International Journal of Environmental Trends (IJENT)
http://dergipark.gov.tr/ijent

International Journal of Environmental Trends (IJENT)
2021; 5 (1),7-15
ISSN: 2602-4160
Turkish JournalPark ACADEMIC

Research Article

Grey water characterization in terms of sustainable water management and food safety

Hakan ÇELEBİ*[1]

[1] Aksaray University, Department of Environmental Engineering, Aksaray, Turkey (*ORCID Number: 0000-0002-7726-128X)*

Received
26 November 2020

Accepted
17 June 2021

Abstract

Water is not just a liquid consisting of H_2O for the life of all people, it is one of the basic components of nature in many aspects. Today, water is present in every product produced, from food to clothing, from automobiles to technological equipment. In addition, water plays an important role in ensuring food safety as well as being a beverage. Today, agricultural food production has the most important share in water consumption. Despite the increasing population, unplanned urbanization, global warming, agricultural use and growing economies, water resources that remain limited have an importance that will affect the future of the world. The way to reduce these risks is through efficient use of available quality water resources and water management. In this context, recycled wastewater should be used instead of potable water in agricultural irrigation. Gray water has a great importance and share in recycled wastewater. In particular, the ease of treatment and the lack of complex pollutant components increase the use of gray water from homes. In this study, gray water characteristics were determined for a pilot house selected in Aksaray province. The suitability for agricultural irrigation was evaluated according to the data obtained from the selected house. For this purpose, physical, chemical and microbiological analyzes were carried out on kitchen, shower/bath and mixed wastewater. According to the results, recommendations were made by making national evaluations for food safety and agricultural irrigation.

Keywords
Agricultural irrigation
Grey water
Water management
Wastewater

Sürdürülebilir su yönetimi ve gıda güvenliği açısından gri su karakterizasyonu

Özet

Su, bütün insanların yaşamı için sadece H_2O'dan oluşan bir sıvı olmayıp, birçok yönüyle doğanın temel bileşenlerinden birisidir. Bugün gıdadan giyime, otomobilden teknolojik ekipmanlara, üretilen her üründe su bulunmaktadır. Ayrıca, su bir içecek olmanın yanı sıra gıda güvenliğinin sağlanmasında da önemli bir rol oynamaktadır. Günümüzde, su tüketiminde en önemli payı tarımsal gıda üretimi almaktadır. Artan nüfus, çarpık kentleşme, küresel ısınma, tarımsal kullanım ve büyüyen ekonomilere rağmen sınırlı kalmaya devam eden su kaynakları, dünyanın geleceğini etkileyecek bir öneme sahiptir. Bu riskleri azaltmanın yolu mevcut kaliteli su kaynaklarının verimli kullanılmasından ve suyun yönetilmesinden geçmektedir. Bu kapsamda, tarımsal sulamada içilebilir nitelikteki sular yerine geri kazanılmış atıksuların

Anahtar Kelimeler
Tarımsal sulama
Gri su
Atıksu yönetimi
Atıksu

kullanılması gerekmektedir. Geri kazanılan atıksular içerisinde gri suyun önemi ve payı büyüktür. Özellikle, arıtımının kolay olması ve kirletici bileşenlerinin karmaşık olmaması evlerden kaynaklanan gri suyun kullanımını arttırmaktadır. Bu çalışmada, Aksaray ilinde seçilen pilot bir ev için gri su özellikleri belirlenmiştir. Seçilen evden elde edilen verilere göre tarımsal sulamaya uygunluğu değerlendirilmiştir. Bu amaçla, mutfak, duş/banyo ve karışık atıksulara fiziksel, kimyasal ve mikrobiyolojik analizler gerçekleştirilmiştir. Sonuçlara göre, gıda güvenliği ve tarımsal sulama için ulusal ölçekte değerlendirmeler yapılarak öneriler sunulmuştur.

International Journal of Environmental Trends, *5* (1), 07-15. DOI: not now possible

[1] Corresponding Author Email: hakanaz.celebi@gmail.com

INTRODUCTION

Water is an irreplaceable source of life cycle for all living creatures. High quality water resources in the world are gradually decreasing due to reasons such as unplanned urbanization, excessive population growth, emissions of greenhouse gases and inordinate technological industrialization [1,2]. Even though a large part of the world is surrounded by water resources, only 3% of these resources are of high quality and drinkable. As seen in Fig. 1, 97% of the world's water consists of salt water. Even though usable water resources -considering their characteristics- are so scarce, water consumption rates are increasing rapidly. In addition, the growing industrial area and the irrigation water requirement of the agricultural sector increase this rate even more. Turkey as well as all over the world is very high demand for irrigation water for agricultural purposes. With the rapid increase in the population of societies, agriculture develops to meet the nutritional needs and therefore the irrigation need of agricultural areas increases. In addition, water plays an important role in ensuring food safety as well as being a beverage. Agricultural techniques applied in food production and the quality of irrigation water affect food safety. Today, when water consumption is taken into consideration, agricultural food production leads the way. In order to provide the needed irrigation, the water source used must be of sufficient quantity and quality. In this context, alternative water sources (recycled wastewater) should be used in agricultural irrigation instead of potable water [3,4]. In particular, the use of treated wastewater in agricultural irrigation after meeting the specified standards is one of the preferred alternatives in order to eliminate the demand for new water resources [5,6]. In this context, it is necessary to identify methods for reducing water consumption rates and to develop water saving models and recycling techniques for usable wastewater (grey water) for sustainable water and wastewater management. In terms of sustainable water management and food safety, the reuse of wastewater not only contributes to the protection of the environment and natural resources, but also is a sustainable resource. Reuse of treated wastewater has benefits such as protection of quality and potable water resources or water and fertilizer savings in agriculture. In addition, these waters are not only used in the agricultural sector, but also in recreational areas (park, garden, golf, etc.), industries (boiler water, cooling water, etc.) or for the needs of aquifers or animals (Figure 1) [7,8]. Whether the recycled water is suitable for agricultural use depends on many variables and its suitability should be determined according to the standards. At this point, characterization of these waters needs to be done in every aspect. Grey water has a great importance and share in all recycled wastewater. Especially, the fact that its treatment is easy, and its pollutant components are not complex increases the use of grey water, which is a domestic wastewater.

Figure 1. Schematic representation of the possible environmental effects of grey water characterization.

According to EN 1085 standard, wastewater originating from housing and other small business (such as schools, hospitals), and due to the needs and uses of people in daily life activities is defined as domestic wastewater [9]. Domestic wastewater is mainly handled in two ways as grey water coming from a house (shower, sink, laundry and dishwashing water) and black water (wastewater from toilets containing urine and feces). Grey waters can be divided into two categories as less and more dirty grey waters [10,11,12]. Less dirty grey water refers to wastewater from showers, bathrooms and sinks, while heavily dirty grey water refers to wastewater from kitchen and washing machines [13,14]. Grey water constitutes the largest percentage of domestic wastewater with a share of 75%. Grey water is formed as a result of the contamination of mains water used in homes with chemicals. The content of grey water varies depending on the standard of living, social and cultural habits, the number of people living in the house and the chemicals used in the house [15,16]. Pollution caused by contaminants in water is the result of kitchen habits, personal hygiene products, detergents, dirty clothes and body grime. In this study, grey water characteristics for a pilot house selected in Aksaray province were investigated. Its suitability for agricultural irrigation was evaluated according to the data obtained from the selected house. For this purpose, physical, chemical and microbiological analyzes were carried out for three different grey water (kitchen, shower/bathroom, mixed). According to the results, recommendations were made on a national scale in terms of food safety and agricultural irrigation.

MATERIAL AND METHOD

Samples were collected from three different grey water sources (kitchen, shower/bathroom, mixed) from the house determined in Aksaray province and characterized according to physical, chemical and bacteriological parameters. For the accuracy of the experiments and minimum error margin, triple sampling was performed for each grey water source and the results were given based on average values. Samples were collected and analysed in the three-month summer period within the scope of this study. Samples were generally taken at peak times between 07:00 and 10:00 in the morning and between 17:00 and 22:00 in the evening.
Factors such as pH, conductivity, suspended solids (SS), total phosphorus (P), total nitrogen (N), chemical oxygen demand (COD), turbidity were among the parameters examined. All parameters have been analysed according to the Standard Water and Wastewater Method 2017 [17]. On the purpose of characterization of wastewater, the pH, temperature and electrical conductivity values of the samples were measured with a digital portable device HANNA pH 211. COD and SS analyses were carried out according to SM-5220 D and SM-2540 C. Total and fecal coliform counts were made with 3M Petrifilm, by processing the nutrient media and the indicator prepared under sterile conditions between two films and putting directly into service of the user. Some parameters such as pH, temperature, turbidity and conductivity were measured at the grey water collection points. After the samples were collected, they were immediately transferred to laboratories of Environmental Engineering Department, Aksaray University for qualitative analysis. Samples were stored at 4 °C to prevent any physical or chemical change in the wastewater.

RESULT AND DISCUSSION

The quality and quantity of grey water is affected by a number of factors such as the habits and lifestyle of the building occupants, water source, geographic location, demography, plumbing system, and domestic or commercial use [18,19,20]. In addition, factors such as cleaning products used in dishwashing and laundry, personal care products, bath habits also affect the quality of grey water. Therefore, it is necessary to determine the parameters concerning the grey water quality. Because these parameters are of great importance in terms of human health, food safety, soil quality and plant development. Another important matter in the reuse of treated wastewater is to meet the water quality criteria required by the purpose of use [9,21,22].
Grey water characterization is carried out according to significant and critical parameters by which pollutants can be evaluated collectively. As wastewater characterization may vary from country to country, it may also differ within the same country depending on various factors as well. However, evaluations are made according to basic physical, chemical and biological parameters all over the world. In this study, firstly, physical parameters were examined. Then, the critical chemical and biological parameters for irrigation were evaluated. Temperature, turbidity and suspended solids (SS) are physical parameters, and the physical properties of three different grey water are summarized Figure 2, 3 and Table 1 and 2, where the comparison of irrigation water and water quality classes are included. Since temperature is a variable factor, measurements were made at the point where the sample was taken. Grey water can generally vary between 24-27 ^{0}C according to usage patterns [18,23]. Especially activities such as kitchen work, laundry and showering are among the causes of high temperatures. In Figure 2, the average temperature of grey water in kitchen (23 ^{o}C), shower/bathroom (22.8 ^{o}C) and mixed (kitchen, shower, washing machine) (23.5 ^{o}C) samples was measured as 23 ^{o}C. Figure 2 shows the turbidity change in different grey water sources. At the end of the analysis, turbidity values in kitchen (79.59 NTU) and mixed (60.93 NTU) grey water were found to be higher than shower/bathroom water (41.96 NTU). In this case, kitchen grey water is proving to be much more polluted. The change in suspended solids (SS) concentration is presented in Figure 2. As in the turbidity parameter, high SS concentrations were found in kitchen (242 mg/L) and mixed (167 mg/L) grey waters. Especially, the high SS value in kitchen grey water is due to the living habits of the household. EC values were measured around 1000 µS/cm in three greywaters as seen in Table 2 and Figure 2. In particular, Electrical Conductivity (EC) values were found to be 750 µS/cm, 863 µS/cm, and 807 µS/cm in kitchen, shower/bath and mixed greywater, respectively. According to Samayamanthula et al. (2019), EC values are calculated at high values for mixed-source greywaters [24].

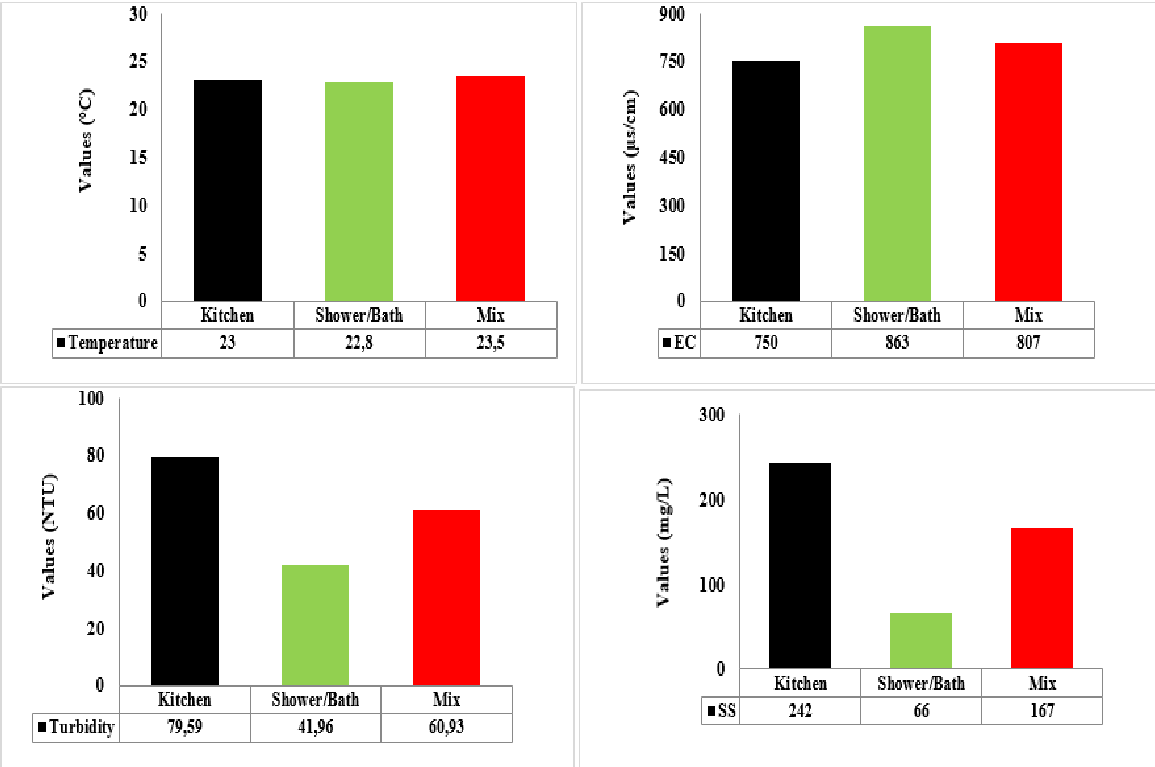

Figure 2. Physical parameters measured in grey water characterization

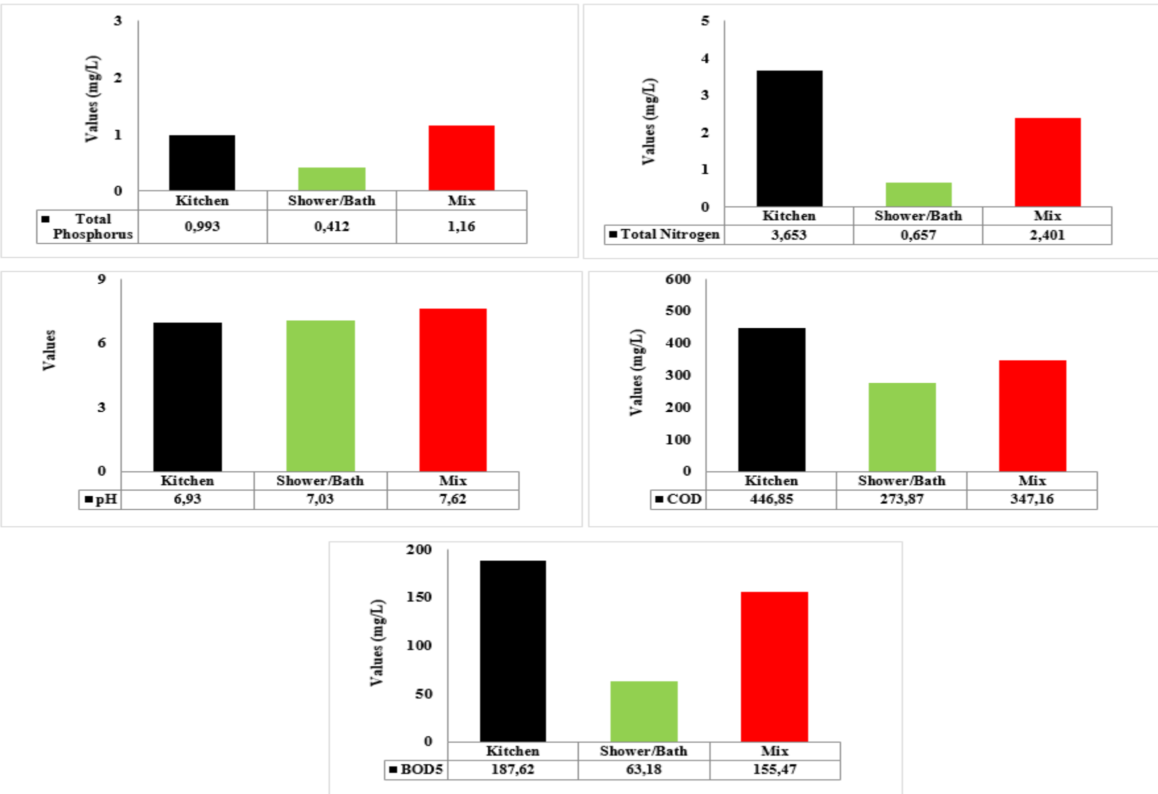

Figure 3. Chemical parameters measured in grey water characterization.

The pH changes of different grey water sources are shown in Figure 4. It was observed that the pH value was close to neutral value in all three sources. Especially, mixed grey water demonstrates higher pH values due to the presence of chemicals such as detergents. The pH values obtained in the study share similarities with the studies in the literature [18,25]. Also, higher pH levels negatively affect the disinfection process in grey water treatment.

However, the determined pH values were in compliance with the standards [26,27]. Figure 4 shows the BOD and COD changes detected from three different grey water sources. BOD and COD concentrations vary depending on the amount of water used and the amount of household products (especially detergent, soap and oil) consumed. In terms of BOD and COD, kitchen and mixed grey waters are richer in organic content than shower/bathroom water. When the analyses made were examined, it was even that especially COD concentrations in kitchen and mixed wastewater were high and have a very variable structure (Table 1). As a result, according to the wastewater analysis, COD concentrations for three different grey water were determined as 446.85 mg/L, 273.87 mg/L and 347.16 mg/L, respectively. Similarly, mean BOD concentrations in kitchen and mixed grey water were 187.52 mg/L and 156.48 mg/L, respectively, while shower/bathroom grey water had a mean value of 63.18 mg/L. Total nitrogen and total phosphorus, which are considered as nutrients, are important parameters [28,29,30]. The currently evaluated grey waters normally contain less nutrients than black water (Table 2). Especially grey water with high phosphorus concentration causes eutrophication. However, grey waters with low nitrogen and phosphorus concentrations provide an advantage in agricultural applications as they provide a fertilizer effect in irrigation purposes. Although the nitrogen level in grey water is low, the main source comes from kitchen waters. The main sources of phosphorus are personal care products and detergents. Accordingly, the values of the total nitrogen parameter in the kitchen, shower/bathroom and mixed wastewater examined in the study were 3.653 mg/L, 0.657 mg/L, 2.401 mg/L, respectively. Total phosphorus concentrations were 0.993 mg/L, 0.412 mg/L, and 1.160 mg/L, respectively. The pH values obtained in the study are similar to the studies in the literature [31,32,33]. The most important parameter to be considered in the use of grey water in agricultural irrigation is the pathogen (Salmonella spp., Norovirus, Enterovirus, E. coli, Giardia, Pseudomonas aeruginosa, Staphylococcus aureus, Clostridia, Rotavirus, etc.) organisms [34,35]. These pathogens in the water have the potential to cause disease in concentrations that have values above the standards. Especially, agricultural land workers and their families, collectors and consumers are at risk. Within these pathogen groups, viruses, bacteria and protozoa show an acute effect since they stay in the environment for a short time. However, helminths pose a risk due to their long stay in the environment. Among all of these, E. coli is generally the most frequently detected pathogen in grey water analysis [36,37]. No growth was observed in total and fecal coliform analyses performed with 3M Petrifilm, which strengthens the utility of grey water that goes to sewer as direct irrigation water. The fact that no microorganism was detected in the study may be due to the fact that instantaneous samples were taken from three different grey water sources and analyses were performed without waiting. Appropriate temperature, pH and time are required for the growth and reproduction of microorganisms. In addition, in previous studies, the total and fecal coliform numbers were not high [38,39]. Analysis results of the study and comparisons with national standards are given in Tables 1 and 2. The data included in the "Regulation on Monitoring of Surface Waters and Groundwater" numbered 28910 published in the Official Gazette and the "Communiqué on Technical Procedures of Wastewater Treatment Plants" numbered 27527 were evaluated in comparison. Table 2 shows the colours of the water quality classes of kitchen, shower/bathroom and mixed grey water. It also states that treated wastewater in Table 1 can be used as irrigation water and all three water sources should be treated according to the water quality classes specified in Table 2. According to the standards, the colour values specified with the names of blue-class I, green-class II, yellow-class III, red-class IV classify the waters in terms of quality and thus it is determined whether the water needs treatment.

Table 1. Comparison of the analysis results of the reuse criteria of treated wastewater as irrigation water

Parameters	Units	Our Study			Table E7.1 Class A[a]	Table E7.1 Class B[b]
		Kitchen	Shower	Mix		
pH	-	6.93	7.03	7.62	6-9	6-9
BOD_5	mg/L	187.62	63.18	155.47	< 20	<30
Turbidity	NTU	79.59	41.96	60.93	<2	-
SS	mg/L	242	66	167	-	<30
Fecal coliform	CFU/100 mL	0/100 mL	0/100 mL	0/100 mL	0/100 mL	<200

[a]Agricultural irrigation: Food products not processed commercially; b Agricultural irrigation: Processed food products

Table 2. Comparison of water quality classes and analysis results in terms of surface water resources

Water Quality Parameter	Units	Our Study			Water Quality Classes			
		Kitchen	Shower	Mix	I	II	III	IV
pH	-	6.93	7.03	7.62	6-9	6-9	6-9	6-9
EC	(µS/cm)	750	863	807	< 400	1000	3000	> 3000
COD	mg/L	446.85	273.87	347.1	< 25	50	70	> 70
BOD_5	mg/L	187.62	63.18	155.4	< 4	8	20	> 20
Total N	mg/L	3.65	0.66	2.40	< 3,5	11,5	25	> 25
Total P	mg/L	0.99	0.41	1.16	< 0,08	0,2	0,8	> 0,8

I: (very good); II: (good); III: (moderate); IV: (poor)

CONCLUSION

The first and most important step to consider when determining the pollution load potential for a wastewater is to express the characterization of that wastewater. Characterization of wastewater can give an idea about the level of pollution load that will reach the treatment facility and in which sector it will be used. At this point, the use of grey water coming out of the houses is of great importance in terms of both production and food safety in the agricultural sector. Analyzes and evaluations made clearly show that the characteristics of three different grey water are affected by some certain factors such as individuals' lifestyle, source water's quality and climatic conditions. As a result of the characterization analysis, the general pollution potentials of three different waters appear as kitchen> mixed> shower/bathroom grey water. For this reason, it would be advantageous to separate grey water as less and more dirty water. Nitrogen (kitchen: 3.653 mg/L, shower/bathroom: 0.657 mg/L, mixed: 2.401 mg/L) and phosphorus (kitchen: 0.993 mg/L, shower/bathroom: 0.412 mg/L, mixed: 1.160 mg/L) content in different grey water sources is limited, and these low concentrations provide a fertilizer effect in food production. On the other hand, since higher temperatures may cause an increase in bacterial growth, the temperature obtained from all three sources is at the optimum level. As a result, according to the wastewater analysis, it was revealed that kitchen and mixed grey water is more polluted than shower/bathroom grey water. The obtained chemical analysis values show that using grey water directly as irrigation water without treatment will pose a risk. Therefore, the use of grey water after treatment will be more beneficial for human health, irrigation water and soil quality, food safety and also for other ecological environments to keep them clean. Instead of using high quality drinking water as irrigation water, the consumption of drinking water can be reduced, and natural water resources can be protected by using treated grey water that is not of drinking water quality. With the on-site package treatment plant for grey water, the amount of wastewater discharged to the sewerage will decrease, so the pollution load and initial investment costs of the treatment facilities will also decrease.

ACKNOWLEDGMENT

This research study was undertaken in the Wastewater Laboratory at Aksaray University Environmental Engineering Department, Turkey.

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