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Design and Development of a Grey Domestic Water Filter

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Abstract

Design and development of grey water filter that can outperform the existing ones formed the objective of this study. Making available reusable water from grey water is not only essential for improving the living standard of the populace but timely because of its contributions to the development and well-being of the masses. In this study, activated carbon was adopted in the place of piece of cloth for filtration of water, and to reduce the weight and make it more portable, lightweight materials were adopted. To optimize the filtration efficiency, multiple filters with varying pores were adopted in the design. The result showed that the developed filter device possessed higher filtering rating than the existing concepts.

Keywords
Grey domestic water, ultrafiltration, Activated carbon, Doulton's water filter, Hippocratic sleeve

1. Introduction
In the efforts to minimize water wastages and conserve freshwater resources, several sectors around the world have urged households to make use of greywater for irrigation of their gardens. Greywater refers to the wastewater that can be reused for irrigation and other purposes that has been previously used for laundry, shower, and hand basin. Reusing greywater will reduce water consumption, conserve water resources, and cut household bills. This will ultimately reduce the demand of freshwater directed to the Department of water resources and maintain the access to safe and clean water to everyone. This project will focus on the development and design of a prototype which is able to extract harmful chemicals from greywater for it to be better suited for reuse. This product will use a filter system to remove harmful chemical substances from greywater and then reclaim this greywater later for use in laundry, car washing, and other domestic purposes. The type of material and filters that are going to be adapted will depend on the chemical composition of greywater which will be reviewed later on in the project.

Water filtration, which has been used since 4000 years ago, is an important part of the water treatment process that ensures safe drinking water. The first version of a filtering device involved the of passing water through a cloth to extract silt and other sediments from water before consumption to minimize the chances of contracting an illness. This device as invented by a Greek Scientist, Hippocrates. This simple device was later named after him as the Hippocratic sleeve. Water was boiled and poured through the cloth of this device in order to filter out to get rid of the impurities that were causing a bad taste and smell, resulting in cleaner, better tasting water (Baker, 1981), Figure 1. The development of this project could adapt the simplicity of this design and make use of a suitable material to filter out unwanted sediments on grey water.

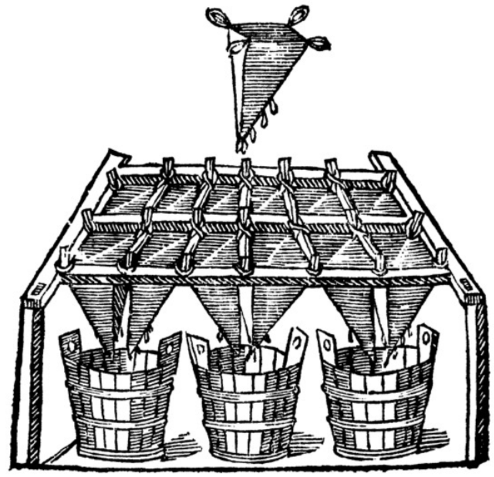

Figure 1. The first water filtration system, the Hippocratic sleeve (adopted from(Baker, 1981)).

The first modern water filtering system was invented in 1827 by John Doulton (the father of English fine China and a pottery manufacturer Henry Doulton). The filter featured a combination of silica and fired clay to create a porous filter that could trap impurities from water. Doulton's ceramic filter was better at removing sediments and dirt from water than the cloth filters that were used at the time. The system worked by placing a porous ceramic bowl on top of another ceramic bowl, allowing the contaminated water to pass through the bowl, trapping particles larger than the tiny holes in the clay, leaving clean water in the container below. A simple, yet effective way to filter water. Figure 2, shows a typical Doulton's ceramic water filter used in the mid-1800s (2023) . Figure 3 shows a reservoir for a for reverse osmosis type water filtering system developed by Shih- ping lee in 2004. It consists of a tank with a separate board defining an upper and lower space in the tank. A water level control system located in the upper space is attached to the tank and is responsible for the control of the volume of the filtered water that enters the upper space. An aperture is defined by the separate board, and a pipe connects the aperture and a pump, allowing filtered water to be pumped from an outlet defined by a tank wall to a faucet via a pipe. The quality of the filtered water in the tank is monitored by a water improvement device located in the upper space (Lee 2004).

Other types of filtering systems use different stages of filtering to filter water such as the Multi-Stage Water Filter System portrayed in figure 4. This filtering device contains a water filter system with a housing for a plurality of serial-flow connected filter cartridges with defined filtering characteristics related to the direction of flow of water being filtered (Bailey et al. 1999). Each filter contains an activated carbon filter body wrapped in a membrane with one filter having a heavy metal bacteriostat. Keyed connectors with rotatable locking rings retain the cartridges in a manifold. Each cartridge has a distinct filtering characteristic and a keying structure to ensure that the cartridge can only be connected to the manifold for placement in the system in proper serial-flow relationship. This system has a spent filter cartridge indicator and is suitable for countertop placement and is to be connected to a faucet.

The machine shown in Figure 5 is the Gamble Company's Water Filter Device. The water device comprises of a connector to allow fluid communication between the water filter device and an untreated drinking water source,(Tanner et al. 2004). It uses a low-pressure water treatment system for untreated drinking water, with a suitable water filter material that contains an F-BLR greater than 2 logs. The device also has an automatic shut-off valve to stop the flow of untreated water into the storage housing and a dispenser for the treated water is included and mounted on the storage housing.

Figure 2. Doulton's ceramic water filter (adopted from(2023)).

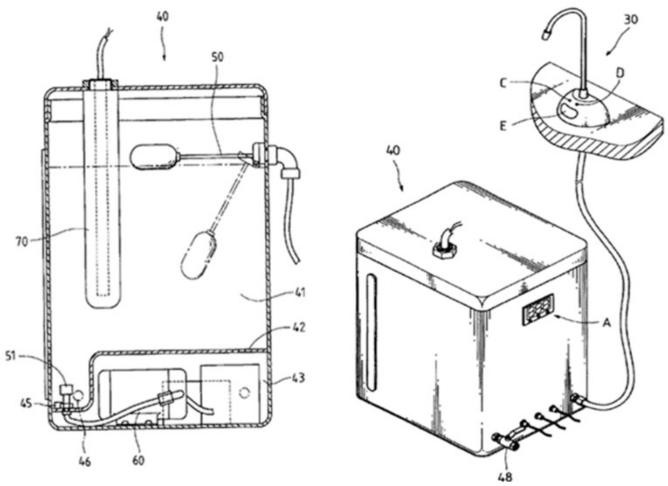

Figure 3. Reservoir for reverse osmosis type water filtering system (adopted from(Lee, 2004)).

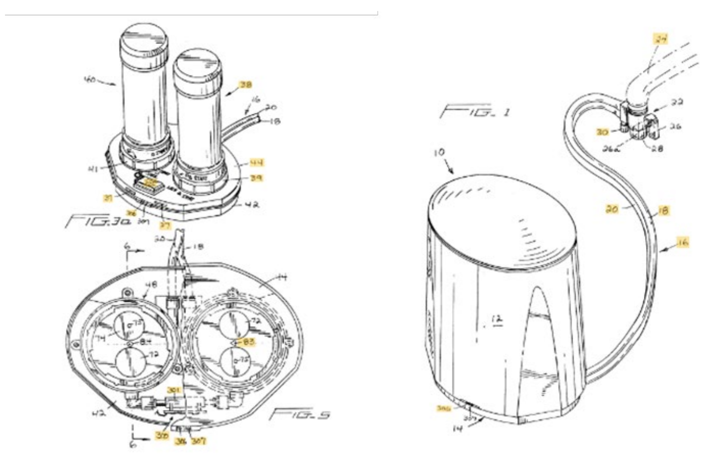

Figure 4. Multi-Stage Water Filter System (adopted from(Bailey et al., 1999)).

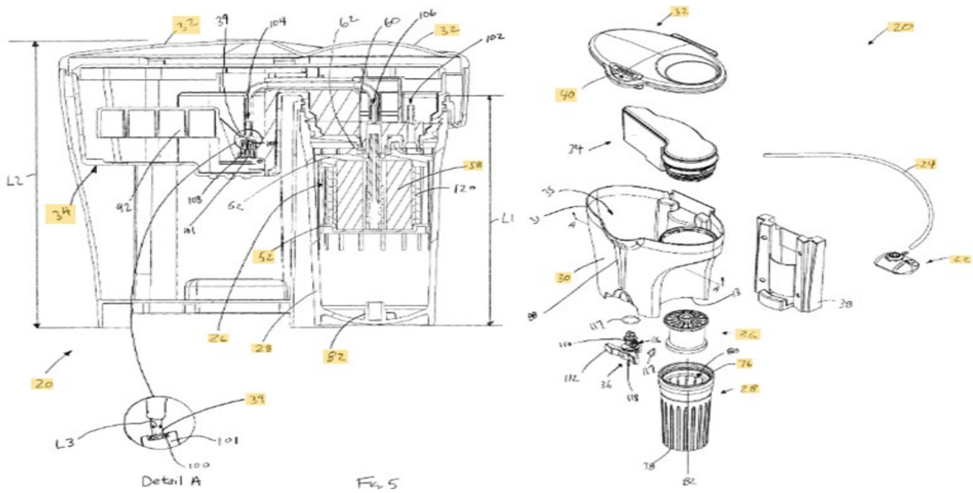

Figure 5. Gamble company's Water Filter Device, (Tanner et al. 2004).

There are water filtration devices that can be carried around and provide clean water whenever it is needed such as the one shown in Figure 6, invented by O'Brien and Engel (O'Brien and Engel, 2010). This device uses a bi-chamber system, the first chamber sucks in untreated water past a pre-filter on its inlet which contains an extremely small pore and an inner cavity with a disinfecting agent which filters most of the contaminants before the water is drawn into a said filtering device. The water is isolated in the chamber for further decontamination using a disinfectant agent before it let through additional filtering substances such as a nano filter or activated carbon (O'Brien and Engel 2010).

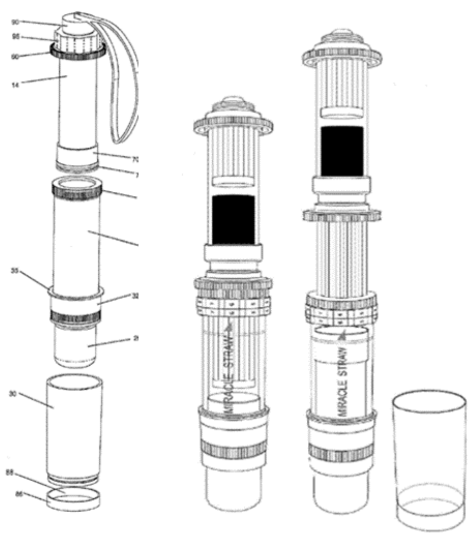

Figure 6. Portable Drinking Water Purification Device (Adopted from(O'Brien and Engel 2010)).

1.1 Objectives
The objective of this study is to design and develop grey domestic water filter.

2. Methods
2.1. Design Strategy
Substitute
The device will consist of either a nano or an activated carbon filter instead of a piece of cloth used in the Hippocratic sleeve that is shown in figure 1. This will allow filtering of microscopic sediments and bacteria. To make the device portable, a lightweight material will be used (Ujah et al. 2023b).
Combine

Instead of a single filter, a multiple filter configuration with different sized pores will be used to reduce clogging in the filter, and to improve the quality of water produced by the unit (Onur et al. 2018).

Adapt

An automatic system will control the inlet and outlet of untreated and treated water. The system will also allow connection to a hose pipe for irrigation and washing cars.

Modify

The outlet pipe will be more suited for connecting a hose pipe for easier irrigation

2.2. Problem Statement

All life on earth depends on water, it is the backbone of any ecosystem. Thus, reducing water wastage is crucial in order to be able to meet current and future demand. One method of achieving this is by reclaiming grey water and using it for irrigation and other domestic purposes. This project aims to design and develop a prototype filter that can remove dangerous chemicals in grey water and reclaim it for later use. Filter material must have the properties of sieving out water pollutants, and this property is found in carbon materials (Ujah et al. 2023b, Ujah et al.,2020). These techniques can help reduce water consumption and conserve water resources. Conserving water saves energy – since it takes energy to filter, heat and pump water into your home, reducing water consumption helps to keep wetland habitats stocked for aquatic animals.

2.3. Requirements

The design of the greywater filter should satisfy the following requirements:

- It should effectively remove contaminants such as soap, detergent and dirt from the greywater.
- It should be easy to install and maintain.
- It should be affordable and use easily accessible materials.
- It should be scalable and better suited for use in households of different sizes.
- The treated water should be suitable for reuse in non-potable applications like irrigation and flushing toilets.

2.4. Constraints

Below are the constraints which refers to the limitations on the design requirements:

- The filter system must be affordable and economical in order to be widely adopted.
- The filter system must be easy to maintain.
- The filter system must yield water which meets the required quality standards for non-potable use.
- The filter system must have the ability to withstand harsh environmental conditions and last for a long time.

2.5. Specifications

The following are the design specifications of the greywater filter:

- Dimensions: 50 cm x 50cm x 100 cm
- Filtration media: Coarse gravel, sand, and activated carbon.
- Filtration rate: 30 litres per hour
- Maximum input temperature: 40 degrees Celsius
- Maximum input flow rate: 50 litres per hour

3. Results and Discussion

3.1. Functional Analysis

Functional elements for the project were established to aid in generating a complete concept of the design. These functional systems are evaluated and explained in table 1 below.

3.2. Chemical Composition of Grey Water

All liquids are composed of molecules that are made of atoms which are bonded by chemical bonds. The chemical composition of a liquid is the kind and ratio of such atoms and molecules which are contained in a substance and varies for every substance. The chemical composition of liquids is very crucial for identification, classification, physical and chemical properties (affects properties such as reactivity, corrosion resistance and stability), and engineering or manufacturing (essential for the design of acceptable materials and optimizing production processes). The chemical composition of greywater typically differs per household depending on depending on the activities which produces it. However, greywater usually consists of a mixture of organic compounds, soaps, detergents, nutrients and pathogens (Aigbodion et al. 2023a).

4. Proposed Improvements

4.1. Ultrafiltration

The first model of filtration is one that utilizes a method of filtration. This process separates particles and solutes from liquid solutions (contaminated) using a semi-permeable membrane. The ultrafiltration filter works by letting water molecules and smaller particles to pass through the membrane while capturing larger-contaminants through the principle of size exclusion. This method proves to be an excellent method when used for grey water treatment due to its ability to remove micro-particles.

Ultrafiltration has emerged as a highly advantageous alternative in recent times due to its capacity to function optimally at minimal pressure requirements leading to lower energy consumption rates significantly. Besides this benefit what makes UF preferable over other methods is that it does not require chemicals during the filtration process making it an ecofriendly solution for greywater treatment – while still remaining cost effective too. Furthermore, once treated through UF - water can be used extensively in numerous non potable applications like irrigation or even factory operations ultimately leading to reduced reliance on fresh water.

Table 1. The Brainstorm of the Components of the Filtration Device

System	Function	Method of realization
Inlet system	Collects and channels greywater from domestic activities to the filter system,	• Collection basin with a screen filter
Filter system	Removes contaminants and impurities from the grey water	• Filter media: sand, gravel, and activated charcoal. • UV sterilizer
Storage system	Store the filtered water in a container that was designed to hold a sufficient amount of water for domestic use. This container will also have a level sensor	• JoJo tank
Distribution system	Distributes the filtered water to various non-potable use points such as toilets and irrigation systems	• Copper pipes

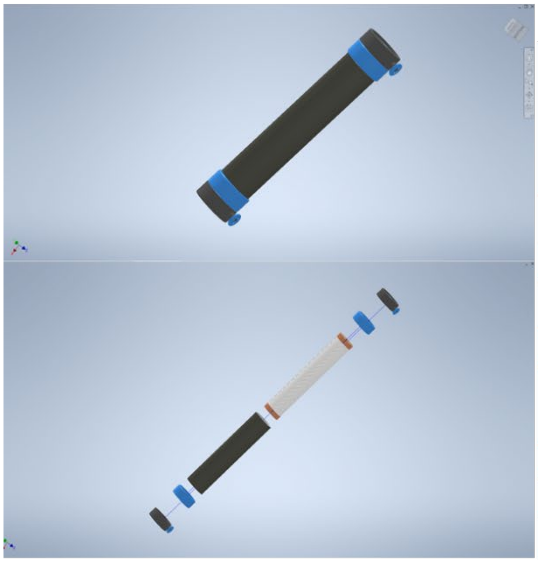

Table 2: Pugh Matrix

Specifications	Weight	Existing concept		Concept 1	
		Score	Weight	Score	Weight
Maintainability	20%	3	0,6	3	0,4
Safety	20%	3	0,6	4	0,6
Ease of cleaning	25%	3	0,75	4	0,25
Cost	20%	3	0,6	3	0,6
Ease of manufacture	15%	3	0,45	3	0,6
Total score	100%		3		3,45
RANK					2
CONTINUE?					NO

Figure 7. Prototype of Water Filter.

5. Conclusion

Design and development of a grey water filter model has been conducted in this paper. From the Pugh matrix employed in this paper, the presented design demonstrated better features that are greater than the existing concept. Therefore, this concept is good and suitable for application in water filtration. Looking ahead, we propose construction and testing of the new model particularly using domestic wastewater generated from kitchen sinks, bathroom tubs and showers and waste water from washing machines.

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Biographies

Mrs Lindelwa Siwisa Lindelwa is a highly experienced mechanical engineer with a Master's degree in Mechanical Engineering and over 15 years of expertise in the wastewater treatment industry. Combining a solid foundation in mechanical design with an extensive background in project management, has made a Lindelwa significant contributor to the design, development, and execution of innovative wastewater treatment solutions. In the last five years, Lindelwa transitioned into project management within the wastewater treatment sector. In this role, she led multidisciplinary teams in the planning, design, and implementation of complex projects, ensuring that they were completed on time, within budget, and to the highest standards of quality. Lindelwa is currently doing PhD in mechanical engineering at the University of Johannesburg.

Prof. Daramy Vandi Von Kallon Prof Dr Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD in Computational Mechanics obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT during 2013. At the start of 2014 Prof Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 Prof Kallon transferred to the University of Johannesburg (UJ) as a full-time Lecturer, then Senior Lecturer and later Associate Professor in the Department of Mechanical and Industrial Engineering Technology (DMIET). He currently teaches simulation-based modules at this Department to final year of Bachelors and Honours students and serves as Head of the Quality Assurance Committee of the Department. Prof Kallon has more than twelve (12) years' experience in research and eleven (11) years of teaching at university level, with industry-based collaborations. He is widely published, has supervised from Masters to Postdoctoral and has graduated four (4) PhDs and twenty-five (25) master's Candidates. Prof Kallon's primary research areas are Acoustics Technologies, Artificial Intelligence, Design and Development, Water Technologies and Energy Technologies.