An overview of sustainable greywater treatment processes

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Abstract. Greywater refers to all domestic wastewater generated, with the exception of sewage. Greywater exhibits a varied composition that mirrors the lifestyle of the residents and the chemicals they utilize within their households. The environment is favourable for the proliferation of bacteria, indicating that it has to be treated before being reused. The treatment objectives also include the removal of organic pollutants, heavy metals, diseases, and other microorganisms. The predominant approach for treating greywater is to pass it via biofilm systems. Using mulch beds in close proximity to crops or trees is a viable alternative to irrigating the entire region. The basic methods of grey water treatment are filtration, coagulation, reverse osmosis, and adsorption, and the energy and resource requirements of the treatment systems differ. They often rise as the level of treatment rises, leading to a bias for natural systems such as sand or fiber filters and built wetlands. These natural systems are more suitable for small-scale greywater treatment since they are more sustainable, eco-friendly, and low-cost.This review finds different approaches to redefine the perception of sustainable greywater management in order to provide assistance to both humans and agriculture.

1 Introduction

Greywater is one of the two categories of household wastewater that is generated /discharged from the showers, bathtubs, washing machines, and kitchen sinks [1]. The composition of grey water constantly varies and is dependent on the lifestyle and climatic conditions of its source. The properties of grey water make it reusable provided that it is subsequently treated using simple and cost-effective treatment techniques. Grey water treatment (GWT) technologies vary in their properties, forms, pollution concentrations, and treatment procedures.

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The appropriate technology is chosen based on the amount of grey water, organic content, final application, and standards of acceptance. Grey water treatment solutions range from simple natural systems to complex Rotating Biological Contactor systems, and these treatment systems are made up of phases of treatment that remove turbidity, Biological Oxygen Demand (BOD), bacteria, and odor [2].

2 A study into greywater

2.1 Contaminants in greywater

2.1.1 Chemical contaminants found in greywater

Chemical contaminants as described by the Environmental Pollution Centre (EPC) are the chemicals that are not naturally present or are found to be in higher concentrations than they would normally occur. Greywater composition constantly varies depending mainly on the source and is affected by lifestyle, climatic conditions and choice of chemicals used for bathing as well as laundry and cleaning [1-2]. This in turn affects the concentration and types of chemical contaminants found in greywater produced. The common chemical contaminants in greywater include soaps, shampoo, toothpaste, laundry detergents and other cleaning products which contain substances such as sodium, phosphates, surfactants, and nitrates from soap powders and soiled clothes [2]. The surfactants found in greywater are as a result of it being the main agent in most cleaning product. Studies have also shown that greywater with high surfactant content when used for irrigation leads to the soil turning hydrophobic (water would collect on the surface of the soil instead of infiltrating into the soil) [3-4].

2.1.2 Physical parameters found in greywater

These criteria pertain to the visual characteristics of the greywater. The pertinent characteristics encompass turbidity, temperature, suspended particles, and electrical conductivity. Greywater typically has a warm temperature, usually ranging from 18-35 °C. The higher temperatures are frequently a result of cooking activity. Elevated temperatures promote the proliferation of microorganisms, which is undesirable. Additionally, in concentrated water, high temperatures lead to the formation of carbonate precipitates, such as $CaCO3$, which become less soluble. The concentration of suspended particles in greywater varies depending on the collection source and falls within the range of 190-537 mg/L (Ote18). The different gathering points include the kitchen, bathroom, and laundry (see Table 1), with the highest concentration being found in kitchen sinks and washing machines. The presence of suspended solids is likely to cause an increase in the turbidity of greywater from the kitchen and laundry [5].

Table 1. Grey water elements from various household sources [6]

Greywater Collection Point	Physical Contaminants
Kitchen	Suspended solids (food particles), oils, fats, grease
Bathroom	Suspended solids (Hair)
Laundry	Suspended solids (dirt, lint)

2.1.3 Biological pollutants found in greywater

Biological pollutants encompass living organisms or agents derived from viruses, bacteria, or fungi [7]. Microbial entities, including bacteria, protozoa, and helminths, are frequently present in greywater and are introduced by direct physical interaction. The act of washing one's hands after engaging in activities such as using the toilet or changing diapers, bathing, washing infants and young children, as well as handling raw food items commonly found in kitchens, all have a role in the dissemination of these bacteria within greywater [8]. Greywater is the term used to describe wastewater that is collected from showers, bathtubs, and hand basins. This particular category of greywater is considered to be the least contaminated. The concentrations of thermotolerant coliforms in bath water were evaluated to be within the range of 102 to 105 colony forming units per 100 milliliters [9]. The microbiological monitoring program conducted in Melbourne, Australia successfully identified the existence of enteric viruses and Pathogenic Escherichia coli in samples of laundry greywater that were collected [10]. The quality of laundry greywater undergoes improvement as it transitions from wash water to first-rinse water and then to second-rinse water. The thermotolerant coliform count exhibited a range of 107 colony-forming units (cfu) per 100 milliliters when laundering underwear, while the count decreased to 25 cfu/100 ml for the second rinse water [10]. Additional research investigations have similarly revealed the presence of E. coli, Staphylococcus aureus, Pseudomonas aeruginosa, and Salmonella spp in greywater [11]. The microbial concentration observed in greywater exhibits a positive correlation with the overall health status of the population responsible for producing the wastewater, as individual’s sick with pathogens tend to excrete a greater quantity of microorganisms.

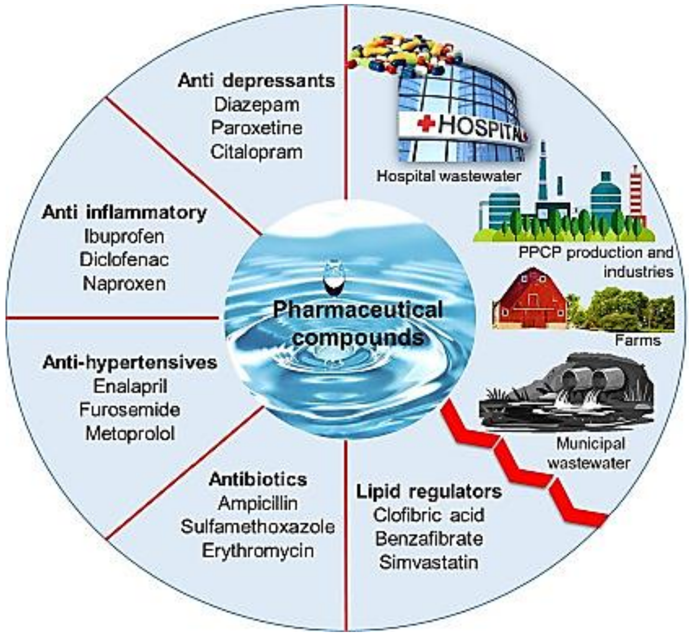

Fig. 1. The primary sources of drug pollution and the methods by which they are released into the environment

2.2 Greywater treatment processes

2.2.1 Coagulation as a Greywater Pre-treatment Method

The methods applied to greywater treatment vary and differ based on their characteristics and treatment procedure (See Figure 2). Certain greywater treatment techniques are selected depending on the organic content, the application after treatment and the quantity of greywater [12]. Coagulation is a popular and critically important pre-treatment method mainly because it contributes significantly to the reduction of turbidity, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS).
Coagulation is a treatment process which aids in reducing the repulsive potential of electrical double layer of colloids using the appropriate coagulants. As a response, colloidal particulates begin to form and eventually clump together to form larger flocs. Charge neutralization, entrapment, adsorption, and complexation with the coagulant's ions forming insoluble aggregates are some of the mechanisms involved in flocculation [13].

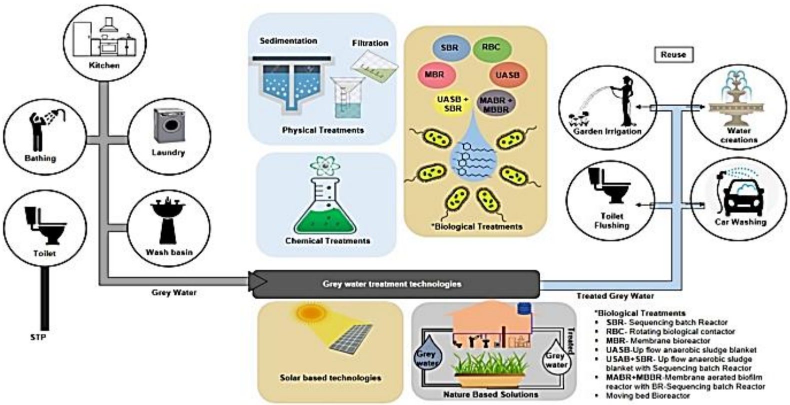

Fig 2. Greywater treatment technologies

2.3 Coagulants in greywater treatment

Coagulants refer to substances or chemicals that, upon introduction into a specific solution, induce the aggregation of suspended tiny particles, leading to the formation of bigger and denser masses known as flocs. Organic or inorganic chemicals or substances comprise their existence. Inorganic coagulants encompass metal coagulants, which are often classified into two main categories: aluminium-based and iron-based coagulants. Aluminium coagulants commonly used in water treatment processes consist of aluminium sulphate ($Al_2(SO_4)_3$), aluminium chloride ($AlCl_3$), and sodium aluminate ($NaAlO_2$). On the other hand, iron coagulants employed in similar applications include ferric sulphate ($Fe_2(SO_4)_3$), ferrous sulphate ($FeSO_4$), ferric chloride ($FeCl_3$), and ferric chloride sulphate ($ClFeO_4S$) [14].
Metal ions, specifically aluminium (Al) and iron (Fe), undergo rapid hydrolysis in an uncontrolled fashion with the addition of metal coagulants to water, resulting in the formation of a series of metal hydrolysis species. The determination of the hydrolysis species that is efficient for treatment is contingent upon the efficiency of rapid mixing, the pH level, and the dosage of the coagulant [15]. Organic coagulants such as snail shells, oxidized starch, cocoyam, and Periwinkle shell typically receive less attention. Various variables such as high cost, health related difficulties associated with inorganic coagulants such as alum provide some challenges. According to a report, the utilization of alum in high quantities for the purpose of treating drinking water has been linked to the development of Alzheimer's disease

[16]. Researchers have demonstrated a keen interest in organic coagulants due to their biological origin and environmentally friendly properties. Additionally, it should be noted that these substances have been found to be non-toxic and capable of undergoing biodegradation [17-18].

2.3.1 Aluminium Sulphate as a Coagulant

Aluminium Sulphate [$Al_2(SO_4)_3$], commonly known as alum, is a soluble chemical (in water) which is mainly used as a coagulating agent in the process of water treatment. Aluminium sulphate is known to be the most commonly used coagulant which suppresses the hydraulically irreversible fouling rate of hollow fibre membranes by about 75–100% [19]. The coagulant dose, mixing, pH, temperature, particle, and natural organic matter (NOM) qualities all affect the efficacy of aluminium sulphate coagulation. When employing alum, the most effective pH range for coagulation is 5–6.5 [20].

When $Al_2(SO_4)_3$ is dissolved in water, the aluminium ions undergo hydrolysis and generate positively charged hydroxides. These hydroxides then cause flocculation by neutralizing the negative surface charge of particles. When the dose of metal hydroxides is increased, a precipitate is formed. This precipitate traps particles in suspension and forces them to settle [18]. Aluminium sulphate is favoured over some coagulants due to its stability, ease of handling, high solubility, superior colour removal efficacy, and greater turbidity removal in certain instances. Furthermore, it has demonstrated superior efficacy compared to ferric coagulants when administered in small quantities. Figure 3 depicts an illustration of aluminium coagulant. The experiment demonstrated that the ideal pH for the coagulant (aluminium sulphate) was 6, and the optimal dosage of aluminium sulphate as a coagulant was 500 mg/L. Alum achieved a 99% clearance of oil and grease at the ideal coagulant dosage [2].

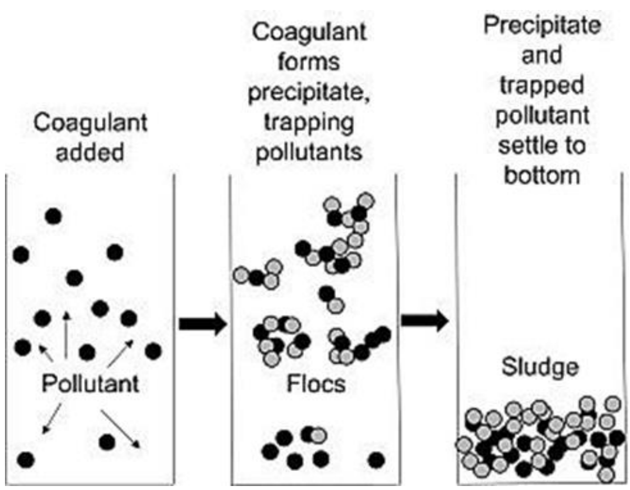

Fig. 3. Aluminium coagulant process

2.3.2 Polyaluminium Chloride as a Coagulant

Polyaluminium Chloride is a highly utilized chemical in water treatment facilities across several sectors globally. Polyaluminium chloride (PACI) coagulant has been developed and utilized globally for water and wastewater treatment since the 1980s [13]. PACI is produced by combining sodium aluminate solution with basic aluminium chloride solution, resulting in a substance with the generic formula Aln(OH)mCl3n−m (when HCl is utilized), where 0

< m < 3n [20]. Evaluation of aluminum-silicate polymer composite as a coagulant for water treatment. Polyaluminium chloride is manufactured in both liquid and solid forms, with a purity ranging from 18% to 30%. The PACI system exhibits mean removal efficiency of 93% for turbidity, 74% for chemical oxygen demand (COD), and 89% for total suspended solids. The coagulation process using hydrolysing coagulants has been thoroughly studied. However, the coagulation activity of pre-hydrolysed coagulants, such as polyaluminium chloride (PACl), and the specific coagulation mechanisms at different coagulant doses and raw water pH values have not been adequately investigated [21]. Due to its numerous advantages, PACl is gaining popularity in the coagulation-flocculation process. Polyaluminum chloride (PACl) offers several advantages compared to traditional hydrolysing aluminum or iron salts. These benefits include superior performance in low temperatures, reduced levels of aluminum residues, decreased sludge volume, and minimal impact on the pH value of raw water [22].

2.4 Coagulant Aids in Greywater Treatment

Coagulant aids are substances added to primary coagulants to assist or modify coagulation or flocculation processes in water treatment. They are used to improve the settling characteristics of floc produced by the primary coagulants [23]. Coagulant aids modify coagulation by; overcoming cool water temperature, strengthening flocs, reducing the primary coagulant dosage and reducing sludge production. Common aids are Non-ionic, cationic or anionic polymers, Sodium aluminate, activated silica, activated clay [24].

2.4.1 Activated Silica as a Coagulant Aid

Activated Silica (AS) is an inorganic coagulant aid with an anionic nature that enhances the overall flocculation process to a comparable extent as the widely employed synthetic acrylamide (CH2=CHCNH2) based long chain organic polymer [25]. The terms "activated silica" and "activated silicic acid" can be employed interchangeably when describing stable silica sols. Activated silica is produced by a series of steps. First, the alkali present in a diluted sodium silicate solution is neutralized. This initiates the formation of silica micelles. Next, the solution is aged to allow these micelles to develop further. Finally, the solution is diluted to prevent the micelles from becoming larger, resulting in the formation of a gel [26]. Activated silica sol is generated through the polymerization process of silicic acid, a compound that does not pose any detrimental impacts on human well-being. The affinity between silicic acid and aluminium is notably robust and distinctive [25]. Activated silica is commonly employed as a supplementary agent alongside primary coagulants, such as aluminium sulphate, lime, or ferric salts, to enhance their effectiveness. A number of experimental studies have demonstrated that the use of activated silica leads to a decrease in residual aluminium levels, resulting in a range of 0.003–0.034 mg/L [27]. Activated silica has been found to generate flocs that exhibit greater density, size, and strength in comparison to those formed by organic polymers.

2.4.2 Moringa Oleifera as a Coagulant Aid

Moringa oleifera (popularly known as the drumstick tree) is a tree from the family of moringaceae which produces long and slender seed pods and is known mainly for its nutritional benefits as well as its usefulness in water treatment [28]. The extracts of moringa have been tested to be effective in the reduction of turbidity and bacteria removal in untreated greywater. Scientists have determined that the seed extracts also contain lipids, carbohydrates, and alkaloids that have carboxyl (-COOH) and free hydroxyl (–OH) surface groups. These surface groups improve the coagulation ability of the extracts. Furthermore, it is favored as a coagulant aid due to its ability to maintain the conductivity and pH of the treated wastewater without any changes. Additionally, it is environmentally friendly, non-toxic, and capable of being broken down naturally [28]. Studies have shown that moringa seed extract could reduce turbidity by 96-98% and TSS by almost 88% as well as remove total coliforms and E. coli by 91-99%. However, COD and BOD are seen to increase after moringa is used for treatment due to the oil and protein content present in the moringa seed [7].

2.4.3 Snail Shells as a Coagulant Aid

Snails are classified under kingdom Animalia, phylum molluscs and class gastropods. Other animals under this classification include slugs. Their shells are made up of calcium carbonate (CaCO3) which is the main constituent and has two crystallite forms such as calcite and aragonite. It is also made up of an organic component known as conchiolin which constitutes 5% of the shell. A study revealed that scanning broken surfaces of shells under an electron microscope revealed stripes of calcium carbonate separated by a thin layer of conchiolin [29 -30]. With reference to these constituents, snail shells can be used as either absorbents or coagulants. It has been used as a coagulant in treating waste water from food industries [31], quarry effluents [32], and fibre-cement effluent.

2.4.4 Seaweed as a Coagulant Aid

Seaweed, also known as macroalgae, can be categorized into three distinct types based on their pigmentation: green algae (Chlorophyta), red algae (Rhodophyta), and brown algae (Phaeophycean). Phycocolloids, such as soda ash and iodine, are produced with this substance [24, 30]. Phytochemicals possess diverse applications, including their utilization as thickening agents in the food industry, as stabilizers in medicinal formulations, and in the varnish industry. In addition to the aforementioned applications, seaweed is also employed in various water treatment procedures. In the context of textile wastewater treatment, this substance is employed to eliminate dyes prior to discharge into the environment. The purpose of this process is to mitigate any potential adverse effects, both direct and indirect, that may arise from exposure to these dyes. Such effects include but are not limited to respiratory, circulatory, central nervous, and neurobehavioral disorders. Additionally, the use of this substance aims to prevent the onset of various health conditions such as allergies, autoimmune diseases, multiple myeloma, leukemia, vomiting, hyperventilation, insomnia, profuse diarrhea, salivation, cyanosis, jaundice, quadriplegia, tissue necrosis, eye or skin infections, and irritation, including lung enema. This information is supported by Hatt et al., [26] . The utilization of (Sargassum sp.) a type of brown algae, has been found to be an efficient method for the removal of direct blue 2 dye from aqueous solutions. This is achieved by the process of coagulation, as demonstrated in previous research [23].

2.5 Adsorption process for greywater treatment

Adsorption is the selective transfer of one or more chemicals from a gaseous or liquid phase to the surface of a porous material, resulting in a mass transfer. When a solution containing a solute that can be absorbed comes into contact with a solid material that has a highly porous surface, the attractive interactions between the liquid and solid molecules cause some of the solute molecules in the solution to gather and stick to the surface of the solid. The adsorbate refers to the solute that is held on the surface, whereas the absorbent is the porous material on which it is held.

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There are two forms of adsorption: physical adsorption, which is defined by weak Van Der Waals forces, and chemisorption, which is characterized by covalent bonding. Additionally, it may be attributed to electrostatic attraction [27]. A study was conducted to evaluate the efficiency of wastewater treatment based on measurements of turbidity, colour, and MBAS (detergent) properties. Adsorption experiments were conducted using 100 mL of wastewater and 1 g of adsorbent. The testing lasted for 2 hours at room temperature with a stirring speed of 150 rpm. The PAn/RH+KIO3 adsorbent demonstrated superior removal efficiency for colour, detergent, and turbidity, achieving rates of 98%, 96%, and 70% respectively. In comparison, the PAn/SH+K2S2O8 adsorbent achieved rates of 58%, 3%, and 95% for the same parameters [24]. Adsorption offers several advantages compared to alternative methods, such as a straightforward design and the possibility of requiring only a small initial financial and land commitment. The adsorption process is commonly used to eliminate organic and inorganic pollutants from industrial effluent (See Figure 4). The column absorption process is a dynamic phenomenon that entails the movement of liquid and the interference of mass through ionic exchange. Additionally, the treatment system provides the assessment of material saturation over time, as well as in terms of space and length of the adsorption column [20 -21]. This feature facilitates a more efficient utilization of the adsorbent.

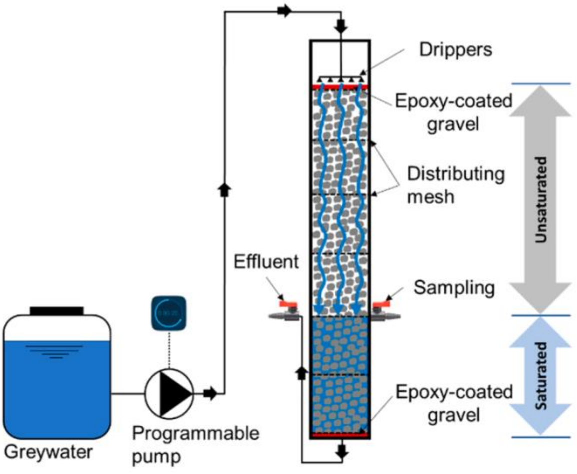

Fig. 4. Adsorption Process for Greywater Treatment

2.6 Adsorbents Used in Adsorption Processes

An adsorbent refers to a solid substance that is characterized by its insolubility and is coated by a liquid layer on its surface, which encompasses capillaries and pores. An adsorbent is defined as a substance that possesses the ability to retain a specified quantity of liquid within small compartments, resembling the structure of a sponge. Adsorbents can be categorized into two main groups: natural and synthetic [18]. Natural adsorbents commonly utilized in various applications encompass activated clay, activated charcoal, zeolites, and ores. Under typical conditions, these materials are characterized by their affordability, abundance, and significant potential for customization, hence facilitating the enhancement of their adsorption capacities. Synthetic adsorbents refer to adsorbents derived from agricultural products, residential wastes, industrial wastes, sewage sludge, and polymeric materials. The porosity, pore structure, and adsorbing surface characteristics vary across different adsorbents. The waste materials encompass various substances such as sawdust, rice husk, petroleum wastes, seaweed and algae, peat moss, clays, and red mud [20].

2.6.1 The Utilization of Seaweeds as Adsorbents

Seaweeds possess attributes that exhibit properties of both a coagulant and an adsorbent. Seaweed has been employed as an adsorbent for a range of substances, including dyes, phenolic compounds, inorganic elements including nitrogen and phosphorus, as well as heavy metals such as Chromium (Cr), Nickel (Ni), Copper (Cu), Arsenic (As), Cadmium (Cd), and Mercury (Hg) [25, 32]. The subsequent paragraphs illustrate the diverse toxins present in various types of waste waters, as well as the varied seaweed species utilized for their removal under specific conditions.

Phosphorus and nitrogen are two essential elements in several biological and ecological processes. The introduction of excessive inorganic nutrients, specifically nitrogen and phosphorus, originating from human activities, has been found to trigger eutrophication in aquatic ecosystems [33]. This process subsequently results in an elevated occurrence of harmful algal blooms and hypoxia, a condition characterized by insufficient oxygen supply to bodily tissues [21]. Eutrophication refers to the ecological response that occurs when an aquatic system is exposed to the introduction of nutrients, whether they are naturally occurring or derived from human activities, such as the use of phosphates in detergents, fertilizers, or sewage. The primary concern regarding water quality in both freshwater and marine environments is the presence of a particular issue. This issue has been identified as having detrimental effects on coral reef health and the overall loss of coral reef communities. Additionally, it has been observed to contribute to an increase in the occurrence of fish kills. These negative impacts on coral reef health and community loss have been extensively documented [28].

2.6.2 Activated Carbon as an Adsorbent

Activated carbon is a type of carbon that has been processed to generate a highly porous structure, which increases the amount of surface area accessible for adsorption or chemical reactions. The material has a non-uniform and imperfect arrangement that possesses high permeability across a broad spectrum of pore sizes, encompassing visible fractures and fissures as well as molecular-scale dimensions, so distinguishing it from graphite. With the inexpensive cost, very high porosity, tuneable pore size, and strong adsorptive capabilities, activated carbon is the most extensively used adsorbent [29]. Activated carbons are noted for having the maximum amount of adsorbing porosity, or strong physical adsorption forces. They can be made from many substances with high carbon content such as coal, bone char, peat, petroleum coke, lignite, coconut shells, woods and other biomass sources. Activated carbon can be made from any carbonaceous material, but lately, the most common sources are anthracite and bituminous coals [30]. Granular Activated Carbon (GAC), Powder Activated Carbon (PAC), Charcoal Activated Carbon Cloth and Extruded Activated Carbon (EAC) are some of the many types of activated carbon (ACC) [31].

2.6.3 Activated Clay as an Adsorbent

Activated clay is a naturally-occurring mineral characterized by its porous structure, which is obtained through the process of drying. This results in the formation of an adsorbent substance. According to previous research [12,16] , the clay has a favorable adsorption capacity within the established temperature and relative humidity parameters. Due to its chemical inertness and non-toxic nature, activated clay can be handled and disposed of safely. According to previous research by Chen [14], adsorbents that are chemically synthesized, such as silica gel or molecular sieves, tend to have higher costs compared to clay. Extensive research has been conducted on clay minerals due to their notable capacity for sorption and complexation [33].

2.6.4 Zeolites as Adsorbents

Zeolites are microporous crystalline solids with well-defined structures. They are utilized for a few applications such as particle trade, partitions, adsorption and catalysis. Natural zeolites are hydrated aluminosilicate materials with excellent ion-exchange and sorption capabilities that are both environmentally and economically friendly. Natural zeolites are another common cation exchange material that can be used to treat water and wastewater at a reduced cost. Their excellent selectivity for water pollutants such heavy metals reached up to 1800 mg/g, and ammonium ion removal progressively increased to 90% [10]. Natural zeolites are made up of three-dimensional aluminosilicate tetrahedral frameworks with covalent bonds connecting the aluminium and silicon structure atoms over common oxygen atoms to form linked cages and channels [9]. One notable characteristic of natural zeolites is their distinctive ability to exhibit selectivity towards cations. The adsorption experiments yield quite favorable outcomes, particularly in the case of the modified variants. The clinoptilolite-Fe system is characterized by its affordability and simplicity in the process of regeneration. Furthermore, it is important to note that this product has been deemed safe for both human use and the surrounding environment. The metal adsorbent exhibits promising potential for high effectiveness. The study focused on the investigation of arsenic removal from drinking water through the utilization of modified adsorbents, specifically natural zeolite. These adsorbents were created by including different iron solutions. The adsorption of arsenic on zeolite that has been swapped with iron has been reported to potentially reach levels above 100 mg/kg [13]. The utilization of modified zeolites, namely those containing aluminium-loaded low-silica zeolites, has demonstrated the capability to effectively remove fluoride from water, achieving concentrations below the current maximum limit of 1.5 mg/l set by the World Health Organization (WHO). The highest level of fluoride adsorption was seen within the pH range of 4-8, as stated in reference [28].

2.7 Filtration for Particulate Matter Removal in Greywater

Biofilters or filters are commonly employed in the field of wastewater treatment. The primary purpose of the filtration process is to assist in the elimination of particulate matter that remains after prior procedures, such as absorption and filtration, have been applied. Filtration systems employ both physical and biological mechanisms to eliminate particulate particles present in the fluid undergoing treatment [31]. The efficacy and compatibility of filtration as a means of removing particulate matter have been investigated, demonstrating its suitability for integration with other systems to effectively implement treatment techniques [11]. The most popular method of treating household greywater is to use a filter bed of a specific height built of porous materials and fed by a water system. The packing material chosen as a filtration medium allows for the holding of particulate matter as well as the fixation of microorganisms that are responsible for the oxidation of carbonaceous and nitrogenous substances, along with other things. Although no packing material has the ability to perform all of these functions completely, each medium has advantages that are useful in wastewater treatment [13].

2.7.1 Coconut Fibre as Filtration Media

The thin and smooth outer layer that surrounds a coconut is called the epicarp. This epicarp covers a middle layer called mesocarp consisting of fibres bound-up with reserve parenchyma's tissue. These fibres according to research have been found to be very effective when used as filtration media/filter packing materials [15]. Coconut coir fibre has been used by researchers as packing media in various anaerobic packed bed column reactors and has been observed to aid in the removal of nitrate- nitrogen which was studied in correlation with other components such as COD, Total Kjeldahl Nitrogen (TKN) and dissolved orthophosphate. A maximum removal of 97-99% nitrate-nitrogen removal was observed. The results obtained indicated that the organic support medium was as efficient in nitrate-nitrogen removal as conventional synthetic support medium with which it was compared in the study [8].

2.7.2 Sand as Filtration Media

Sand is the most widely used packing material used in the construction of filters used in the physical treatment of domestic greywater when the surrounding soil is adversely affected with a direct discharge of the wastewater without treatment as illustrated in Figure 5. A material that is sensitive to changes in the hydraulic loading rate is generally preferred [16].

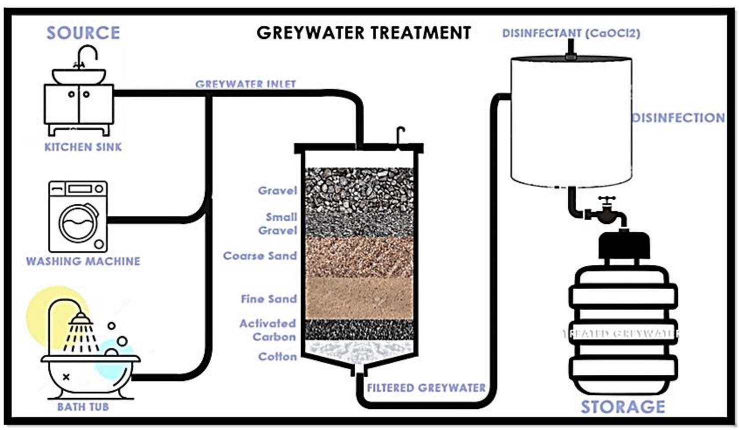

Fig. 6. Sand as Filtration Media

2.8 Water Quality Parameters

There are three types of water quality parameters physical, chemical, and biological.

2.8.1 Physical Quality

The physical quality of wastewater is generally given in color, turbidity, total solids, dissolved solids, temperature, suspended solids, odor, and taste [18].

Color: Pure water has no color. As a result, any color manifestation in water denotes water contamination. Foreign material frequently colors natural water systems. It's called apparent color when the color is caused by suspended particles. True color or real color refers to the color produced by dissolved material that persists after the suspended material has been removed [32].

Turbidity: Pure water is characterized by its transparency and its inability to absorb light. Consequently, the existence of turbidity in water signifies the presence of water contamination. Turbidity in water is influenced by a range of constituents, including suspended particles, dissolved substances, and microbial populations. Typically, the turbidity of water increases proportionally with the concentration of these constituents. Different materials, however, have varying capacities for absorbing light. Compounds that induce turbidity have the potential to pose risks to consumers. Consequently, water that is turbid is unsuitable for human consumption. In addition, it should be noted that turbidity has a detrimental effect on the efficiency of the disinfection process. Turbidity-causing compounds have the ability to retain toxic chemicals [32].

Taste and odor: Pure water is devoid of any discernible taste or odor. Consequently, the presence of any discernible taste or odor indicates the potential occurrence of water pollution. The development of flavor and odor in water can be attributed to both natural and artificial factors. The occurrence of taste and odor in water can be attributed to the disinfection process, specifically chlorination. Certain naturally occurring contaminants that are dissolved in water have the potential to impart distinct taste and odor characteristics. In aqueous solutions, inorganic salts such as sodium chloride (NaCl) and potassium chloride (KCl) elicit a distinct taste sensation. Conversely, some chemicals like hydrogen sulfide (H2S) can evoke both taste and olfactory perceptions. There is a potential health risk associated with the presence of compounds that impart taste and odor to water, as they may be hazardous to consumers. Therefore, it is recommended that drinking water be devoid of any discernible taste or odor [31-32].

Temperature: The potability (drinkability) of water is not determined based on its temperature. Temperature is a crucial physical factor that influences the quality of water in natural aquatic ecosystems, such as lakes and rivers. As the temperature increases, the solubility of oxygen in water decreases. In addition, with increasing temperature, aquatic microorganisms exhibit a higher rate of consumption of dissolved O2, resulting in a decrease in the quantity of dissolved O2. Temperature affects the disinfection process by decreasing disinfection efficacy at lower temperatures [32].

Foam: Water foams because foaming chemicals such as detergents and soaps breakdown in it. Because foam causes anaerobic conditions in natural water systems, it is considered harmful. Consumers are poisoned by some foaming substances. As a result, drinking water with foam is not recommended [31].

Conductivity: The conductivity of water is attributed to the presence of ionizable inorganic compounds. The electrical conductivity of clean water is quite low. In the case of distilled water, the electrical conductivity is 1 mho. Consequently, the quantification of conductivity provides insights on the concentration of ionizable inorganic substances present in water [32].
Total dissolved solid: The solid residue remaining in water following the filtration process, which is intended to remove suspended solids, is indicative of the total dissolved solids present. Dissolved solids in water can be classified into two categories: organic, which includes animal or plant waste, and inorganic, which encompasses various compounds such as carbonate, sulfate, and bicarbonate. The effects produced by these substances vary depending on the characteristics of the dissolved substance, encompassing attributes such as hardness, taste, and odor. According to a study [33], the presence of dissolved solids in water at concentrations over 300 mg/ltr has detrimental effects on both biological organisms and industrial goods.

2.8.2 Chemical Parameters of Water Quality

PH: The initial parameter to be assessed in the evaluation of water quality is the measurement of pH. The determination of water pH can be achieved through the utilization of a straightforward pH sensor or test kit, enabling the identification of the water's acidic or basic nature. Acidic water will consistently exhibit a higher concentration of hydrogen ions. In contrast, ordinary water has a higher concentration of hydroxyl ions. The pH scale encompasses a range of values spanning from 0 to 14. A pH reading of 7.0 indicates that the water is in a state of neutrality. Acidic values are characterized by a numerical measurement below 7.0, whereas alkaline readings are indicated by a numerical measurement over 7.0. The pH value of clean water is considered to be neutral. In contrast, precipitation has a somewhat higher level of acidity, as indicated by its pH value of 5.6. According to Nnaji et al., [34], water is considered acceptable for consumption when its pH falls within the range of 6.5 to 8.5.

Acidity: The pH value of distilled water is 7.0. In contrast, precipitation exhibits a slightly acidic nature, as evidenced by its pH value of 5.6. Water with a pH range of 6.5-8.5 is considered suitable for consumption. The alteration of pH levels can result in a diverse array of effects on both flora and fauna. The survival of most aquatic flora and fauna is contingent upon the presence of water with a specific pH level. Consequently, even minor fluctuations in pH can detrimentally affect their overall well-being. The presence of mildly acidic water can lead to irritation of fish gills, resulting in membrane damage and a reduction in the number of hatched fish eggs [34].

Alkalinity: Alkalinity is the parameter used to quantify the acid-neutralizing capacity of water. The primary purpose of assessing the alkalinity of a water sample is to ascertain the appropriate quantities of soda and lime required for the process of water softening. The utilization of water softening techniques is particularly advantageous in mitigating the occurrence of boiler corrosion. In the event that water possesses alkalinity, its pH level exceeds 7.0. The presence of bicarbonate, carbonate, and hydroxide ions has been found to contribute to an increase in the alkalinity of water [34].

Chlorine: Although chlorine is not naturally present in water, it is frequently employed as a means of disinfecting wastewater. Although elemental chlorine gas is toxic, its aqueous solution is considered safe for human use. The presence of a low concentration of chlorine in water indicates that the water is free from contaminants and has undergone a purification process. The determination of chlorine residual can be achieved by employing either a spectrophotometer or a color comparator test kit [34].

Hardness: Water exhibits hardness when it contains elevated concentrations of minerals. If the minerals present in the water are not addressed, they have the potential to precipitate and form scale deposits on the inner surfaces of hot water pipes. Individuals may have challenges while attempting to create lather with soap during a shower that utilizes water with a significant concentration of minerals. The primary factor contributing to water hardness is the occurrence of magnesium and calcium ions, which have the ability to infiltrate water from geological formations and soil. Typically, the mineral content of groundwater is greater in comparison to surface water, resulting in a higher level of hardness. The hardness of water can be determined with a colorimeter or test strip [34].
Dissolved Oxygen: This water quality statistic is important for evaluating the extent of pollution in rivers, lakes, and streams. When the concentration of dissolved oxygen is high, it can be confidently assumed that the water quality is excellent. The presence of dissolved oxygen is a result of the oxygen's ability to dissolve in a liquid. The level of dissolved oxygen (DO) in water is affected by various important elements, with salinity, pressure, and temperature being the most critical parameters. The measurement of dissolved oxygen levels can be conducted using either a colorimeter or the electrometric technique.
Biological Oxygen Demand: Microorganisms, such as bacteria, depend on organic matter as their source of nourishment. During the degradation of this substance, oxygen is consumed.

If this process occurs in water, the concentration of dissolved oxygen in a water sample will decrease. The existence of a significant amount of organic matter in water requires a big amount of dissolved oxygen to break down this organic substance [35].

2.8.3 Biological Parameters of Water

Bacteria: Bacteria, which are unicellular organisms, have the ability to consume nutrients and undergo fast reproduction under optimal conditions of water pH, food availability, and temperature. Due to the quick growth rate exhibited by bacteria, quantifying the exact quantity of bacteria present in a water sample is a highly challenging task. Typically, bacterial reproduction exhibits a reduced pace in lower temperature environments. Numerous aquatic diseases, such as cholera, tularemia, and typhoid, can arise due to elevated bacterial levels in water [35].

Algae: Algae are tiny organisms that require photosynthetic pigments in order to exist. These plants have the ability to sustain themselves by efficiently converting inorganic substances into organic matter through the utilization of solar energy. During this process, the algae consume carbon dioxide and emit oxygen. Algae are essential in wastewater treatment methods, such as stabilization ponds. Algae often give rise to unusual odours and unpleasant flavours, which are frequently reported as major concerns. It is important to note that certain types of algae can pose a risk to human health. Blue-green algae, such as cyanobacteria, possess the capability to cause the death of cattle [33-35].

Viruses: Viruses are minuscule biological entities capable of causing detrimental effects on an individual's well-being. Viruses can only be observed using high-powered electronic microscopes. In order to ensure their survival, all viruses are dependent on parasitic organisms. Viruses possess the capability to traverse the majority of filtration systems owing to their diminutive dimensions. Certain aquatic viruses have the potential to induce health complications such as hepatitis and other related ailments. Although there are inherent difficulties in treating viruses, it is generally expected that the majority of water treatment facilities possess the capability to effectively eliminate viruses through the process of disinfection. Understanding the three primary categories of water quality measurements can be advantageous in the context of water treatment and the elimination of diverse contaminants. A range of therapies can be implemented in cases when water exhibits severe turbidity, low pH levels, or a high bacterial count [35].

3 Conclusion

This study reviewed Grey water, treatments and various uses. Observations reveal that grey water adds up to 60–70% of the household wastewater produced. The dumping of grey water into bodies of water can lead to a rise in levels of contamination due to a decrease in dissolved oxygen and rapid microbial activity. Not only have the dangers of improper grey water management been recognized in recent years, but there is also growing international recognition that grey water reuse, when done properly, has the potential to serve as an alternative water source for purposes such as irrigation, toilet flushing, and some others.

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