifespan of 2–3 years.

However, despite their proven potential, ceramic pot filters remain underdeveloped and underutilised in Nigeria due to the absence of standardised production processes, limited commercialisation, and inadequate dissemination at the community level. This gap necessitates focused research and commercialisation efforts to transform ceramic filters into a scalable, sustainable, and widely accessible water treatment option capable of improving drinking water quality and reducing the burden of waterborne diseases in vulnerable populations.

1.3 Objectives of the Study

This project aims to standardise, commercialise, and scale up the production of ceramic pot filters (CPFs) as an affordable, community-based water treatment solution in Enugu State and beyond. The specific objectives are to:

I. Conduct physicochemical and mineralogical analyses of available clay deposits around Enugu State to determine their suitability for ceramic pot filter production.
II. Standardize and optimize the production of CPFs using locally available clay minerals, diatomite, and sawdust.
III. Develop a commercially viable manufacturing model through the design and fabrication of metallic moulds integrated with hydraulic pressing technology for improved efficiency and product uniformity.
IV. Design and construct insulated refractory kilns capable of firing up to 50 CPFs per batch to support scalable, low-cost production.
V. Enhance filter performance by improving flow rate, durability, and microbial and chemical contaminant removal efficiency.

VI. Undertake systematic water quality analyses of untreated and treated water samples, assessing microbial load, pH, total dissolved solids (TDS), total suspended solids (TSS), turbidity, heavy metals, cations, anions, and alkalinity.

VII. Expand community access to potable water through the establishment of a ceramic cottage industry and the training of local potters within selected rural communities in Enugu State, Nigeria.

VIII. Implement community outreach programmes in vulnerable areas with deplorable water conditions to raise awareness, build capacity, and promote adoption of CPFs.

This project seeks to standardize, optimize, and scale the production of ceramic pot filters (CPFs) as an affordable water treatment solution in Enugu State and beyond. It will involve characterizing local clay deposits, improving filter design and performance, and developing cost-effective manufacturing processes including hydraulic pressing and refractory kilns. Water quality analyses will assess microbial, chemical, and physical parameters to validate efficiency. The project also aims to commercialize CPFs through cottage industries, train local potters, and implement community outreach to expand access to potable water, enhance public health, and promote sustainable adoption.

2.1 Research Methodology

This study will adopt an experimental and analytical research design to develop and standardize ceramic pot filters (CPFs) produced from locally sourced clay minerals, diatomite, and sawdust wastes. The methodology will involve material optimization, filter fabrication, characterization, and performance evaluation.

2.2 **Raw Material Characterization**

Clay deposits from Enugu State and supplementary raw materials (diatomite and sawdust) will be collected and prepared for analysis. The following characterisations will be conducted:

- Physicochemical and mineralogical composition using X-Ray Fluorescence (XRF) spectrophotometry and X-Ray Diffraction (XRD).
- Particle size distribution and blending ratios to identify suitable formulations for CPF production.

2.3 Optimisation of Filter Body Mixtures

Different proportions of clay, diatomite, and sawdust will be blended and processed. Test specimens will be fabricated and subjected to the following physical property evaluations:

- Modulus of rupture (MOR)
- Water absorption capacity
- Apparent porosity
- Apparent density

The optimum mixture will be identified based on mechanical strength and permeability criteria.

2.4 Fabrication of Ceramic Pot Filters

The solid casing method will be employed for CPF fabrication. Hydraulic pressing technology will be integrated for consistency in shape and porosity. The green filters will be fired in an insulated refractory kiln at temperatures ranging between 850°C and 1200°C to determine the most effective firing range for strength and filtration performance.

2.5 Performance Evaluation of CPFs

The fabricated filters will undergo systematic testing to assess their suitability for household water treatment:

- Flow rate determination for efficiency in household applications.
- Morphological analysis of the best-performing filters using a Scanning Electron Microscope (SEM).
- Durability testing under simulated household conditions to establish lifespan.

2.6 Water Quality Analyses

Raw water samples will be collected from rivers, streams, wells, and boreholes in target communities (e.g., Neke and Ikem in Isi-Uzo LGA). Both untreated and treated water will be subjected to chemical and microbial analyses, including:

- Chemical parameters: pH, hardness, alkalinity, turbidity, total dissolved solids (TDS), and total suspended solids (TSS).
- Microbiological parameters: total coliforms and *Escherichia coli (E. coli)*.

- Heavy metals and ions: where relevant, using atomic absorption spectroscopy or equivalent techniques.

2.7 Data Analysis and Standardisation

The data obtained will be statistically analyzed to establish correlations between material composition, firing temperature, and filter performance. Based on these results, a standardized production protocol will be developed for scaling up CPF manufacturing through a commercially viable cottage industry model.

3.1 Work Plan

Objective	Key Activities	Expected Outputs	Timeline
I. Physicochemical and mineralogical analyses of Enugu clay deposits	- Collect clay samples from identified deposits- Conduct XRF, XRD, SEM, and other analyses- Assess physicochemical suitability	Report on mineralogical and physicochemical properties of clays in Enugu	Months 1–3
II. 2 Standardize and optimize ceramic filter production	- Experiment with clay–diatomite–sawdust ratios- Test firing temperatures- Evaluate filter porosity, strength, and microbial removal	Optimized CPF formulation with reproducible quality	Months 2–6
III. Develop a commercially viable manufacturing model	- Design and fabricate metallic moulds- Integrate with hydraulic press technology- Pilot test moulded filters	Metallic mould + hydraulic press system for uniform filter production	Months 4–8
IV. Develop insulated refractory kilns	- Source refractory materials- Construct prototype kiln- Test batch firing (50 CPFs)	Operational refractory kiln with capacity of 50 CPFs per batch	Months 6–9

Objective	Key Activities	Expected Outputs	Timeline
V. Enhance filter performance	- Conduct flow rate tests- Assess durability under household use- Microbial/chemical removal efficiency testing	Improved CPF performance with higher flow rate and safety standards	Months 7–12
VI. Conduct systematic water analyses	- Collect untreated and treated water samples- Perform microbial and chemical analyses (pH, TDS, TSS, turbidity, heavy metals, ions)- Compare results against WHO standards	Comprehensive dataset on CPF water treatment performance	Months 8–14
VII. Expand community access via cottage industry	- Identify and engage local potters- Establish ceramic cottage industry- Train artisans and community members in CPF production	Operational cottage industry with trained local workforce	Months 12–18
VIII. Implement community outreach	- Develop outreach materials- Conduct sensitization campaigns- Engage health workers and NGOs in deployment	Increased community awareness and adoption of CPFs in target areas	Months 16–24

4.1 Expected Outcomes

The successful implementation of this project will deliver the following outcomes:

I. **Standardized Production Process**: A validated and optimized protocol for producing ceramic pot filters (CPFs) using locally available clay minerals, diatomite, and sawdust wastes, ensuring quality, reproducibility, and compliance with WHO drinking water standards.

II. **Functional Prototypes with Proven Efficacy**: High-performance CPFs with demonstrated ability to significantly reduce microbial and chemical contaminants (e.g., *E. coli*, coliforms, heavy metals, turbidity, and suspended solids) while improving flow rate, durability, and water acceptability.

III. **Commercially Viable Manufacturing Model**: Development of a scalable production system supported by metallic moulds, hydraulic pressing technology, and insulated refractory kilns capable of firing up to 50 filters per batch.

IV. **Improved Public Health and Water Security**: Provision of safe, affordable, and sustainable household water treatment solutions in vulnerable rural communities, thereby reducing the burden of waterborne diseases such as cholera, typhoid, and diarrheal infections.

V. **Capacity Building and Local Empowerment**: Establishment of a cottage ceramic industry and training of at least 20 local potters and artisans, creating opportunities for technology transfer, youth employment, and women's participation in water innovation.

VI. **Knowledge Dissemination and Advocacy**: Publication of research findings in Scopus-indexed journals, as well as workshops, symposiums, and community outreach programmes that promote awareness, adoption, and policy support for ceramic water filters.

VII. **Sustainability and Scale-Up Potential**: A sustainable pathway for large-scale production and commercialization of CPFs across Nigeria, with potential extension to other African countries facing similar water challenges

5.1 Track Record / Preliminary Results

The project team has a strong track record in the design, development, and evaluation of Ceramic Pot Filters (CPFs) and other low-cost water treatment technologies. Over the past decade, significant milestones have been achieved, demonstrating both technical feasibility and innovation potential.

I. Prototype Development

A functional prototype of ceramic pot filters has been successfully fabricated and tested under laboratory and field conditions. The results confirmed the filters' effectiveness in improving household water quality, thereby establishing proof of concept for large-scale development.

II. **Patent**

Our innovation has been recognized with a national patent:

- **Agbo, S.C., Ogbebe, P.O., & Ekpunobi, U.E. (2022).** *Ceramics Pot Water Filters.* Patent No: NG/P/2022/565. Trade Marks, Patents & Designs Registry, Federal Ministry of Industry, Trade & Investment, Abuja, Nigeria.

This patent protects the design and production process of the CPF prototype, underscoring novelty and commercialization potential.

III. **Publications and Scholarly Contributions**

The team has published extensively in reputable journals and conference proceedings, thereby contributing to global scientific knowledge on ceramic water filters and water quality management:

1. **Agbo, S.C., & Tsague, C.F. (2025).** Strategic Management of Wastewater from Natural Rubber Processing Industries. In *Strategic Management of Wastewater from Intensive Rural Industries* (pp. 191–212). Springer Nature Switzerland.

2. **Agbo, S.C., Ekpunobi, E.U., Onu, C.C., & Akpomie, K.G. (2015).** Development of Ceramic Filter Candle from Nsu (Kaolinite Clay) for Household Water Treatment. *International Journal of Multidisciplinary Sciences and Engineering*, 6(10), 18–23.

3. **Ekpunobi, E.U., Agbo, S.C., & Ajiwe, V.I.E. (2019).** Evaluation of the Mixtures of Clay, Diatomite, and Sawdust for Production of Ceramic Pot Filters for Water Treatment Interventions Using Locally Sourced Materials. *Journal of Environmental Chemical Engineering (Elsevier)*, 7(1), 2213–3437. DOI: https://doi.org/10.1016/j.jece.2018.11.036.

4. **Ekpunobi, U.E., Aboloma, E.J., & Agbo, S.C. (2020).** Production of Silver-Coated Ceramic Filter Candle Using Locally Sourced Materials for Household Water Treatment. *Journal of Chemical Society of Nigeria*, 45(1), 79–85.

5. **Alum, O.L., Akpomie, K.G., Ofomatah, A.C., Chukwuemeka-Okorie, H.O., Ani, J.U., Agbo, S.C., et al. (2023).** Assessment of Pollution Status of River Ajali in Enugu State Using Water Quality Index. *IOP Conf. Ser.: Earth and Environmental Science*, 1178, 012024. DOI: 10.1088/1755-1315/1178/1/012024.

6. **Agbo, S.C., & Ekpunobi, U.E. (2014).** Investigation of Nsu Clay for the Production of Candle Filters for Rural Water Treatment. Paper presented at *13th Annual Nigerian Materials Congress (NIMACON-2014)*, Lagos, Nigeria.

5.2 Highlights of Preliminary Results

- Prototype developed and validated for household water purification.
- Patent secured (*Ceramic Pot Water Filters*, NG/P/2022/565).
- Five peer-reviewed journal articles published in high-impact outlets (Elsevier, Springer, etc.).
- One international conference presentation delivered.

6. Composition of the Research Team

1. Dr Agbo, Sunday Chukwuemeka

- Institute: Projects Development Institute (PRODA), Enugu

- Designation: Principal Research Officer
- Area of Specialisation: Materials and Water Chemistry
- Highest Qualification: Ph.D., Inorganic Chemistry
- Role in Project: Principal Investigator

2. Dr. Ogbobe, Peter Okwudiri Chukwu

- Institute: Projects Development Institute (PRODA), Enugu
- Designation: Director General
- Area of Specialisation: Electrohydraulics Simulation and Testing Systems
- Highest Qualification: Ph.D., Mechatronics Engineering
- Role in Project: Research Partner (Technology Systems Integration)

3. Onu, Caius Chukwudi

- Institute: Projects Development Institute (PRODA), Enugu
- Designation: Principal Research Officer
- Area of Specialisation: Ceramics Design and Fabrication
- Highest Qualification: MFA, Ceramics
- Role in Project: Research Partner (Ceramic Design & Production)

4. Ogbuzuru, Stephen Ejike

- Institute: National Board for Technology Incubation (NBTI)
- Designation: Chief Scientific Officer
- Area of Specialisation: Food and Water Microbiology
- Highest Qualification: B.Sc., Microbiology
- Role in Project: Research Partner (Microbial Testing & Quality Assurance)

5. Okereke, Okam Chinwe

- Institute: Projects Development Institute (PRODA), Enugu
- Designation: Chief Technologist
- Area of Specialisation: Ceramics Modelling
- Highest Qualification: PGD, Fine Arts (Ceramics)
- Role in Project: Research Partner (Ceramic Modelling & Prototyping)

7. Budget Summary

S/No	Name	Description	Amount (₦)
A	Personnel Costs / Allowances	Allowances for the Principal Investigator and the Research Team Members (2 years)	8,000,000
B	Equipment		
	Digital Water Test Kits	Exact 20 Digital Water Testers (10 sets)	2,000,000
	TDS Meter	HM Digital TDS Meter	500,000
	pH Meter	Apera Instrument pH Tester	350,000
	Conductivity Meter	HM Digital EC-3 Handheld Conductivity Tester with casing	500,000
	Combined Water Testers	HI-98594 Multiparameter Meter with Bluetooth Connectivity	10,000,000

	COD Meter	Benchtop COD Meter (COD-100B)	2,500,000
	Dissolved Oxygen Meter	Bench-top DO-B400F	1,500,000
	Laptop	HP Spectre 13-X360 Convertible, i7, 32GB RAM	2,000,000
	Hydraulic Press Construction	With metallic moulds	10,000,000
	Generating Set	SUMEC Firman SPG 3000 E2, 2.8 kW	500,000
	Test Kiln	Laboratory test kiln	5,000,000
	Brick Kiln	Construction of a brick kiln (30 cubic ft)	6,000,000
C	Materials		
	Kaolin Clay	100 bags	700,000
	Montmorillonite Clay	36 tonnes	3,000,000
	Sodium Hypochlorite	60 liters	300,000
	Colloidal Silver	1,500 mL	1,000,000
	Calcium Hypochlorite	20 kg	100,000
	Silver Nitrate (Sigma)	3 kg	2,500,000
	Pot Filter Containers	200 pieces (16 L plastic with cover)	600,000
	Stainless Steel Receptacles	100 pieces (filter chambers)	3,000,000

	Plastic / Stainless Taps	400 pieces	300,000
	Burnt-out Materials	200 bags (Gmelina cellulose)	1,000,000
	Production Tools	Turning tools, kidney shape tools, scrapers, boards, spatulas, knives	3,000,000
D	Water Analysis	Comprehensive analysis of raw and treated water (flow rate, microbial counts, turbidity, TDS, TSS, alkalinity, pH, heavy metals, biofilm, colour) to ASTM and SON standards	3,000,000
E	Dissemination of Results		
E.1	Workshops & Seminars	For two (2) research members, water-related research	2000,000
E.2	Publications	Two (2) Scopus-indexed journal publications	1,600,000
E.3	Research & Development Movement	Travel for four (5) research team	3000,000

		members related to project activities	
E.4	Community Outreach	Workshops and symposiums in Enugu communities (distribution of 100 water filter pots at Umuegwu, Neke – Isi-Uzo LGA)	3,000,000
F	Contingency (5%)	For unforeseen expenses	3,847,500
TOTAL			76,950,000

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