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Potable Water Filtrater For Household Use

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ABSTRACT: *Water Treatment is very important due to dissolved and solid impurities that are contained in water. The study investigated the efficiency of a multi-layer filtration system for the treatment of raw water from Ezu-River, Anambra State, Nigeria. The filtration system was constructed using gravel, sand and activated carbon arranged in layers. Using a sterile bottle, sample collected from the Ezu-River at 0.3meters depth for treatment using the set-up and treated samples were collected at 0, 10, 30, 60, and 90 minutes intervals. The filtrates were analysed for Lead (Pb), Mercury (Hg), Total coliform, pH, Turbidity and Colour. The results showed significant reductions in all contaminants with lead decreasing from 0.382mg/l to 0.042mg/l for sample 1 and 0.376mg/l to 0.039mg/l for sample 2, mercury from 0.265mg/l to 0.034mg/l and 0.258mg/l to 0.028mg/l for samples 1 and 2 respectively. Total coliform and turbidity achieved about 92% removal efficiency. The pH improved from 6.4 to 7.1 for both samples, moving closer to neutral. Conclusively, multi-layer/media filtration is effective in improving water quality from Ezu-River although disinfection would be required to ensure full microbial safety.*

Key words: *Contaminant, Ezu-River, Filtration, Multi-media,Water.*

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I. INTRODUCTION

Generally speaking, water is very essential for life existence, but a good quality and quantity of water is critical for health, development and sustainability. Beyond drinking, clean water is vital for sanitation, agriculture, food preparation, healthcare and industrial activities. Access to adequate and potable water remains a fundamental requirement for humans. According to the World Health Organisation (2022) approximately 2 billion people worldwide currently rely on contaminated surface or groundwater sources for domestic purposes. It is therefore crucial that the United Nations captured the availability and sustainable management of water and sanitation for all by 2030 as Sustainable Development Goal 6 (United Nations, 2015).

In developing countries, there is much dependence on untreated surface water sources due to constraint of inadequate public water supply infrastructure and poverty (Okonkwo and Uzochukwu, 2020). Other factors responsible for this situation include over population (Khan, Khan, Ahmed, Faroqi, Dhingra, et al 2019; Nwankwo and Nwaiwu 2025), urbanization, industrialization, deforestation, agriculture and climate change (Gurung, Dahl and Jansson, 2016; Nair and Sreedharan, 2018;Al-Qodah and Al-Shannag 2017; Nwankwo and Nwaiwu 2025; Ebba 2021).

Filtration is one of the methods for purifying and providing clean water by removing particles by passing through a porous medium (Kawamura, 2000). Multi-layer filtration (MLF) works with principles of combining multiple media layers of different grain sizes, densities and properties. The effectiveness of filtration is heavily dependent on the characteristics of the media. Multi-layer filtration has many advantages over the conventional water treatment methods such as reverse osmosis, ultra-violet disinfection, chemical coagulation and chlorination. These conventional methods though very effective, are technically complex, expensive and enervating (Shannon et al, 2008). Therefore, employing locally available materials for filtration of water enhances efficiency, availability, affordability, sustainability and local resource utilization. This paper aims to design, construct and assess the performance of a multi-layer water filtration system in treatment of Ezu River water.

II. MATERIALS AND METHODS

Location and water quality status of Ezu River
Ezu River is located at Amansea, Awka North LGA in Anambra State, Nigeria. According to Nwankwoala, (2016), the river has an average flow rate of about 18.6m^3/s during wet session. Anyanwu and Ezenwa (2021) observed that due to pollution coming from anthropogenic activities, the river water cannot be used directly for domestic activities without treatment.

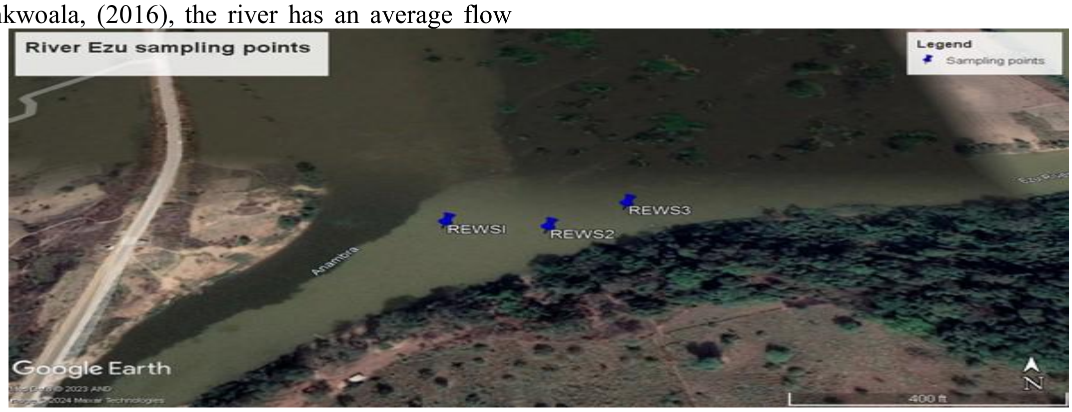

Plate 1:Map of Ezu River where sample was collected

Water Sample Collection
The water sample for this study was collected at Ezu River at the point of latitude 6 degrees 14' N and longitude 7 degree 03' E using 500ml sterile bottles at the depth of 30cm (0.3m) below the surface of the water.

Design and Fabrication
Materials and Equipment: The following materials and equipment were used in the construction of MLF and analyzing water quality as shown in Table 1.

Table 1: Materials and equipment

S/N	Material / Equipment	Use and Specification
1	Plastic Column	Total height of 48.2cm with 26.4cm inlet diameter on top and 3cm outlet diameter at the bottom.
2	Gravel	Coarse gravel of 5-10mm particle size for coarse particle removal.
3	Sand	Fine sand of 0.5-1mm particle sizes for turbidity and suspended solids removal.
4	Carbon	Locally prepared charcoal for adsorption of organics, colour and heavy metals.
5	Fine Screen	Placed at based of column to prevent media loss
6	Raw water sample	Collected from Ezu River.
7	Turbidity Meter	Nephelometric method, reading in NTU.
8	PH Meter	Digital, calibrated with buffer solutions (PH 4,7,10).
9	Colifer testing kit	Membrane filtration apparatus with M-Endo agar and selective incubation.
10	Lead Testing	Atomic Absorption Spectroscopy (AAS)
11	Mercury Testing	Cold vapour AAS
12	Colourimeter	For colour measurement in PCU
13	Stopwatch	For time measurement
14	Beakers and Bottles	Sample collection, storage and testing

Filter Set-up
i) **Top layer**- Coarse gravel (4.5cm): For support, draining of large particles and prevention of clogging.
ii) **Middle Layer**- coarse gravel and fine sand (1cm and 4.5cm respectively): For removal of suspended solids, turbidity reduction and trapping of micro-organism.
iii) Bottom layer- Carbon (4.5cm): Adsorbed dissolved organics heavy metals colour and odour and causing substances.

Design calculation
Bucket (Top compartment) – Inlet diameter = 26.4cm, outlet diameter = 20.3cm and bucket height = 26.7cm
Therefore V= $1/3\pi h\,(R^2 + r^2 + Rr)$ = 1400cm^3≈ 11.4 liters

Filter setup

1. **Top layer** — coarse gravel (4.5cm): For Support, draining and large particles and prevention of clogging.
2. **Middle layer** - Couse gravel and fine sand (1cm and 4.5cm respectively): For removal of suspended, solids, turbidity reduction and trapping & micro-organism.
3. **Bottom layer** - Activated carbon (4.5cm): Adsorbed dissolved organics heavy metals colour and odour causing substances.

Design Specification

Bucket (Top compartment) - Inlet dia= 26.4cm, outlet dia = 20.3cmand bucket height = 26.7em

:. $V = {}^{1}/_{32}\pi h\ (R^2+r^2+ r) = = 11{,}400cm^3 \approx 11.4$ litres.

Funnel (Bottom compartment)

For Frustrum - Height = 15.2cm, R= 21.6cm and r=5.1 cm

$V=-2172.89\ cm^3 \approx 2.17$ Litres

for cylinder – Height=6.3cm, r=3em

$V = \pi r^2h = 178.13\ cm^3 = 0.19$ litres

Veybinder = 2.17+0·19

$V_{total} = V_{frustrum} + V_{cylinder} = 2.17 + 0.19 = 2.36$ litres

Drawing of the MLF System: The architectural drawing of the multi-layer filtration system is shown in Fig. 1.1 below

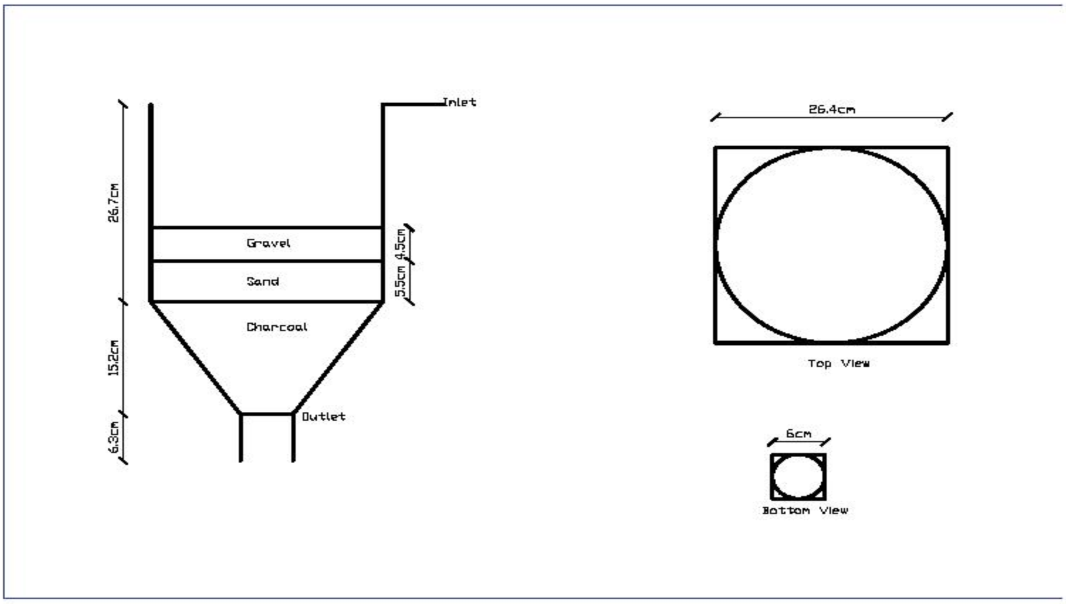

Fig. 1.1: MLF System

Sampling Method

Raw samples were taken from Ezu-River and introduced into the MLF system through the top after pre-treatment testing. Samples were also taken from outlet for post treatment testing at the intervals of 0,10,30,60,90 minutes intervals. All testing procedures followed international laboratory standards (APHA 2017; WHO 2011).

Statistical Method

The following statistical tools were used to analyze the result obtained.

(i) Mean-This is the average of the sample one and sample two run on the filter device.

$$\text{Mean} = \frac{SP1+SP2}{2} \quad 1$$

where

SP_1 = result of the first run

SP_2 = result of the second run

(ii) Removal Efficiency: This is a percentage reduction in the level of concentration of the tested parameters before and after treatment using the equation below

$$\text{Removal Efficiency (\%)} = \frac{Ci-Cf}{Cf} \times \frac{100}{1} \quad 2$$

Where Ci= initial concentration, Cf = final concentration

III. RESULTS AND DISCUSSION

Results

Table 2 presents the results of the raw samples collected from Ezu River. Five (5) key parameters were examined to evaluate the performance of the MLF unit, including Water Quality of Raw water from Ezu River

Table 2

Parameter	Value	Unit	W
Lead (Pb)	0.12	mg/l	0.
Mercury (Hg)	0.015	mg/l	0.
Turbidity	220	NTU	≤
Colour	185	Pt-Co	≤
Nitrate	11.86	mg/l	1

Discussion

Lead (Pb): The concentration of lead is 0.12 mg/l which is far above the WHO limit of 0.01 mg/l is alarming and calls for urgent attention although this is in contrast with the work of Eze et al (2025) which, got lead concentration value of 0.006 mg/l which is lower that WHO safe value. This indicates that this contamination might be from discharge of industrial effluent or agricultural runoff. Therefore, the big difference may depend on the time of discharge of wastewater, distance from the point of discharge and other contributing factors. Moreso self-cleansing of streams might also explain this. Direct consumption of untreated Ezu River water according to Saira et al (2019) can exposed victims to protracted health risk such as headache, loss of appetite, birth deficiencies, mental retardation, hypertension, lung cancer and renal damage because of the extremely toxicity of lead (Pb.) (Ugwu, Maduka, Suru andAnakwo 2022).

Turbidity: From table 2 the turbidity value is 220 NTU which is very much above the WHO safe limit of 5 NTU. This shows that the water is relatively turbid suggesting that there is high amount of total suspended solids (TSS) in the water hence it's murky nature as also observed by Wakawa and Nwaiwu (2019). The turbidity value 220 NTU obtained in the pre-treatment test is close to 240.3 NTU obtained byWakawa and Nwaiwu (2019) and 261.3 obtained by Eze, Egeceonu, Okoro, Emele, Aralu (2025). The slight differences might have been caused by time, point and season of sample collection. Furthermore, according to Sam etal (2023) high turbidity values in water samples can harbor microbial pathogens and result to health risks when consumed untreated.

Mercury: Mercury has a concentration of 0.015mg/l which is also above WHO safe limit.This is evidence of contamination possibly from artisanal mining or untreated waste disposal. Mercury contamination has severe health consequence even at a very low concentration. It is also non-degradable and toxic in both organic and inorganic forms (Ugwu et al 2022). According to Jamp, (2003) while the inorganic mercury (Hg) is toxic to the kidney, its organic form is harmful to nervous system. Another research by Hammer and Hammer (2004) indicated that since mercury is lethal among other effects have connection with the development of joint ailments and decline of mental status. Therefore, mercury concentrations in raw Ezu River need to be reduced or removed.

Colour: The colour also exceeded WHO standard. Aesthetically, Ezu River will be undesired for drinking and other domestic uses (WHO, 2011). It has colour value of 185 pt-co against 15 Pt-CO permissible limits. Good drinking water should be colourless. The colour probably, might be as a result of organic matter and decayed vegetation as, also observed by Wakawa and Nwaiwu (2019).

PH: The pH value of 6.8 is within the WHO recommended range of 6.5-8.5. Therefore, the pH value is considered acceptable. According to Okieimenetal (2012), a highly acidic or alkaline water body cannot support fish life. Thus, Ezu River is also considered a good aquatic environment for most fishes.

The test results of filtered water (first and second run) are presented in table 3 below.Table3 presents the result of analysis of the filtrate after passing through the filtration device

Table 3: Result of analysis of the filtrate

Time/ Parameter	10min SP1	SP2	30min SP1	SP2	60min SP1	SP2	90min SP1	SP2
Lead mg/l	0.218	0.211	0.121	0.115	0.067	0.061	0.042	0.039
Mercury mg/l	0.144	0.138	0.083	0.079	0.048	0.049	0.034	0.028
Colour Pt-Co	78.6	74.5	45.2	41.8	22.8	20.9	9.7	8.9
Turbidity, NTU	26.4	24.9	12.8	11.2	5.3	4.9	2.1	1.8
Nitrate mg/l	9.84	9.67	7.46	7.32	6.22	6.05	5.18	4.98

Discussion

A close look at table 3 showed that both the first filtration run and the second filtration run exhibited similar performance. Butthe second filtration run achieved slightly higher efficiencies due to filtercake formation. This is the accumulation of trapped solid particles on the surface of a filter medium as the water passes through it. This Layer which is built upover time plays important role in water treatment. This post treatment result showed that most of the contaminants were properly treated by the filtration device.

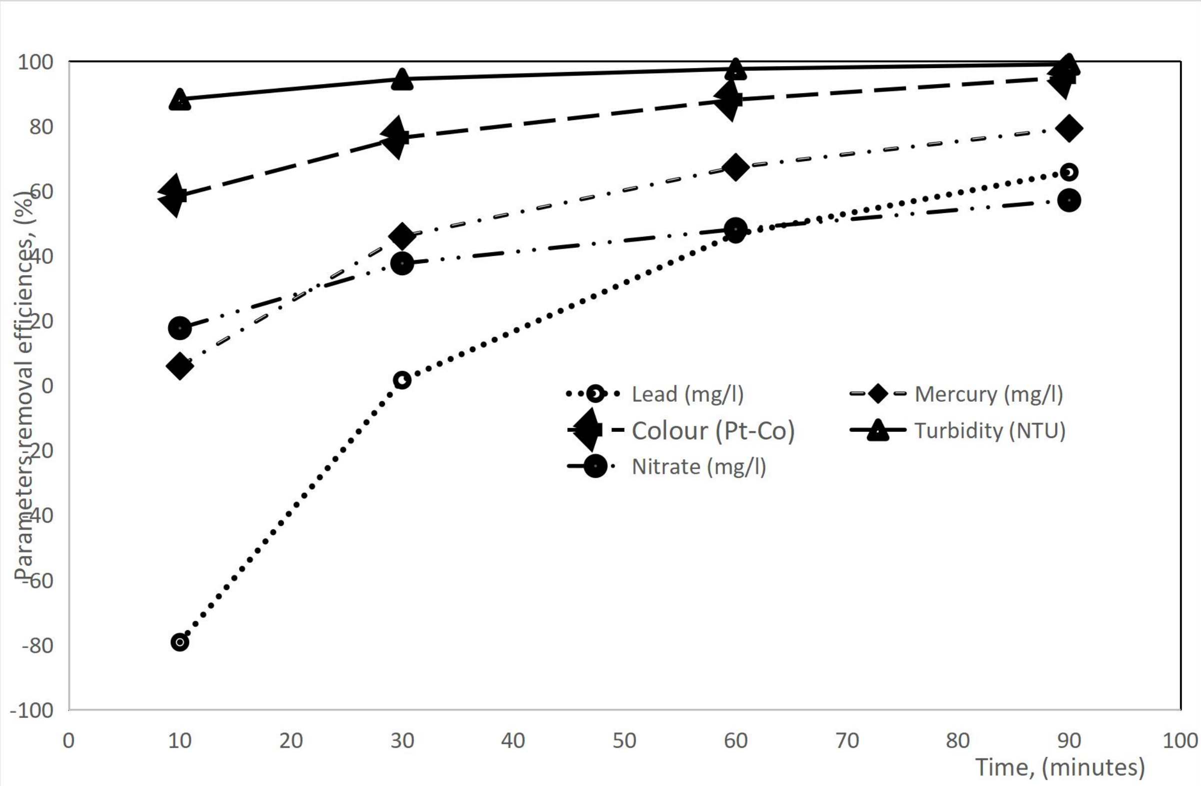

Fig.1: Parameters removal efficiencies with respect to time

Discussion

(i) **Turbidity** - The MLF unit achieved more than 95% turbidityreduction within go minutes, thus bringing the final value of turbidity within acceptable limits. 1-8 NTU is less than 5.0NTU. Therefore,it is now safe (WHO, 2017).

(ii) **Nitrate**- Nitrate removal efficiency was the least of the five parameters tested. They are 58.0% and 59.1% for the first and second runs respectively. Nitrate (NO_3^-) found naturally in the environment; as an important plant nutrient, it can be in varying concentrations in every plant. Though the MLF system did not remove very high percentage of the nitrate content, yet it was able to reduce its concentration below WHO permissible limit of 11.3mg/l (WHO, 2011). Therefore, the MLF system is efficient in removing nitrate impuritysince the final concentrations are 5.18mg/l and 4.98mg/l respectively.

(iii) **Colour:** From table 3 the colour reduction was above 90% showing that the MLF unit wasefficient. The final valuesof9.7 and 8-5 Pt-co are less than15 Pt-co WHO standard value. This reduction according to Obi and Okonkwo (2021) is as a resultof adsorption of humicsubstances and organic dyeson the micro-porous surface of charcoal.

(iv) **Lead (Pb):** The post treatment valueof lead 0.04mg/L show that the system exhibitedsignificant removal efficiencyfor lead though this is still abovepermissible safe limit of 0.01mg/L (WHO, 2017). The removal may improve whenthe system continues to operate more runs.

(v) **Mercury:** The MLF unit also demonstrated more than 85% removal of mercury. By this, the concentrationof mercury was brought to 0.03 mg/L. Though the charcoallayer shows high adsorptive potential, yet is value ishigh than WHO standard. Further treatment is therefore recommended.

IV. CONCLUSION

In conclusion, multi-layer filtration system constructed with locally sourced and abundantly available materials has significantly improved the quality of raw water. This research has also shown that within one and half hours we can have a filtrate that is purer than the raw water supply and approaching World Health Organisation (WHO) standard for potable water. It has equally shown that further treatments like disinfection are needed.

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