Evaluation of gray water treatment with pilot filter for irrigation purposes

Batool H. Ibraheem1,2, Musa Habib Alshammar1,3and Husam H. Alwan 1,4

1University of Karbala/College of Engineering, Iraq
2 batoolkarbala0@gmail.com
3 drmuhabib@uokerbala.edu.iq
4 hussam.hadi@uokerbala.edu.iq

Abstract. Warming and water scarcity are issues that attract global interest. In particular, it is vital to reduce the demands on supplies of fresh water. This study investigates the use of gray sewage from domestic and restaurant settings for agricultural purposes, following treatment and purification using simple and available techniques. The reduction of agricultural fertilizer use is a secondary economic purpose: ideally, a suitable economic target for society can be achieved. In this study, purification was achieved by filtering gray water using system of sand filtration (sand and gravel) with the use of other materials to increase the effectiveness of treatment. These other materials included coal, active carbon, bentonite, pomegranate peel, and chlorine. Each substance was used individually and chemical tests were conducted on the gray water. The results of the chemical tests were pleasing and can be summarized as: PH 7.1-8.7; EC 1298-2590mg/l; TDS 415-965mg/l; turbidity 45-108); temperature 12.3-24.6 deg. C; Ca2+ 59.12-160.32mg/l; Mg2+ 7.32-79.79mg/l; Na+ 1 141.6-518.6mg/l; SAR 5.4-16.6; K 9.6-38.2mg/l; SO4 302-854mg/l; CaCO3 104-169mg/l; NH4-N 16-28.627mg/l; T-P 0.639-10mg/l; BOD5 17-68mg/l; COD 117-1300mg/l. Total coliforms were 10-280000 cfu/100 ml.

Keywords: Active carbon, gray water, irrigation water, pilot filter, primary treatment.

1. Introduction

The demands for water continually increase due to population growth without the addition of any new resources. The lack of water has, in recent decades, inspired researchers to create the strategies for water management and these have included water recycling techniques. The treated gray water is one such method, and its potential to fulfill non-potable water needs merits investigation [1]. Wastewater treatment and reuse for irrigation may well hold the key to reducing demands made on limited freshwater reserves, while improving the diet and production capacity of households and farms [2]. However, there are concerns about the security of wastewater reuse for irrigation purposes. The key issue is the potential for damaging effects caused by low quality water to soils, plants and humans. Agricultural water need not be of drinkable quality, which opens the door to wastewater and surface water irrigation, but the microbial population of untreated water is highly variable, and may include dangerous organisms [3]. Microorganisms that can cause illness or similar adverse effects are collectively known as pathogens. Irrigation water contaminated with pathogens has often been blamed for outbreaks of food-borne disease. It is important to manage this risk efficiently when promoting the reuse of non-potable water sources to fulfill the water requirements of agricultural irrigation activities [4].
The design of a greywater treatment system primarily hinges on water quality, the quantity to be treated, and the reuse applications [5]. Water treatment involves a series of successive operations to ensure that water is eventually obtained in accordance with internationally-approved standards and specifications. The process of filtration is one of the most important, most widespread and frequently used processes, and is applied in large purification plants that are concerned with the basic treatment as well as smaller stations and small and domestic units that are interested in secondary treatment. The process examined in this study has gained this importance because of the role it plays in improving the physical, chemical and even biological water specifications [6].

2-Materials and Methods

2.1 Gray Water
Gray water is the water that comes from sources like bathtubs and laundries; it is distinguished by the fact that it does not contain organic matter. This differentiates it from black water, which comes out of toilets. Gray water does not contain feces or manure [7]. Gray water can be reused, particularly in agriculture, being less contaminated than black water. Gray water can be used intensively, particularly in irrigated fields, after treatment because it contains a range of plant nutrients and components from washing and bathing. There is a global trend to reuse this water in irrigation because of the great effect this may have on providing water and thereby enhancing the availability of drinking water from its natural sources. This is done by recycling gray water, using methods that rely upon mechanical and biological means. There are many benefits in recycling gray water, including the saving of drinking water and natural water resources by re-using water for agriculture. The recycling of gray water also eases the load on sewers and water collection sites, and can provide human use of agrarian fertilizers. In addition to this, the provision of water indirectly lessens expenses for the individual [8].

2.2 Gray Water Reuse Guidelines
The reuse and reclamation of gray water should fulfill four criteria: aesthetics, hygienic safety, economical feasibility, and environmental tolerance [9]. The various reuse applications require different water quality specifications and thus, they request various treatments, ranging from modest processes to more advanced ones. Standard rates for gray water observing vary by country. Very few reuse guidelines were prepared with gray water recycling in mind [10]. In practice, most nations apply the same standards to reclaimed domestic wastewater as they do to gray water. However, some nations have built up particular norms for gray water reuse, such as Germany, Australia, Japan, Jordan, and the UK. Table 1 shows examples of standard values for gray water reuse from the UK, Japan, and Jordan. The variance observed between reuse criteria reflect differences in applications, social factors, and need [11].

The World Health Organization (WHO) published guidelines for gray water reuse in 2006 [2]. This publication was considered a significant shift towards wastewater and gray water reuse. The guidelines were based on the Stockholm framework, which combines risk management and risk assessment to control water-related ailments [12]. This guideline outlines microbiological requirements without considering the other chemical and physical parameters. Moreover, the guidelines no longer give water quality standards, but instead describe the appropriate health protection measures that are needed to achieve health-based aims [2]. As one out of numerous choices to lessen hazard related with gray water the WHO guidelines refer to treatment, rather than defining water treatment as the sole option for reusing gray water. Health protection measures such as withholding periods between water application and harvest, crop restriction, and hygienic food handling and food preparation practices can reduce the hazards associated with gray water without going through the choice of advance treatment according to the WHO guidelines. However, the implementation of these guidelines has faced some obstacles [13],
as it needs full cooperation and understanding by all stakeholders to manage and assess the risks. Therefore, in 2015 the WHO improved sanitation safety planning methods and published these in a manual that covered the safe use and disposal of wastewater, gray water, and excreta [14].

Table 1. Gray water reuse standards in the UK, Japan and Jordan (Reference : [15]; [16]; [17]).

| a) UK greywater standards (BS 8525)[1] | Spray application | Non-spray application |
|---------------------------------------|-------------------|----------------------|
| Parameter | Pressure washing, garden sprinkler use and ear | WC flushing | Garden watering | Washing machine use |
| E.coli (number/100ml) | Not detected | 250 | 250 | Not detected |
| Intestinal enterococci (number/100ml) | Not detected | 100 | 100 | Not detected |
| Turbidity NTU | <10 | <10 | Not available | <10 |
| pH | 5.9.5 | 5.9.5 | 5.9.5 | 5.9.5 |
| Residual Chlorine (mg L⁻¹) | <2.0 | <2.0 | <2.0 | <2.0 |
| Residual bromine (mg L⁻¹) | 0.0 | 0.0 | 0.0 | 0.0 |

| b) Japan[2] | Toilet flushing | Landscape irrigation | Environmental (aesthetic settling) | Environmental (limited public contact) |
|-----------------|-----------------|----------------------|------------------------------------|----------------------------------------|
| pH | 5.8-8.6 | 5.8-8.6 | 5.8-8.6 | 5.8-8.6 |
| Turbidity NTU | Not unpleasant | Not unpleasant | ≤10 | ≤5 |
| BOD₅ (mg L⁻¹) | ≤ 20 | ≤ 20 | ≤10 | ≤3 |
| Residual Chlorine (mg L⁻¹) | ≤ 0.4 | | | |
| Total Coliform (number/100ml) | ≤ 1000 | ≤ 50 | ≤1000 | ≤50 |

| c) Jordanian greywater standards (JS1767:2008)[3] | Irrigation | Trees and fodder irrigation “restricted irrigation” | Landscape and vegetables to be eaten cooked | Vegetables to be eaten uncooked | Toilet flushing |
|-----------------|-------------|-----------------------------------------------|-----------------------------------------------|----------------------------------------|-----------------|
| Parameter | COD (mg L⁻¹) | TSS (mg L⁻¹) | pH | NO₃ (mg L⁻¹) | TN (mg L⁻¹) | Turbidity | E.coli (number/100ml) | Egg nematodes (number/IL) |
| BOD₅ (mg L⁻¹) | 300 | 500 | 150 | 60 | 40 | 50 | 60 | ≤ 10 |
| COD (mg L⁻¹) | 60 | 70 | 70 | 70 | 70 | 70 | 70 | ≤ 10 |
| TSS (mg L⁻¹) | 120 | 100 | 50 | 50 | 50 | 50 | 50 | ≤ 10 |
| pH | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | ≤ 10 |
| NO₃ (mg L⁻¹) | 60 | 50 | 50 | 50 | 50 | 50 | 50 | ≤ 10 |
| TN (mg L⁻¹) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | ≤ 10 |
| Turbidity | 25 | Not available | Not available | Not available | Not available | Not available | Not available | ≤ 10 |
| E.coli (number/100ml) | Not specified | 10 | 10 | 10 | 10 | 10 | 10 | < 10 |
| Egg nematodes (number/IL) | ≤ 1 | ≤ 1 | ≤ 1 | ≤ 1 | ≤ 1 | ≤ 1 | ≤ 1 | < 10 |
2.3 Treatment method

To store and use raw gray water, treatment is a prerequisite. Untreated gray water reuse would present dangers to the health and wellbeing of people and their environments, hence it must be treated to attain a higher standard before reuse [18]; [10]; [19]. The objective of treatment is to conquer aesthetic, health, and technical problems that can be brought about by organic matter, pathogens, and solids, and to meet reuse guidelines [19]. Various studies have been conducted on the treatment of gray water, with various technologies that differ in both performance and complexity [10].

In this research, the gray water treatment process was carried out using a standard sand filter made of galvanized iron with dimensions of 80 cm * 12 cm * 12 cm. The choice of dimensions and characterization of the filter were chosen for test work in laboratory, and used of five layers of sand and gravel with certain gradations. The height of each layer was 12 cm and the setup contained a vessel at the top for the purpose of collecting water. The treatment system contained a valve control for the passage of water before it entered the filter, as shown in Figure 1. The second part of the equipment comprised a cubic tank for the purpose of collecting water after filtration. Various materials were used to increase the quality of the treatment and improve the properties of the water out of the filter, and these will now be described.

First, coal was used as charcoal powder in the form of small granules similar to the type used in filter filters for drinking water. It was placed under the second layer of gravel at a height of 6 cm. Second, active carbon was used, whereby a 3 cm-thick layer was placed below the first layer of sand. Third, the peel of pomegranates was used, with a layer thickness of 6 cm, in the form of a fine powdered bottom layer of gravel. Fourth: Bentonite was mixed with gray water before passing to the filter at 5 g per liter. Fifth: Chlorine was mixed 5 ml per liter with gray water after exiting the filter. Each material was used separately between the layers of filter (sand and gravel). The chemical properties of the water coming out of the filter were examined and compared with arable water.

![Figure 1. Filter section and its gradients.](image-url)
3-Results and discussion

3.1 Grain Size Analysis

The analysis of the sand and gravel used in the sand filter was carried out according to Iraqi Standard 1555 for the year 2000, and the first amendment of 2002 for the sand and gravel of the filters. The determined gradients of the aggregate are shown in Figure 2 and Figure 3. Regarding uniformity coefficient, coefficient of curvature and sorting coefficient, the results were as follows:

For sand:
- Uniformity coefficient \((U_c)=1.210\)
- Coefficient of curvature \((C_c)=0.994\)
- Sorting coefficient \((C_t)=1.104\)

For gravel:
- Uniformity coefficient \((U_c)=3.20\)
- Coefficient of curvature \((C_c)=0.722\)
- Sorting coefficient \((C_t)=1.863\).

![Figure 2. Sieve analysis for sand.](image1)

![Figure 3. Sieve analysis for gravel.](image2)
3.2 Water Quality Analysis

This test replicated patterns used in most water treatment forms, and used gray water from two sources, namely a house and an eating establishment. In this paper, examination of key parameters, namely PH, EC, TDS, turbidity, temperature, CaCO₃, Mg+2, Na+1, Ca+2, SAR, K+1, SO₄−2, NH₄−N, T-P, BOD₅, COD, and coliform content, was conducted between November 2018 and April 2019. Table 2 and Table 3 provide the results.

| parameter | Raw gray water | Use of filter only | Raw gray water | Use of coil | Raw gray water | Use of Active carbon |
|-----------|----------------|--------------------|----------------|-------------|----------------|----------------------|
| pH        | 7.3            | 8.7                | 7.6            | 8.6         | 7.7            | 7.4                  |
| EC(μs)    | 1315           | 2050               | 1325           | 1886        | 1370           | 2155                 |
| TDS(mg/l) | 740            | 965                | 691            | 790         | 714            | 946                  |
| Temp.( °C) | 16.9          | 15.5               | 21             | 12.3        | 23             | 14.7                 |
| Turbidity | 54             | 76                 | 50             | 98          | 65             | 50                   |
| COD(mg/l) | 326            | 128                | 310            | 117         | 338            | 168                  |
| BOD5(mg/l)| 63             | 27                 | 61             | 28          | 68             | 24                   |
| K+(mg/l)  | 11.5           | 24.4               | 14.5           | 29.6        | 15.2           | 38.2                 |
| Na+(mg/l) | 171            | 203.4              | 179            | 240.1       | 180.2          | 209.8                |
| Ca+2(mg/l)| 76.1           | 100.2              | 72.3           | 120.2       | 80.3           | 160.32               |
| Mg+(mg/l) | 20.9           | 14.6               | 22.7           | 79.79       | 19.8           | 7.32                 |
| SAR       | 6.313          | 7.088              | 6.631          | 5.87        | 6.577          | 6.21                 |
| Caco3(mg/l)| 154           | 140                | 151            | 137         | 158            | 133                  |
| So₄−2(mg/l)| 634.6        | 301.6              | 644.1          | 325.4       | 650.3          | 318.8                |
| T-Po4(mg/l)| 0.639        | 1.921              | 0.699          | 4.484       | 0.824          | 3.844                |
| NH4-N(mg/l)| 21.248       | 20.451             | 22.218         | 19.224      | 22.541         | 25.084               |
| Total Coliforms (cfu/100 ml) | 280000 | 240000 | 280000 | 45000 | 280000 | 30000 |

Table 2. The results of tests of water from house.

| Parameter | Raw gray water | Use of bentonite+ chlorine | Raw gray water | Pomegranate peel+ chlorine |
|-----------|----------------|---------------------------|----------------|----------------------------|
| pH        | 7.5            | 8.5                       | 7.1            | 7.4                        |
| EC(μs)    | 1350           | 2590                      | 1330           | 1298                       |
| TDS(mg/l) | 704            | 787                       | 693            | 631                        |
| Temp.( °C) | 24             | 20.3                      | 24             | 21                         |
| Turbidity | 55             | 103                       | 52             | 45                         |
| COD(mg/l) | 315            | 160                       | 318            | 158                        |
| BOD5(mg/l)| 60             | 23                        | 58             | 21                         |
| K+(mg/l)  | 13.5           | 19.2                      | 12.4           | 16.4                       |
| Na+(mg/l) | 177            | 462.3                     | 188.7          | 172                        |
| Ca+2(mg/l)| 78.1           | 120.24                    | 82.4           | 82                         |
| Mg+(mg/l) | 21             | 19.52                     | 18.9           | 15.5                       |
| SAR       | 6.473          | 14.538                    | 6.875          | 6.441                      |
| Caco3(mg/l)| 140           | 133                       | 155            | 141                        |

Table 2. … (Continued).
Table 3. The results of tests for restaurant water.

| Parameter          | Raw gray water | Use of filter only | Raw gray water | Use of coil | Raw gray water | Use of Active carbon |
|--------------------|----------------|--------------------|----------------|-------------|----------------|-----------------------|
| 1 pH               | 7.4            | 7.1                | 7.3            | 7.1         | 7.2            | 7.6                   |
| 2 EC (µS)          | 1450           | 1667               | 1550           | 2336        | 1430           | 2110                  |
| 3 TDS(mg/l)        | 756            | 446                | 767            | 709         | 743            | 817                   |
| 4 Temp. (°C)       | 16.5           | 17.2               | 22             | 15.2        | 24             | 17.1                  |
| 5 Turbidity(NTU)  | 104            | 57                 | 98             | 86          | 108            | 90                    |
| 6 COD(mg/l)        | 1295           | 433                | 1200           | 330         | 1300           | 363                   |
| 7 BOD5(mg/l)       | 39             | 31                 | 45             | 19          | 43             | 18                    |
| 8 K+(mg/l)         | 9.6            | 19.9               | 11.5           | 15.4        | 12.13          | 17.2                  |
| 9 Na+(mg/l)        | 171.6          | 181.9              | 173.4          | 150         | 179.41         | 141.6                 |
| 10 Ca+2(mg/l)      | 60.9           | 104.2              | 65.4           | 80.21       | 59.12          | 77.4                  |
| 11 Mg+(mg/l)       | 26.3           | 22.9               | 24.1           | 9.27        | 27.33          | 15.9                  |
| 12 SAR              | 6.520          | 6.196              | 6.563          | 5.965       | 6.819          | 5.402                 |
| 13 Caco3(mg/l)     | 160            | 114                | 166            | 130         | 166            | 117                   |
| 14 So4\(^-2\)(mg/l) | 596.1         | 329.2              | 588.1          | 332.1       | 601.12         | 323                   |
| 15 T-Po4(mg/l)     | 1.281          | 2.561              | 1.542          | 15.87       | 1.124          | 9.609                 |
| 16 NH4-N(mg/l)     | 26.627         | 25.929             | 25.142         | 18.143      | 26.241         | 28.231                |
| 17 Total Coliforms (cfu/100 ml) | 280000 | 280000            | 280000         | 240000      | 280000         | 160000                |

Table 3. … (Continued).

| Parameter          | Raw gray water | Use of bentonite+ chlorine | Raw gray water | Pomegranate peel+ chlorine |
|--------------------|----------------|----------------------------|----------------|----------------------------|
| 1 pH               | 7.9            | 8.7                        | 7.5            | 7.8                        |
| 2 EC (µS)          | 1680           | 1841                       | 1650           | 1550                       |
| 3 TDS(mg/l)        | 490            | 576                        | 480            | 415                        |
| 4 Temp. (°C)       | 23.5           | 17.1                       | 24.6           | 22                         |
| 5 Turbidity(NTU)  | 100            | 79                         | 107            | 56                         |
| 6 COD(mg/l)        | 1212           | 330                        | 1233           | 200                        |
| 7 BOD5(mg/l)       | 44             | 18                         | 40             | 17                         |
| 8 K+(mg/l)         | 13.2           | 20.3                       | 10.5           | 15                         |
| 9 Na+(mg/l)        | 189.1          | 518.6                      | 185.6          | 163.2                      |
| 10 Ca+2(mg/l)      | 63.9           | 120.28                     | 64.9           | 60.2                       |
| 11 Mg+(mg/l)       | 23.8           | 16.6                       | 20.2           | 18.5                       |
| 12 SAR              | 7.226          | 16.576                     | 7.269          | 6.652                      |
| 13 Caco3(mg/l)     | 169            | 104                        | 156            | 112                        |
| 14 So4\(^-2\)(mg/l) | 594.3         | 420.6                      | 608.8          | 314.5                      |
| 15 T-Po4(mg/l)     | 1.861          | 7.686                      | 2.432          | 10                         |
| 16 NH4-N(mg/l)     | 28.627         | 15.996                     | 27.129         | 18.1                       |
3.2.1 Raw gray water

Tables 2 and 3 show the characteristics of raw gray water, which is variable and contingent upon the number of beds, occupants, health status, age, tap water sources, lifestyle, pattern of water use and domestic products used (such as soap, shampoo, detergent, lotion, toothpaste, hair dyes, shaving cream, and body oils) [20]. It can be noted that most of the values of the household gray water are less than their counterpart values for the restaurant water.

3.2.2 Gray water after treatment

The results of the treatment of gray water using different materials showed an improvement in some properties. In contrast, some values were higher than they had been before treatment. Generally, most of the values fell within the acceptable limits of water used for agriculture and there were no very significant differences in most measured values, except for some properties such as total coliforms. The number of samples tested was 10 samples for each type of treated water (house water and restaurant water). The tests were conducted in the laboratories of the college of Civil Engineering and Environmental Laboratories. The most important results were: TDS 415-965 mg/l; BOD5 17-31 mg/l; SAR 5.40-16.6; SO₄²⁻ 302-854 mg/l; NH₄-N 16-28 mg/l; total coliforms 280000-10 cfu/100ml.

3.2.3 Comparison of materials used in treatment

The materials used in the treatment of gray water with sand filter proved to be effective in improving most of the properties of gray water. The chlorine was added in the last two stages of treatment to eliminate the total coliforms found in the water; chlorine has been proven effective in treatment, as the percentage of total coliforms reduced significantly, as Tables 2 and 3 show. Comparing the materials used in terms of obtaining the best results, there is a similarity or convergence in the obtained values, so the use of any of these materials with the filter sand can give the desired result.

3. Conclusions

The portable sand filters introduced in this article can be used for a wide range of applications, including single-family residences, big commercial establishments, and small communities. The separation of sewage water into gray water and black water reduces demands upon wastewater treatment plants and consequently, decreases the expense. The materials that have been used are simple, available and relatively inexpensive materials and have given good results. This wastewater is mainly suitable for watering, but it may affect plant species, as such saline water is acceptable to most plants apart from some citrus trees and other flowers and plants that cannot tolerate salts. The degree of turbidity does not affect the plants, but the high turbidity affects some irrigation systems such as sprinkler irrigation, where it leads to clogging of the sprays. As for the function of acidity or alkalinity, the results did not show a significant change in chemical treatment. For the physical, chemical and biological parameters of gray water: BOD5, NH₄ –N, COD, T-P and total fecal coliforms, these were of acceptable value and would not affect the soil or plants. There was an increase in the value of SAR when using bentonite, due to the containment of bentonite in a combination of elements of sodium, calcium, magnesium and potassium. In addition to other elements, all of the materials used proved to be very efficient in the treatment of gray water, and the use of sand filter only without any additions itself improved many properties of gray water.
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