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# Selection of optimal technique for greywater pretreatment

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**Abstract**
Greywater can be reused after treatment. Several techniques for treating greywater can be adopted. However, the selection of the optimal technique is a difficult action. Therefore, this study adopted an experimental approach to compare two different techniques to determine the optimal one. Two systems were designed and constructed to study the optimal technique for greywater pretreatment. The first system consists of a 5000L anaerobic fiberglass tank of 2.5m depth whereas the other system consists of 5 separated cylindrical tanks; each tank of 1000L fiberglass. The pH, biological oxygen demand (BOD5), total suspended solids (TSS), Total N, Total P, chemical oxygen demand (COD), total organic Carbon (TOC), SO4, Alkaline, Na+1, Ca+2, K+1, and water temperature for raw greywater and effluent from each tank were continuously measured for ten months. According to performance data, ineffective anaerobic bacteria weaken wastewater in septic tanks by roughly 30–40% while extremely effective aerobic bacteria do the same in protonated tanks by more than 93%. Compared to anaerobic bacteria, aerobic bacteria enhance the quality of greywater that exits a septic tank. The present study exposed the nitrification of waste through aerobic treatment of greywater using ozone and air (1:1 volume %) to reduce odor, COD, TSS, and BOD5 and remove nitrogen.



*Keywords*: Water treatment, Greywater, Optimal technique, Pretreatment, Aerobic and anaerobic

## 1. Introduction

Nowadays, human needs are almost limitless [1] [2]. The demand for resources increases with the increase in world population every year [3] [4] [5]. However, this adversely affects the environment [6] [7] [8]. Therefore, finding some ways to overcome such problems is required [9] [10]. Among all resources, water is the most important demanded material [11] [12] as it is used in all industries in addition to its major usage (personal human uses such as drinking and washing) [13] [14]. With this increase in demand, the reuse of greywater can be a good solution to provide sufficient quantities of demanded water [15] [16]. Greywater reuse can support sustainability [17] which is considered one of the most effective strategies in the world to solve recent global problems [18] [19]. Several ways can be adopted to treat wastewater to be suitable for reuse [20] [21]. The drive to eliminate minute organic pollutants and to adhere to stricter disinfection standards has led to the employment of ozone (O3) during the treatment of wastewater [22] [23]. The O3 capacity to oxidize a range of medications, personal care items, and other trace organic pollutants during wastewater treatment has been demonstrated in several investigations [24]. In secondary and tertiary treated effluents, coliform disinfection by O3 has been shown in several investigations [25]. High dissolved organic carbon (DOC) concentrations, however, can lead to an increase in O3 demand, faster O3 decay rates, and hydroxyl radicals scavenging (HO), which can reduce the O3 process efficiency in wastewater applications [26]. EfOM, or effluent organic matter, is the term used to characterize the DOC in treated wastewater [27].

On filter treatment effectiveness, microbiology, and NOM transformation, ozonation prior to filtration can have a favorable effect [28]. Preozonation is critical to obtaining good reductions of NOM from surface water because filtering alone can only remove 5-25% of NOM [29]. Ozone typically improves the biodegradability of NOM, boosting biological activity in the filter and BOM removal. Long-chain chemical compounds are converted into shorter-chain molecules, which are more readily biodegradable, in order for them to function. In more detail, it was discovered that ozonation of NOM created low molecular weight compounds capable of supporting bacterial growth composed of facultative anaerobic or obligate aerobic bacteria with strong and varied heterotrophic capacities [30]. Preozonation thereby raises the NOM's BDOC concentration, increases the elimination of UV absorbance, and also changes NOM into forms that are more hydrophilic and have a lower potential for THM production [31]. This demonstrates unequivocally that ozonation is beneficial in enhancing NOM's biodegradability. Since filtration alone often does a poor job of removing TOC, the winter months are when the impacts of ozonation on TOC reduction are most noticeable. In fact, preozonation increased TOC reduction in cold water (8 Co) by 220% as opposed to warm water (>8 Co) by 75%. Preozonation is therefore crucial for optimum NOM removal in the slow sand filter under cold water conditions.

In a wastewater treatment plant, ozone can be used to disinfect effluent, lower COD, remove BOD, increase DO, lessen color and odor, and reduce turbidity, among other things [32]. Additionally, secondary sludge can be treated with ozone to oxidize it and cause partial or total organic volatilization [33]. Ozone's special qualities make it a valuable asset in the treatment of wastewater [24]. First, chlorine has half the potential of ozone, a strong oxidizing agent. Ozone can be predicted to oxidize substances more thoroughly than chlorination [34]. Additionally, ozone is a very effective germicide. With less sensitivity to pH and temperature than chlorine, this action produces a more reliable bactericidal effect with shorter contact durations. Third, as a reaction product of ozone, which increases DO, beneficial oxygen is left behind. Fourth, products that have been partially or fully oxidized tend to be less hazardous than chlorinated or unreached species [30].

This study intends to achieve greywater on-site treatment to produce effluent within the irrigation standards based on the ideas presented in the preceding paragraphs. The methodology followed a number of steps. Pollutant physical removal is first accelerated by a pilot plant that implements the anaerobic-aerobic bio treatment concept consisting of an internal (design) structure work by decreasing the settling distance. Monitoring the performance of the pilot plant in terms of the operational circumstances is the second (time of the operational cycle, discharge time, flow direction, and aeration techniques). The third step is to characterize the effluent and sludge quality and test the effluent's appropriateness for irrigation at the pilot plant's maximum removal capacity. In this study, three distinct ideas for storing and treating greywater were evaluated. (1) A system operated at varying input rates and volume of liquid reactor with constant outflow rate. (2) A system operated in fed-batch/batch mode at varying inflow rates over the day. (3) A system operated with a constant volume of liquid reactor, 1-day HRT.

## 2. Experimental work

The first system is a 2.5-meter-deep, 5000-liter fiberglass septic tank. The septic tank's velocity is slowed as greywater from the house enters it, causing heavier solids to sink to the bottom and lighter materials to float to the surface (Figure 1). Some of the organic particles in this tank are broken down by anaerobic bacteria, which are constantly present in greywater. The middle of the septic tank's clarified wastewater is displaced into the leaching bed where it continues to be treated by the earth.

A four-phase aerobic therapy system (ATS) is used as the second method. An ATS may be added to an existing septic tank to further process the primary effluent in the first phase, which consists of two fiberglass tanks connected in series, each tank with a capacity of 1000L, to remove large solids and other undesirable substances from the greywater. This stage functions similarly to a septic system. The aerobic bacteria in the second step, which includes an aeration stage, decompose the biological wastes in the greywater. The third phase comprises a settling stage to allow for the sedimentation of any uneaten solids. The sludge that results from this must be routinely cleaned from the system. The fourth phase comprises the disinfection stage when water and chlorine are combined to create an antiseptic output.

When a sterile effluent is needed, such as when the effluent is distributed above ground, the disinfection stage, which is optional, is used. Typically, waste treatment systems use calcium hypochlorite tablets, which are designed specifically for disinfection. After the effluent is spread, stabilized forms of chlorine will continue to exist and can damage the plants in the leach field, avoiding non-digestible substances because they will accumulate in the system and necessitate more frequent sludge removal.

The suspended growth aerobic systems (SGAS), which are designed to withstand continuous flow without providing a bed for a bacterial film and instead rely on bacteria suspended in the greywater, were employed in a 1000 L fiberglass cylindrical tank. An ozone generator was fed through the aeration chamber, providing a constant stir of the greywater in addition to the oxygenation, which is how suspension and aeration are generally delivered. The generated bio-mat is reversed by the lowering of the TOC, COD, BOD5, and TSS. Additionally, effluent containing lots of aerobic bacteria and dissolved oxygen flows to the distribution component and breaks down the bio-mat. Because the effluent from an aerobic system using an ozone agent is of greater quality than that from a septic tank, the leach field can be smaller.

## 3. Effluent quality

The quality is crucial since the effluent from an ATS is either released onto the surface of the leach field or used in pretreatment operations. When used properly, a typical ATS will generate effluent that has a biochemical oxygen demand (BOD) of less than 40 mg/liter, a total suspended solids content of 100 mg/liter, and a BOD of 10,000 cfu/mL for fecal coliform bacteria. This area is so clean that a bio-mat or slime layer, like in a septic tank, cannot grow there. A well-functioning system will produce wastewater that smells musty but not like sewage. ATS effluent is comparatively odorless. Since most septic tanks lack oxygen, aerobic bacteria quickly disappear in anaerobic tanks, leaving the anaerobic bacteria to handle waste breakdown. As a result, the majority of septic tanks have an anaerobic atmosphere. Because aerobic bacteria produce 20 times or more energy from the same amount of organic material as anaerobic bacteria and reproduce and consume organic material at an explosive rate, there is a significant difference between their ability to break down organic material and that of anaerobic bacteria. According to the findings, the regulated aeration process significantly lowers the amount of organic waste that leaves the septic tank—by at least 90%.

Therefore, the air is injected into the treatment tank and circulated there by aerobic treatment units. Bacteria that thrive in oxygen-rich conditions work to break down and digest the greywater inside the aerobic treatment unit. Aerobic systems treat greywater utilizing natural processes that need oxygen. Greywater is stage-by-stage treated by aerobic systems. Before being released back into the environment, the treated greywater leaving the unit needs to undergo additional treatment or disinfection.

## 4. Pretreatment

To lessen the amount of particulates in the greywater entering the aerobic unit, a strainer is used. Grease, oils, and other substances that are flushed into the system or dumped down the drain are considered solids. An excessive amount of solid material can block the unit and inhibit efficient treatment, according to ongoing monitoring. Septic tanks, principal settling compartments in pretreatment units, and trash traps are a few examples of pretreatment techniques. Performance of a unit is improved by mixing. By combining ozone and air, the aeration chamber introduces oxygen. A 5g O3/h ozone generator was used efficiently with 50% air. Greywater's organic components are combined with the bacterial population during aeration, allowing the bacteria to attack and break down the organic components. The immersed tank and sprinkler system chamber reintroduces sludge that has settled at the bottom of the tank into the aeration tank.

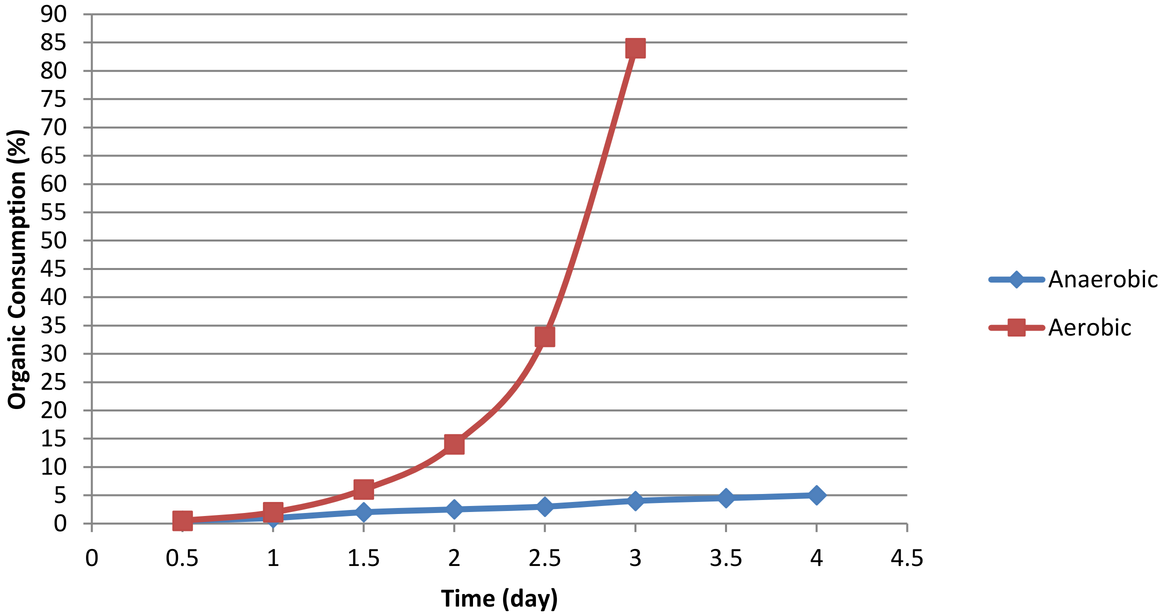


Figure 1. Growth rates for aerobic and anaerobic bacteria

## 5. Treatment systems

Grease, oils, toilet paper, and other solids and foreign items are collected in a pre-treatment tank where greywater enters to lessen the amount of solids that enter the aerobic tank. An overabundance of solids can block the system and lead to problems. The aerobic tank receives the greywater after it has been compressed and pushed with air and ozone to promote the growth of good bacteria that break down the solids. The fluid next goes into a settling or clarifying tank where any sediments that weren't completely digested by the bacteria could settle. The pump will receive a signal to discharge the water to another treatment system from a float valve inside the pump tank. Ordinarily, installing and maintaining aerobic systems doesn't cost much more than doing so with traditional septic systems. The aerobic units are hurt by grease.

## 6. Results and discussion

### 6.1. Greywater constituents in pretreatment

A mixture of inorganic and biological materials makes up greywater. Fecal matter, fats, soaps, greases, detergents, and food particles are all examples of organic compounds, which are molecules based on carbon (such as garbage grinders area). The bacteria in the septic system may easily break down these big organic compounds. To break down large molecules into smaller molecules, and ultimately into carbon dioxide and water, oxygen is necessary.

The first experimental septic tank's sewage treatment is anaerobic because the sewage entering the tank contains so much organic waste that any oxygen is destroyed. However, a large portion of the BOD in sewage (particularly detergents and oils) goes to another treatment system or leaching field. Some organic matter is eliminated in the septic tank by anaerobic digestion and by sediments that sink to the septic tank bottom. BOD fosters the development of the microbial bio mat that grows beneath the leaching field because it is a food supply for bacteria. In both positive and bad ways, this. In both positive and bad ways, this. A healthy bio-mat is desired on the one hand because it can get rid of a lot of the bacteria and viruses that found in the sewage.

Most BOD fragments in the sewage is likewise broken down by the microorganisms in a good bio-mat. However, an excessive amount of BOD can promote uncontrollable bacterial development in the bio-mat. The bio mat can turn anaerobic if the BOD fragments is elevated that all the current oxygen is used (or if the leached field is inadequately aerated, as can happen in an unvented leaching field placed under pavement or deeply buried).

Because of the death of the beneficial bacteria and protozoans as a result, the ability of bio-mat to treat sewage is reduced. Anaerobic microorganisms also flourish in the low oxygen environment of bio-mat (bacteria that grow without oxygen). By supplying a supply of ozone with air during the treatment process, BOD may be easily removed from greywater. Ozone transforms to oxygen, which promotes bacterial development and breaks down the organic BOD.

Aeration tanks that actively oxygenate the greywater by zonation are efficient enhanced treatment units that lower BOD. BOD is used as a food supply for the denitrification of bacteria that are required in systems that use bacteria to remove nitrogen. In these circumstances, BOD is desired because both nitrification and denitrification processes need enough BOD to sustain the bacterial growth that carry out the process to work effectively.

Large amounts of suspended organic and inorganic materials are typically found in domestic greywater. The main reason why this suspended material should not be used is that greywater can carry it. Due to their size, most suspended solids have the potential to block the tiny pore spaces between media in the secondary treatment or between the grains of soil in the facility of leaching. To minimize TSS, a variety of different techniques are employed, most frequently settling compartments/filters made of sand or different media.

The septic system contains nitrogen in a variety of forms. Most of the nitrogen excreted by people is organic nitrogen, which includes proteins, amino acids, and dead cell matter, as well as urea. The microbes in the septic tank quickly and fully convert this organic nitrogen after it enters the tank to ammonia, or NH3. The main form of nitrogen leaving the septic tank is ammonia. When oxygen is present, bacteria convert ammonia to nitrate, or NO3, which is a byproduct.

Ammonia is biologically converted in two steps to nitrogen gas. Prior to nitrate being reduced to nitrogen gas, ammonia is oxidized to nitrate. These processes frequently take place in different parts of the greywater treatment system because they require various conditions. It is obvious that any treatment system of wastewater that intends to extract nitrogen through the nitrification/densification process must be built with both aerobic and anaerobic zones to allow for the successful completion of both nitrification and denitrification.

Human greywater typically contains roughly 10 mg/liter of phosphorus, on average. The three main types are orthophosphates, polyphosphates, and phosphorus that is bonded to organic matter. When these substances are biologically broken down, organically bound phosphorus, which comes from human and animal waste, is transformed into orthophosphates. As much as half of the phosphates in greywater come from polyphosphates, which are used in synthetic detergents.

Nowadays, automatic dishwasher detergent and human waste account for many domestic phosphate inputs. Orthophosphates can be produced by hydrolyzing polyphosphates. As a result, although other forms of phosphorus may occur, orthophosphates are thought to be the main source of phosphorus in greywater. The negative ions PO43-, HPO42-, and H2PO4- make up orthophosphates. These could combine chemically to produce certain effects (positively charged ions).

### 6.2. Greywater pretreatment

Sewage treatment is primarily a biochemical process where living microorganisms change the sewage's chemical composition. Diverse conditions encourage the development of various populations of microbes, which influences the effectiveness, outcomes, and thoroughness of sewage treatment. Sewage treatment systems, whether they use conventional septic systems or more sophisticated treatment applications, aim to manage the sewage treatment process by establishing particular biochemical conditions.

As sewage is treated, three fundamental types of biochemical reactions take place. Firstly, the elimination of organic debris that is soluble. Most of the sewage's BOD content is made up of carbon-dissolved compounds such as detergents, greases, and bodily wastes. Secondly, the insoluble organic materials digestion and stabilization takes place. The remaining portion of the BOD is made up of these sewage solids, which include food and bodily waste. Inorganic substances that are soluble, such as nitrogen and phosphorus, are transformed as the third step.

The terms "aerobic" and "anaerobic" refer to the two main biochemical conditions used for sewage treatment. An aerobic environment is one where there is enough dissolved oxygen available for microorganisms to thrive and respire without being constrained by a lack of oxygen. When dissolved oxygen is either absent or present at extremely low concentrations that prevent aerobic metabolism, the environment is said to be anaerobic. The microbial community that processes sewage has a major impact on the ecology of the biochemical environment. Most food chains of bacteria, rotifers, and protozoans are often supported by aerobic conditions. These microorganisms digest organic matter via a variety of aerobic respiration-based metabolic pathways, with carbon dioxide as the primary byproduct.

In systems that remove nitrogen, aerobic sewage treatment is primarily utilized to lower BOD and nitrify waste in order to later denitrify it. Most aerobic treatment units are built to support sewage with extra oxygen to maintain the aerobic nature of the treatment process because the BOD in raw greywater is often high and available oxygen is quickly absorbed by the sewage. Use prolonged aeration in an aerobic system to more thoroughly digest the solid waste.

Greywater is treated in a batch reactor with solids removed by settling; the treated sewage is aerated, mixed, and allowed to settle for an anaerobic period (this process may be repeated several times on the same batch). The final batch of sewage is pumped out after treatment is finished, and the next batch enters the unit to start treatment.

### 6.3. The effect of anaerobic pretreatment on $BOD_5$ and COD

The biological oxygen demand (BOD5) removal efficiency of an aerobic treatment system's wastewater shows that it increased over time, rising from 17.79% after two days of treatment to 53.70% after twelve. The measurements of influent BOD5 ranged from (246-398 mg/l) with an average of 305 mg/l, while the effluent values of BOD5 ranged from (184-211 mg/l) with an average of 201 mg/l. The average removal efficiency was 32%.

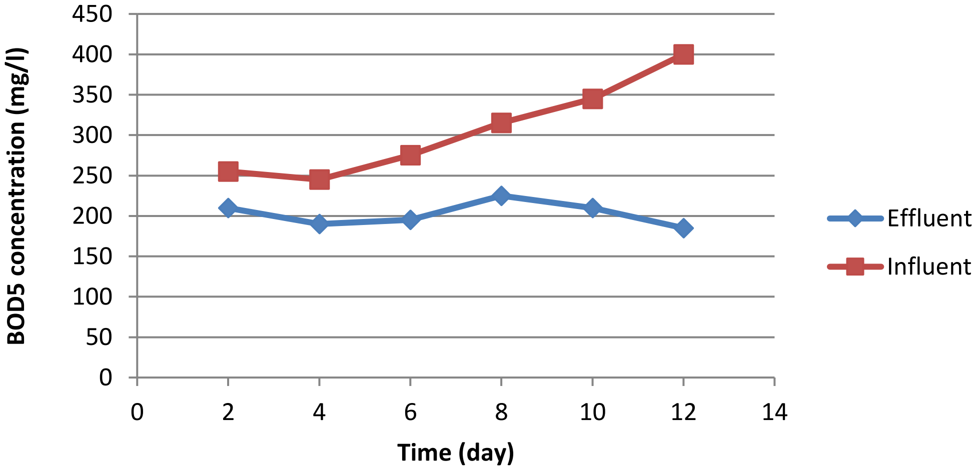


Figure 2. The effects of anaerobic pretreatment on biological oxygen demand in different operational times

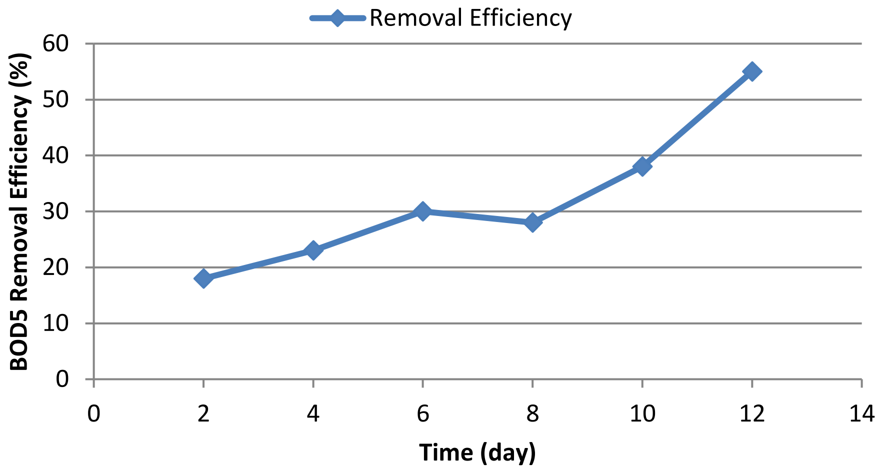


Figure 3. The effects of anaerobic pretreatment on removal efficiencies for biological oxygen demand in different operational times

Figure 4 and Figure 5 demonstrate the effect of anaerobic pretreatment on COD, the result shows the variation in the influent and effluent COD concentrations and the results were (296-447mg\l) with an average of 4305.5mg\l, and (198-287mg\l) with average 230.5 mg\l for influent and effluent respectively. While the average removal efficiency is 32%.

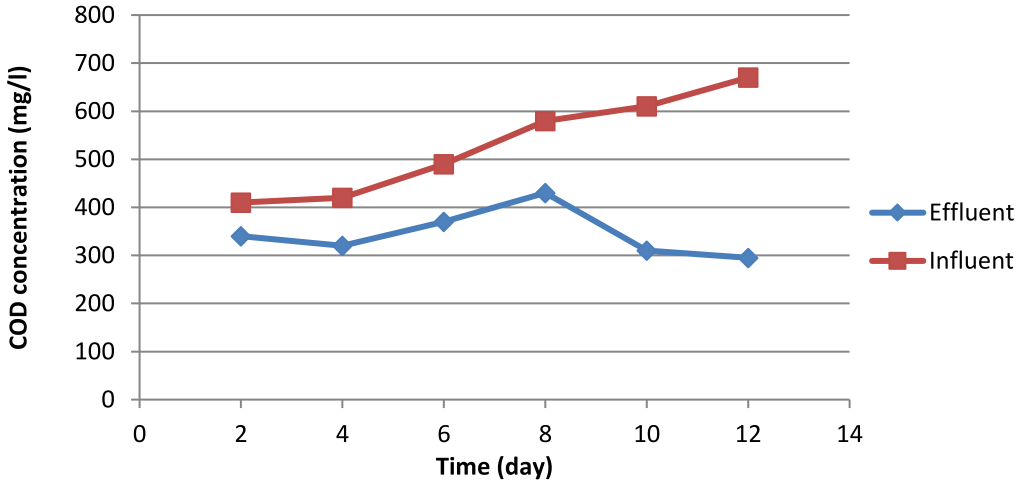


Figure 4. The effects of anaerobic pretreatment on chemical oxygen demand in different operational times

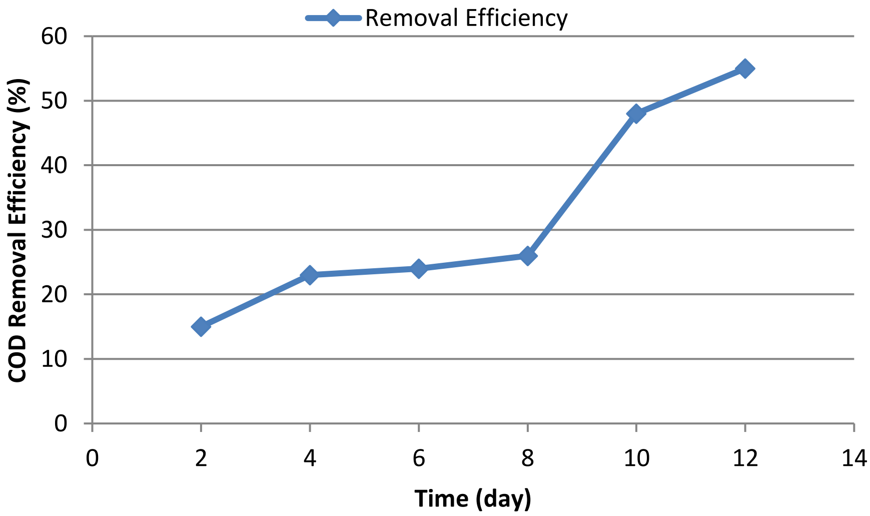


Figure 5. The effects of anaerobic pretreatment on removal efficiencies for chemical oxygen demand in different operational times

### 6.4. The effect of aerobic pretreatment on $BOD_5$ and COD

According to BOD5 results, elimination effectiveness rises over time, from 40.7% after eight hours of treatment to 76.5% after thirty-two. Sets of studies on the effluent BOD5 ranged from 72 mg/l to 165 mg/l with an average of 112 mg/l, and the average removal efficiency was 58%. The influent BOD5 ranged from (278 mg/l to 306 mg/l) with an average of 271 mg/l.

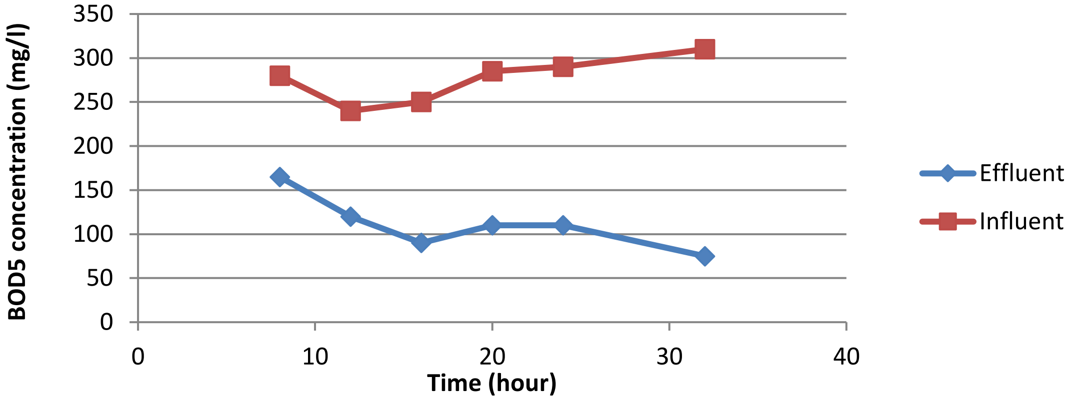


Figure 6. The effects of aerobic pretreatment on biological oxygen demand in different time

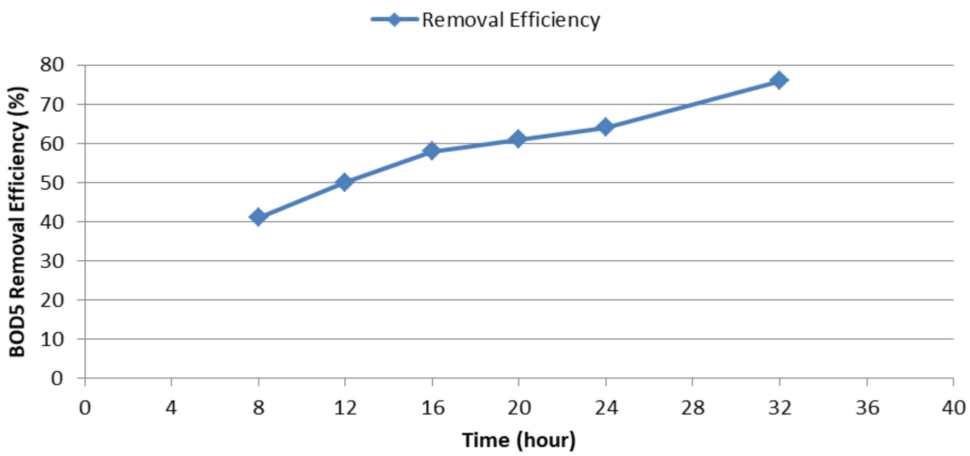


Figure 7. The effects of anaerobic pretreatment on chemical oxygen demand in different operational times

The effects of aerobic and preozonation pretreatment on COD are shown in Figures 8 and 9, which clearly show the variation in effluent COD concentrations. The range of COD was (303-418mg/l) with an average of 336mg/l and (113-201mg/l) with an average of 147.5mg/l for influent and effluent, respectively. However, the typical removal efficiency is 54%. Aeration and preozonation together can enhance BOD5 and COD, with removal efficiency increasing with time like in BOD5.

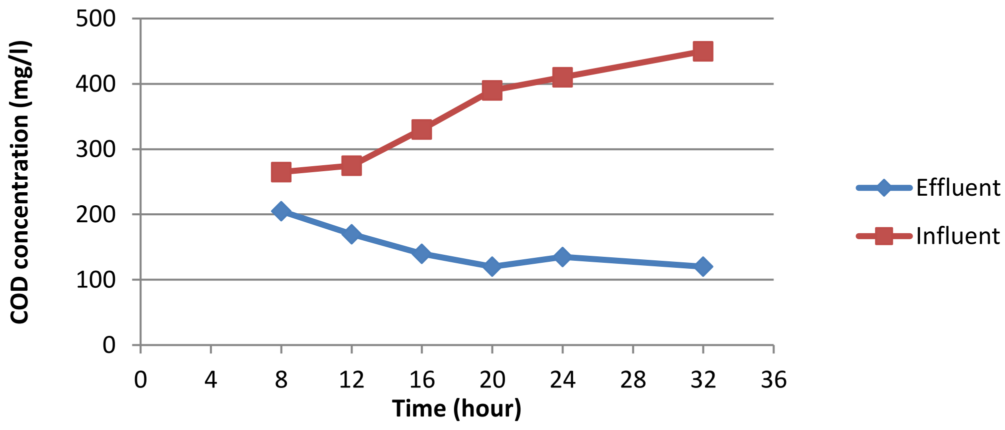


Figure 8. The effects of aerobic pretreatment on biological oxygen demand in different operational times

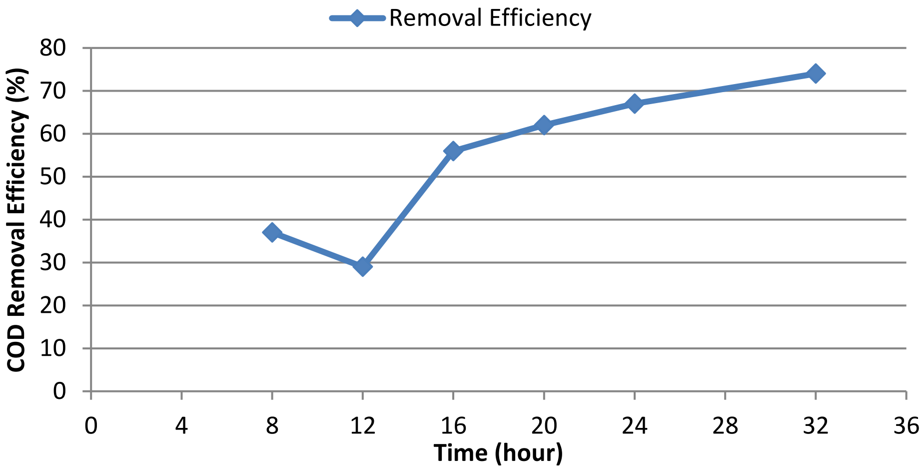


Figure 9. The effects of aerobic pretreatment on chemical oxygen demand in different operational times

Since most of the organic pollutants in wastewater are biodegradable and can be broken down by bacteria, the quality of the wastewater has gotten better over time, and the removal efficiency for BOD5 and COD is near.

## 7. Conclusions

- The smell of rotten eggs, corrosive hydrogen sulfide gas, and methane are all products of anaerobic septic systems.
- Because the greywater treatment process uses a living ecosystem of microbes to break down the waste products in the water, using too much bleach or antibiotics can harm the ATS environment and lessen the efficacy of the treatment.
- Compared to anaerobic bacteria, aerobic bacteria enhance the quality of greywater that exits a septic tank.
- Nitrification of waste through aerobic treatment of greywater using ozone and air (1:1 volume %) to reduce odor, COD, TSS, and BOD5 and remove nitrogen (denitrified).

### Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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