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Use of Zeolite in the Removal of Surfactants in Gray Waters and Plant Growth

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Abstract The decline of freshwater resources due to rapid population growth, industrialization, and wrong agricultural practices in the world has become the major problem of mankind. Along with water scarcity, which is one of the major problems of the 21st century, the occurrence of food problems will be a major threat to humanity in the near future. For this reason, it is of great importance that wastewater is treated and used to redress the water need in order to manage water resources in a sustainable way. Many methods used in the treatment of wastewater require a long time and have a high cost. In order to prevent the waste of freshwater resources, gray water was used for plant cultivation in the first phase of this project. In the second part, a setup consisting of zeolite and glass pipe was prepared for the filtration of gray water. The treated water was obtained by filtration of gray water with zeolite. The water obtained as a result of filtration was used in plant growing. As a result of experimental studies, the usability of gray water and treated water has been determined in the cultivation of horticultural crops such as grass as well as foods such as potatoes, beans, chickpeas. 3 months of water consumption has been determined for a garden of 80 square meters. Based on the data, in the third part, a treatment unit was designed for apartments to generalize the use of gray water obtained from houses after filtration with zeolite.

Keywords Filtration, gray water, water consumption, Zeolite

Introduction

The clean water resources in the world are rapidly depleting. The reasons for this are rapid population growth, technological developments, and the negative effects of global warming. As a result of the use of wrong irrigation methods in rural areas, the underground water level gradually decreases, the chemical wastes used in agriculture pollute the groundwater by mixing with the soil, and the evaporation resulting from unconscious irrigation increases water losses. In urban areas, water problems arise as drinking and utility water deficiencies and water pollution. These problems have led to the increasing importance of clean water resources day by day [1].

One of the biggest problems of the 21st century is water scarcity. It is thought that water scarcity will be one of the most sensitive environmental issues in the coming years due to the uneven distribution of resources, treatment and climate change events. The gradual decrease in water resources in the world brings the treatment and reuse of wastewater to the agenda. Increasing pressure ABOUT water in terms of scarcity and deterioration of water quality has gained importance in evaluating reclaimed water as a new water source. Environmental and economic benefits and also reclamation technologies offer opportunities for wastewater reuse. It is possible to meet the industrial, urban, agricultural water needs by recycling wastewater [2].

Among the priority tasks of global and regional cooperation are the effective and sustainable management of water resources and the prevention of ecological hazards. The increasing gap between natural water resources and water requirement has brought about the reuse of wastewater by treating it. The reuse of treated wastewater instead of clean water in homes and industry reduces the cost of clean water and wastewater disposal costs of the facility [3].

Domestic wastewater is defined as wastewater originating from small businesses such as housing, schools, hospitals, and caused by the needs and uses of people in their daily life activities. Domestic wastewater is evaluated in two parts as gray water and black water. Water from showers, baths, washbasins, washing machines and dishwashers is defined as "gray water", while the remaining toilet water is defined as "black water". Gray water is divided into two as slightly polluted gray water and highly polluted gray water. Slightly polluted gray water includes wastewater from showers, baths and sinks, and heavily polluted gray water includes wastewater from kitchens and washing machines. Gray water constitutes the largest percentage of domestic wastewater by volume with a share of 75% [4].

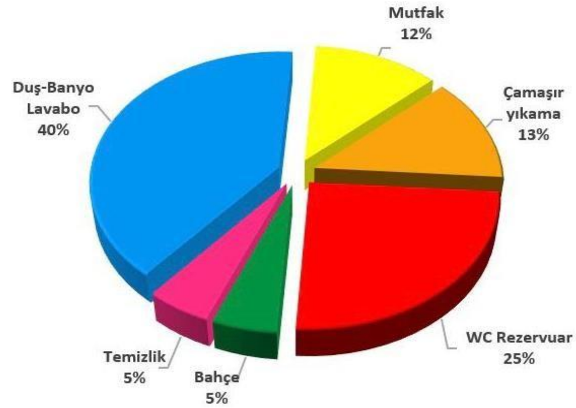

Figure 1: Daily Domestic Water Consumption Rates [4]

Pollution in gray water is caused by the personal hygiene products used, detergents, dirty clothes and body dirt (Table 1) [5].

Table 1: Contaminants formed by the source of gray water [6]

Source of Gray Water	**Contaminants**
Washing machine	Suspended solids, organic matter, oil and grease, salinity, sodium, nitrate, phosphorus (from detergent), bleach, pH
Dishwasher	Suspended solids, organic matter, oil and grease, increased salinity, pH, bacteria and detergent
Bathtub-Shower	Bacteria, hair, suspended solids, organic matter, oil and grease, soap, shampoo residues
Sink (including kitchen)	Bacteria, suspended solids, organic matter, oil and grease, soap,

Chemical parameters of gray water include dissolved biological oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), nitrogen, phosphorus, pH, alkalinity, heavy metal content, salinity, oil and grease, surfactants, and other chemical parameters household chemicals [5].

Biological Oxygen Demand (BOD) is a parameter used to determine the number of organic substances that can be decomposed by microorganisms in water and expresses the amount of oxygen required to decompose these substances [7]. Chemical Oxygen Demand (COD) is one of the most important parameters showing the degree of pollution in water and wastewater, and it expresses the amount of oxygen required for chemical stabilization of organic substances in wastewater [7]. Surfactants pass through the wastewater to the environment and cause environmental pollution; They are also substances used in many industrial processes. These substances cannot be separated by conventional methods such as transfer, filtration, coagulation and chlorination [8].

Wastewater must be treated in order to become usable. For the reuse of gray water, Treatment technologies such as Artificial Wetland (CW), Rotary Biological Reactors (RBC), Sequential Batch Reactors (SBR), Membrane Bioreactors (MBR), Electrocoagulation (EC) and Photocatalytic Oxidation are used. These technologies have advantages as well as disadvantages in terms of cost and efficiency [5].

Zeolite, known as "Boiling Stone", is also used in the treatment of wastewater, although it is not very common. Zeolite was first discovered in 1756 by Swedish mineralogist Freiherr Axel Fredrick Cronstedt [9, 10]. Zeolites are a mineral group consisting of hydrated natural silicates of alkalis and earth alkalis as a result of the alteration of volcanic ash in the aquatic environment over millions of years. In addition to more than 40 known natural minerals, there are also more than 150 synthetic minerals [11].

After the 1950s, zeolite formations began to be detected in the world. Major zeolite producing countries are Cuba, China, former USSR, Canada, USA, Japan, Italy, South Africa, Slovakia, Hungary, and Bulgaria. The zeolite formations generally observed in our country consist of Clinoptilolite and Analsim minerals. Analcime formations were determined for the first time in Turkey around Gölpazarı-Göynük. Later, analcime and clinoptilolite deposits were discovered in the west of Ankara [12, 13].

The only zeolite field that has been studied in Turkey is around Manisa-Gördes, which is licensed by the General Directorate of Mineral Research and Exploration (M.T.A). 18 million tons of visible zeolite reserves and 20 million tons of zeolitic tuff reserves have been identified in the field. The most important zeolite formations in Turkey have been identified in the Balıkesir-Bigadiç region and it is estimated that there are approximately 500 million tons of easily exploitable reserves. Although no detailed study has been carried out in other regions, it is estimated that the total reserves in our country are around 50 billion tons [14].

Zeolite is an aluminosilicate mineral consisting of an infinitely extensible three-dimensional network of tetrahedral AlO_4 and SiO_4, which are bonded to each other by sharing oxygen atoms. Their structure is similar to honeycomb, they contain exchangeable cations and water. The micropores between the units combine with the micro windows to form one-, two- or three-dimensional space systems and channels. The amount of space is between 20-50% of the total volume. It gives zeolite minerals the "molecular sieve" feature; It comes from liquid and gas molecules and alkaline earth ions that can easily enter and displace these spaces. Zeolites have a wide range of uses. E.g., due to its properties such as ion exchange, water and gas retention, it is among the areas of use in agriculture, fishing, cleaning of water, gas and radioactive residues, drying, solar energy and gas storage, odor control, building material and making good quality paper. [15].

Zeolite species have a significant potential for use in water and wastewater applications, especially in various areas such as heavy metal and hardness removal. On the other hand, natural zeolites are also used in the energy sector, agriculture and livestock sectors. Today, the most important environmental problems that countries need to solve are problems such as increasing the quality of drinking water with rapid population growth and industrialization, making wastewater reusable, or not harming the environment, and preventing air pollution. In our country, R&D studies continue to find solutions to environmental problems. In this sense, it is necessary to investigate the reserves, usage areas and technological properties of zeolite mines in our country [16].

The use of zeolite should be expanded in order to improve Turkey's cultivated lands and increase agricultural productivity. Zeolite is important in terms of giving water to plants in a measured way and acting as a cellar. Therefore, it is a natural resource that provides savings by stably adjusting water consumption [11].

In this context, in order to prevent environmental pollution in our country, the use of zeolite reserves in the field of water and wastewater treatment will also contribute to national capital. Although the treatment of gray water with zeolite is included in the literature, studies on the efficiency of the treated water in horticultural and vegetable growing have not been found. In this sense, it is thought that our study will set an important example for agricultural practices and economy and will fill the deficiency in this field.

While the need for water increases in the world due to drought, global warming, increasing population and industrialization, freshwater resources are decreasing. This decrease raises the issue of treatment and reuse of wastewater. In this study, it is aimed to investigate the usability of the gray water obtained from the washing machine and the purified water obtained as a result of the filtration of the gray water with zeolite in the cultivation of vegetables and horticultural crops, as well as the importance of water retention of the zeolite in water saving.

Material and Method

Zeolite: The 5-9 mm Clinoptilolite used in our study (Figure 2).

General structural formulas of zeolites: They can be given as $X[(M^{+}_{1},M^{++}_{1/2}).(AlO_2)]$. $ySiO_2$. zH_2O (Figure 3). M+ is a monovalent cation such as Na+ or K+,

M++ :Ca++ is a divalent cation like Mg++ and Ba++.

The mole ratio of SiO_2 / AlO_2 (y/x) varies between 1 and 5 depending on the zeolite type [14].

Figure 2: The 5-9 mm clinoptilolite zeolite we use

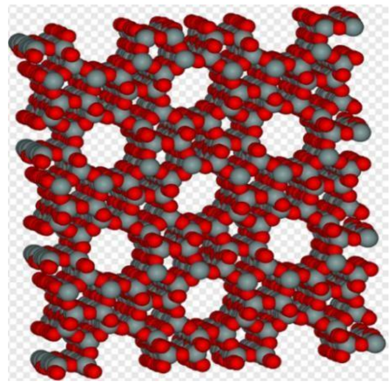

Figure 3: Chemical structure of clinoptilolite zeolite

Gray water: It was obtained by taking all of the washing and rinsing water from the washing machine (Figure 4).

Figure 4: Gray water extraction stage

Filtration assembly: The mechanism for filtration of gray water is a 3 cm diameter, 83 cm long glass pipe, a faucet and a leg (Figure 5).

Figure 5: Filtration assembly

Weight: A 1000 g capacity and 1 g precision weight was used to take the zeolite weights (Figure 6).

Figure 6: Weight

Beaker: Beakers with a volume of 700 ml were used to collect the purified gray water passing through the filtration device (Figure 7).

Figure 7: Beaker

Stages of experimental study;

- Supply of gray water
- Filtration process of gray water with zeolite
- Planning of controlled experiment
- Planting of plants
- The process of growing plants by irrigation with regular tap water, gray water, and zeolite water.
- The process of growing plants on which zeolite is placed by regularly irrigating them with tap water, gray water, and zeolite water.
- Photographing and making measurements while the plants are growing
- Drawing tables and graphs of the obtained data.

The gray water was supplied as a homogeneous liquid by connecting the washing machine drain hose to a carboy, taking it from the washing and rinsing water of the laundry and mixing it. Then, 350 g of zeolite (Figure 8) and 300 ml of gray water were added to the filtration device and the water passing through the device was filtered into the beaker drop by drop. Approximately 5 l of water was purified from a prepared setup.

Figure 8: Weighing the zeolite

Planning the Controlled Experiment

3 plantings were made for each plant variety. Control group plants were irrigated with tap water, 1st experimental group plants were watered with gray water, 2nd experimental group plants were irrigated with zeolite-treated gray water. Potatoes, beans, onions and grass plants were planted. The plants were watered every 3 days. The amount of water given to the plants is given in Table 2. Plant measurements were taken for 30 days after germination started.

Table 2: The amount of water given to the plants

	Grass	Zeolite-based Grass	Bean	Zeolite-based Bean	Onion	Potato
The amount of water	15 mL	12 mL	50 mL	25 mL	50 mL	40 L

Results and Discussion

Germination times were determined in all plant species. Height measurements were started after germination, and the day when measurements were started was determined as the 1st day.

Findings Obtained from the Experiment Process of Grass Plant

After sowing the grass, morphological examinations of seed germination and development were made, and measurements were taken. The findings are shown in Figure 9, Figure 10, Figure 11 and Table 3, Table 4.

Figure 9: First germination

Figure 10:10th day grass growth

Figure 11: 30th day grass growth

Figures 9, 10 and 11 show the morphological appearance of the grass plant at the first germination, 10th day and 30th day. Germination and growth were observed and measured periodically in control group and experimental group plants.

Table 3: Germination time of grass plant

Control group	Experimental groups	
Tap Water	**Purified Washing Machine Water**	**Washing Machine Water**
6 days	5 days	10 days

As observed in Table 3, the germination time of the plant irrigated with purified water was realized in a shorter time.

Table 4: Periodic height developments in the development process of the grass plant

	Tap Water	Purified Washing Machine Water	Washing Machine Water
1st Day	---	2.5 cm	---
3rd Day	1.5 cm	4 cm	---
5th Day	4 cm	7.5 cm	1 cm
10th Day	7 cm	10 cm	4 cm
15th Day	7.5 cm	10.5 cm	5 cm
20th Day	8 cm	11 cm	6 cm
30th Day	9 cm	12 cm	7 cm

As observed in Table 4, improvement was observed in all three groups. The best improvement was found in the experimental group grown with purified water.

Findings Obtained from the Experiment Process of the Bean Plant

After the bean planting, seed germination and morphological examinations were made, and measurements were taken. The findings are shown in Figure 12, Figure 13, Figure 14 and Table 5, Table 6.

Figure 12: First germination

Figure 13: 10th day height growth

Figure 14: 30th day height growth

Figures 12, 13 and 14 show the morphological appearance of the bean plant at the first germination, 10th day and 30th day. Germination and growth were observed in control group and experimental group plants.

Table 5: Germination time of bean plant

Tap Water	Purified Washing Machine Water	Washing Machine Water
9 days	8 days	9 days

As seen in Table 5, the germination time of the plant irrigated with purified water was realized in a shorter time.

Table 6: Periodic height developments in the development process of the bean plant

	Tap Water	Purified Washing Machine Water	Washing Machine Water
1st Day	---	5 cm	---
3rd Day	4.5 cm	13 cm	5.5 cm
5th Day	8 cm	25 cm	15 cm
10th Day	21 cm	38 cm	30 cm
15th Day	26 cm	42 cm	36 cm
20th Day	29 cm	46 cm	38 cm
30th Day	31 cm	50 cm	39 cm

As seen in Table 6, improvement was observed in all three groups. The best improvement was found in the experimental group grown with purified water.

Findings Obtained from the Experiment Process of the Potato Plant

After potato planting, seed germination and morphological examinations were made, and measurements were taken. The findings are shown in Figure 15, Figure 16 and Table 7, Table 8.

Figure 15: First germination

Figure 16: 30th day height growth

In Figure 15, the first sprouting of the potato plant was detected in the washing machine water. The development of the potato plant continued very slowly. Germination and growth were observed in control group and experimental group plants.

Table 7: Germination time of potato plant

Tap Water	Purified Washing Machine Water	Washing Machine Water
11 days	16 days	7 days

As seen in Table 7, the reason for the longer germination period of the plant irrigated with purified water is thought to be the pH change in the soil.

Table 8: Periodic height developments in the development process of the potato plant

	Tap Water	Purified Washing Machine Water	Washing Machine Water
1st Day	---	---	1 cm
3rd Day	---	---	3 cm
5th Day	1 cm	---	6 cm
10th Day	4 cm	0.5 cm	12 cm
15th Day	9 cm	1 cm	17 cm
20th Day	13 cm	1 cm	22 cm
30th Day	16 cm	1 cm	25 cm

As seen in Table 8, improvement was observed in all three groups. However, it is thought that the reason for the development of the plant irrigated with purified water is less and slow compared to other plants, because the development season is not suitable for potatoes, and the change made by the purified water in the soil has a negative effect on plant growth.

Findings Obtained from the Experiment Process of Onion Plant

After onion planting, seed germination and morphological examinations were made, and measurements were taken. The findings are shown in Figure 17, Figure 18, Figure 19 and Table 9, Table 10.

Figure 17: First germination

Figure 18: 10th day height growth

Figure 19: 30th day height growth

Figures 17, 18 and 19 show the morphological appearance of the onion plant at the first germination, 10th day and 30th day. Germination and growth were observed in the control group plant and the plant from the experimental group irrigated with gray water. However, no growth was observed in the onion plant irrigated with purified water.

Table 9: Germination time of onion plant

Tap Water	Purified Washing Machine Water	Washing Machine Water
16 days	---	10 days

As seen in Table 9, it is thought that the reason for the lack of germination in the plant irrigated with purified water is due to the pH change in the soil.

Table 10: Periodic height developments in the development process of the onion plant

	Tap Water	Purified Washing Machine Water	Washing Machine Water
1st Day	---	---	2 cm
3rd Day	---	---	8 cm
5th Day	---	---	17.5 cm
10th Day	6 cm	---	31 cm
15th Day	14 cm	---	43 cm
20th Day	23.5 cm	---	53 cm
30th Day	37 cm	---	64 cm

As seen in Table 10, growth was observed in both the control group plant and the plant irrigated with gray water from the experimental group. It is thought that the reason for this situation is that the treated water negatively affects the soil structure and has a negative effect on plant growth.

Findings Obtained from the Experiment Process of the Grass Plant with Zeolite on the Base

After planting the grass plant with zeolite on its base, morphological examinations were made with seed germination and measurements were taken. The findings are shown in Figure 20, Figure 21, Figure 22 and Table 11, Table 12.

Figure 20: Preparation of pot with Zeolite

Figure 21:10th day height growth

Figure 22: 30th day height growth

Figure 20 shows the preparation of the zeolite-based plant pot, and Figures 21 and 22 show the morphological appearance of the grass plant on the 10th and 30th days. Germination and growth were observed in control group and experimental group plants.

Table 11: Germination time of zeolite-based grass plants

Tap Water	Purified Washing Machine Water	Washing Machine Water
2 days	2 days	2 days

As seen in Table 11, all groups germinated in the same time period.

Table 12: Periodic height developments of zeolite-based grass plants during the development process

	Tap Water	Purified Washing Machine Water	Washing Machine Water
1st Day	1.5 cm	1.5 cm	1.5 cm
3rd Day	4.5 cm	4 cm	3.5 cm
5th Day	7 cm	6.5 cm	5.5 cm
10th Day	8 cm	8 cm	7.5 cm
15th Day	9 cm	9.5 cm	8 cm
20th Day	9.5 cm	10.5 cm	8.5 cm
30th Day	10 cm	12 cm	9 cm

As seen in Table 12, improvement was observed in all three groups. The best improvement was found in the experimental group grown with purified water.

Findings Obtained from the Experiment Process of Bean Plant with Zeolite on the Base

After planting the bean plant with zeolite on its base, morphological examinations were made with seed germination and measurements were taken. The findings are shown in Figure 23, Figure 24, Figure 25 and Table 13, Table 14.

Figure 23: Preparation of pot with Zeolite

Figure 24: 10th day height growth

Figure 25: 30th day height growth

Figure 23 shows the preparation of the zeolite-based plant pot, and Figures 24 and 25 show the morphological appearance of the bean plant on the 10th and 30th days. Germination and growth were observed in control group and experimental group plants.

Table 13: Germination time of zeolite-based bean plants

Tap Water	Purified Washing Machine Water	Washing Machine Water
6 days	6 days	6 days

As seen in Table 13, all groups germinated in the same time period.

Table 14: Periodic height developments of zeolite-based grass plants during the development process

	Tap Water	Purified Washing Machine Water	Washing Machine Water
1st Day	3 cm	2 cm	1.5 cm
3rd Day	15 cm	20 cm	15 cm
5th Day	26 cm	28 cm	30 cm
10th Day	37 cm	39 cm	38 cm
15th Day	43 cm	46 cm	44 cm
20th Day	45 cm	49 cm	46.5 cm
30th Day	46.5 cm	52 cm	48 cm

As seen in Table 14, improvement was observed in all three groups. The best improvement was found in the experimental group grown with purified water.

Gray Water and Purified Water Analysis

After the experimental process was completed and plant growth was observed, analyzes were made to determine the chemical contents of the waters. The comparative analysis results of the gray water used in the experiment and the zeolite-treated gray water are given in Table 15.

Table 15: Comparison of the parameters of gray water and zeolite-treated gray water

Parameters	Gray Water	Zeolite-treated Gray Water
Biological Oxygen Demand (mg/l)	1450	1430
Chemical Oxygen Demand (mg/l)	2142.9	2142.8
Total Organic Carbon (mg/l)	691	402
Total Nitrogen (mg/l)	34	19.3
Total Phosphorus (mg/l)	1.8	1.6
Sulphate (mg/l)	280.6	271.4
Chloride(mg/l)	102	229.9
Surfactant (mg/l)	78.8	56.05
pH	6.73	7.26

As seen in Table 15, there were no great differences in chemical oxygen demand (2142.9-2142.8) and total phosphorus (1.8-1.6) values. But it was determined that there was a significant difference in biological oxygen demand (1450-1430) total organic carbon (691-402), total nitrogen (34-19.3), sulfate (280.6-271.4), chloride (102-229.9) surface active substance (78.8-56.05) and pH (6.73-7.26) values.

Considering the clarity, a noticeable difference was detected. Figure 26 shows the state of clarity.

Figure 26: Clarity status of gray water and zeolite-treated gray water

As seen in Figure 26, zeolite-treated gray water has a clearer appearance than gray water.

Planned Unit Design for Gray Water Treatment

The mechanism shown in Figure 27 has been designed in order to purify the gray water coming out of the washing machines in places such as houses, dormitories and nursing homes and make them reusable.

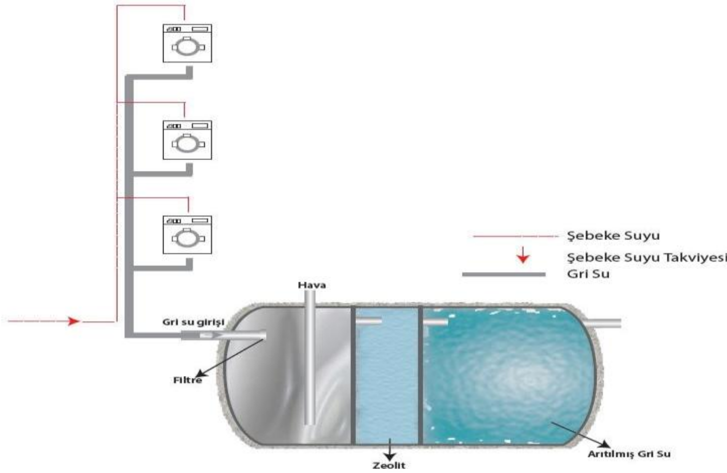

Figure 27: The mechanism of gray water treatment unit

As seen in Figure 27, the gray water coming from the washing machines will be filtered and taken to the storage area. Ventilation will be provided to prevent odor. It will be transferred to the second compartment containing zeolite and will be kept there for a while, and the purified gray water that passes into the last compartment will become usable.

Zeolite Cost Calculation:

The zeolite used in the study was bought for 77 TL in the form of 25 kg. The cost calculation of the water treated with the received zeolite is given in Table 16.

Table 16: Zeolite cost calculation

Zeolite	Amount of Treated Water	Cost of zeolite gray water	Cost of clean water
1 kg	1000 L = 1 m^3	3 TL	7 TL*

The price of the metropolitan municipality in January 2021.

As seen in Table 16, purifying gray water is more affordable than using clean water.

Table 17: Water expense cost calculation of a garden of 80 m^2

Months	May-2020	June-2020	July-2020	August-2020
Amount of clean water consumed	10m^3	16m^3	14m^3	13m^3
Cost	36 TL	56 TL	50.50 TL	47 TL
The cost of Zeolite water consumed	30 TL	48 TL	42 TL	39 TL

As seen in Table 17, an 80 m^2 garden with grass and trees has high clean water consumption and cost. An automatic irrigation system with a fountain is used in this garden. Although this system provides water savings compared to irrigation with a hose, 1 month's water consumption is approximately equivalent to the water consumption of 1 flat.

Conclusion

With the gradual decrease of clean water resources in the world, the reuse of treated wastewater has become an increasingly important issue. The use of wastewater after treatment is of great importance in water management. In order to overcome the water shortage, they are faced with, countries resort to reuse of wastewater in various water consumption areas [17].

With the climate changes that have occurred in recent years, it has gained importance to work on the protection of clean water resources in our country. Domestic wastewater is divided into two as gray water and black water. Gray water is less polluted than black water. Therefore, gray water is easier to treat. With the decrease of freshwater resources, the treatment of gray water is frequently on the agenda. Irrigation water constitutes a part of the freshwater consumption. The use of alternative waters to fresh water in irrigation waters will help reduce freshwater consumption. In this study, the use of washing machine water, which is one of the gray water types, as irrigation water in plant cultivation after being treated with a zeolite device, and the effect of zeolite on plant growth by placing it in the soil and taking advantage of its water retention feature were investigated.

Wastewater can be treated with many absorbents such as zeolite. However, most of these absorbents are not preferred due to their high cost or low source. Zeolite is more advantageous than other absorbents, both in terms of cost and due to the fact that it has many sources, especially in our country [18]. As can be seen in the cost calculation (Table 16) we have calculated in the study, treatment with zeolite can be achieved with a lower budget.

In recent years, many studies have been conducted on the use of zeolite in wastewater treatment [14, 19, 20, 21, 22]. As a result of these studies, it was concluded that zeolite can remove surfactants in wastewater. While the amount of surfactant in the gray water used in our study was 78.8 mg/l, it decreased by 56.05 mg/l after passing through the zeolite, which is consistent with the literature studies.

Studies on the treatment of gray water are increasing day by day [4, 5, 7, 23, 24, 25]. According to the results of the studies, gray water can be purified and made suitable for reuse and can be used as irrigation water. Our study results were also compatible with the literature in this regard. It was determined that the growth was better in beans (Table 6 - Table 14) and grass plants (Table 4 - Table 12) grown with purified gray water.

Zeolite is frequently used as a plant growing medium in agriculture. In the studies conducted [9, 26, 27], results such as reducing the use of zeolite fertilizer, using potassium and ammonium effectively by the soil, increasing the amount of water retained in the soil, regulating the water regime and increasing plant productivity have been achieved. In the second part of the experimental study, it was seen that our results were compatible with the studies, with the plants that we placed zeolite under the pots shortened the germination period (Table 11 and Table 13), the need for less water (Table 2) and the plants showed faster growth (Table 12 and Table 14).

In the gray water treatment study conducted by [5], it was emphasized that gray water can be used directly in irrigation, even though some countries implement it, it is strongly recommended to treat it. The better development of potato and onion plants grown with gray water (Table 8 and Table 10) is in line with the studies carried out. It is mentioned that when gray water is used directly in irrigation without purification, it will cause the accumulation of salts, surfactants, oil and grease in the water, and will adversely affect plant health and soil structure in long-term use. For this, evaluation can be made by analyzing the soil irrigated with gray water for a certain period of time.

Treatment studies with zeolite and studies on gray water treatment are increasing day by day. However, there was no study on the use of zeolite as a plant growing medium with the treatment of gray water with zeolite. This is the feature that distinguishes our study from other studies. According to the results of our study, beans, zeolite-based beans, grass and zeolite-based grass plants irrigated with washing machine water treated with zeolite were more productive than plants irrigated with tap water and washing machine water. While little growth was observed in the potato plant irrigated with purified water, no growth was observed in the onion plant. Potatoes and onions irrigated with washing machine water were more efficient than those irrigated with tap water. When we compare the plants with zeolite on the bottom and those without, it has been seen that zeolite-based plants germinate faster, retain their moisture for a longer time and require less irrigation.

In this context, it has been seen that it is possible to treat gray water and use it in irrigation, and even more efficient for some plants. It has been concluded that although it is not recommended due to the harmful substances in it, it can be used for direct irrigation of gray water. In addition, it was determined that placing the zeolite on the plant base gave positive results in terms of yield studies. The result of our study showed results consistent with the studies in literature.

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