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Water Efficiency in Small Ports

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Abstract

Water is an indispensable resource for the continuation of life. Human beings consume and pollute water resources very quickly. If the current rate of water consumption continues, it is predicted that our country will become water-poor in a few years. It is estimated that water wars will break out between countries experiencing water scarcity around the world in the coming years. Therefore, water resources need to be protected urgently. A savings plan should be prioritized in every area where water is used. There are many areas of water consumption in port structures, especially for boat cleaning and maintenance. In order to minimize water consumption, a water efficiency project was created at the Fenerbahçe Fishing Shelter Port, and it was calculated that an average of 57% water was saved annually.

Keywords: *Water efficiency in fishing harbors and small ports, Water efficiency in architectural areas, Water scarcity, Water stress, Gray water treatment.*

Küçük Limanlarda Su Verimliliği

Öz

Su yaşamın devamı için vazgeçilmez bir kaynaktır. İnsanoğlu su kaynaklarını çok hızlı tüketmekte ve kirletmektedir. Su tüketim hızı bu şekilde devam ederse birkaç yıl sonra ülkemizin su fakiri bir ülke olacağı öngörülmektedir. İlerleyen zamanlarda dünya genelinde su kıtlığı yaşayan ülkeler arasında su savaşları çıkacağı tahmin edilmektedir. Bu nedenle su kaynaklarının acilen korunması gerekmektedir. Su kullanılan her alanda öncelikli olarak tasarruf planı yapılmalıdır. Liman yapılarında tekne temizlik ve bakımı başta olmak üzere birçok su tüketim alanı mevcuttur. Su tüketiminin minimum düzeye indirilmesi için Fenerbahçe Balıkçı Barınağı Limanı'nda su verimliliği projesi oluşturularak yıllık ortalama %57 civarında su tasarrufu yapıldığı hesaplanmıştır.

Anahtar Kelimeler: *Balıkçı barınakları ve küçük limanlarda su verimliliği, Mimari alanlarda su verimliliği, Su kıtlığı, Gri su arıtma.*

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1. Introduction

Water, as a resource that cannot be completely replaced, is one of the most critical natural resources for all living things. To put it another way, water is the basis of life and vitality. Water is needed in many areas, such as human use, maintenance of ecosystems, economic growth, energy production, and national security (Aksungur & Firidin, 2008). Rational and sustainable use of water resources can be achieved through spatial and sectoral planning and the coordination and integration of decision-making processes. A person can survive without food for 30 days and without water for 7 days. (Kurtoğlu, 2018).

In a study conducted in 2015, the countries of the world were ranked in terms of water stress. While Turkey was ranked 41st in terms of water scarcity in 2010, it is projected to be the 27th country in the water stress ranking by 2040 (Turan & Bayrakdar, 2020). Global warming increases the importance of water resources and highlights the risk of desertification in many parts of the world. Decreases in annual flows in river basins due to global warming will lead to water shortages in urban areas (Karaman & Gökalp, 2010). The effects of climate change on water resources include variations in water potential depending on basin locations, alterations in underground aquifers, more frequent occurrences of events such as floods and droughts, changes in precipitation patterns, erosion caused by changes in vegetation and land use, shifts in river flow regimes, and increased water demands in agricultural areas (Karaman & Gökalp, 2010).

Using the literature review method under the title of Water conservation methods and water efficiency in buildings, many articles and theses have been examined, especially grey water treatment technologies, rainwater harvesting methods, and water-saving methods in equipment. Following the literature review, water efficiency methods were researched in the port area in Istanbul Fenerbahçe and solutions were tried to be found. First of all, all the structures in the port were identified and the water conservation method for each area was evaluated and discussed. Saving suggestions were presented in terms of water efficiency in offices and restaurants, which are architectural buildings in the port, irrigation techniques for gardens and landscaping areas were mentioned, measures for water efficiency inside and outside the ships were examined and suggestions were made. Water losses in the port area were found and all water efficiency methods, especially grey water treatment and rainwater harvesting methods, were applied to this area and the amount of water saved was calculated.

1.1. Rainwater Harvesting and Gray Water Treatment Technologies

The method of rainwater harvesting has been used since ancient times, especially during the Roman period when the water demand was high. Cisterns, such as the famous Yerebatan and Binbirdirek cisterns, were constructed to collect rainwater due to insufficient water availability to meet the population's needs (Kılıç & Abuş, 2018). Additionally, basements of buildings were often utilized as cisterns to supplement water storage. Rainwater is utilized in various architectural structures, contributing significantly to water conservation. This method is prevalent in many African countries where drinking water is obtained through rainwater treatment. Water usage in buildings constitutes 78% of domestic water consumption. Among this, 59% is utilized in non-residential areas such as garden irrigation, while 19% is used in residences (Şahin & Manioğlu, 2011). Installing separate systems for using rainwater for both drinking and domestic purposes would increase costs. Therefore, utilizing rainwater primarily for non-residential purposes can help reduce costs.

Cisterns are typically built underground to ensure water tightness, and silica sand is employed in the filtration process (Tanık, 2017). Silica sand serves as a filter material in water purification within cisterns. The suitability of silica sand for cisterns should be determined through necessary tests, and its application should be based on these test results. Cisterns are used in rural areas, semi-arid, and scattered settlements. Typical cisterns have four components (Tanık, 2017).

Rainwater Collection: These are systems created by collecting rainwater from roofs.

Rainwater harvesting systems such as Waterfull and Aquatecture are examples of modern systems used today. The Aquatecture water collection system, designed by Shaakira Jassat, integrates into the surfaces of buildings specifically for arid regions (Tavşan, Bahar & Tavşan, 2022).

The collected water is filtered, stored, and made available for external use via a tap.

Transmission via Gutter System: Gutter systems used for collecting rainwater are designed to channel water to a catchment area. These gutters are typically optimized to efficiently collect and transport rainwater to the cistern.

Storage of Rainwater: Cisterns can take the form of large tanks or reservoirs used to store collected rainwater. These storage areas are crucial for storing rainwater to be used during dry periods.

Simple Purification Methods: Water used in cisterns generally requires purification. Therefore, simple purification methods can be employed to improve water quality. For instance, water quality can be enhanced through operations such as filtration, sediment removal, or disinfection. Since freshwater resources are increasingly scarce and depleting rapidly, rainwater harvesting methods are widely used today as an alternative to purifying gray water. Rainwater collected from buildings with sufficiently large roofs, such as airports, military zones, stadiums, and tourist areas, undergoes a simple purification process before being made available for use. In arid areas facing water scarcity issues, using rainwater for garden irrigation plays a crucial role in water conservation. Swimming pools or ornamental ponds can be filled using rainwater collected in tanks, and it can be used for cleaning and washing operations. Additional piping can facilitate the use of rainwater for garden irrigation and toilet flushing. Purified rainwater can also be utilized in washing machines and showers.

Gray Water Treatment Technologies

Recycling gray water offers the advantage of being an alternative urban water source that can be easily treated due to low concentrations of organic pollutants and pathogens (Revitt et al., 2011). Gray water is classified into less and more polluted categories. Water from showers, bathrooms, and sinks contains minimal pollutants, whereas water from kitchens and washing machines is heavily contaminated (Özgün, 2020).

Physical, biological, and chemical treatment methods are employed in the treatment of gray water to achieve desired standards of water quality. Filtration and precipitation methods are examples of physical purification technologies. Prior to biological or chemical treatment methods, filtration is conducted as a preliminary step. In this pre-treatment process, sand filters, coarse filters, or membrane filters are utilized to remove some organic substances and pathogens. Physical purification methods are not effective for nutrient removal; chemical treatment methods are preferred for this purpose. Treatment of gray water typically includes photocatalytic processes, coagulation, and ion exchange, followed by filtration or disinfection processes (Pidou, Memon, Jefferson & Jeffrey, 2007)

Chemical treatment methods (Üstün & Tirpanci, 2015):

- Electrocoagulation (EC)
- Ion exchange
- Photocatalytic oxidation
- Granular activated carbon

Biological treatment methods (Üstün & Tirpanci, 2015):

- Artificial wetland (ANN) for biological gray water treatment
- Rotary biological reactor (RBR)
- Sequential batch reactor (SBR)
- Membrane bioreactor (MBR)

Purifying gray water and using it for garden irrigation, car washing, washing machines, or toilet cisterns is not a new technology. It has been utilized in many countries since the 1980s. It is quite common to implement gray water systems with dual distribution. In multi-storey commercial buildings, in addition to standard plumbing, separate gray water plumbing systems are often installed. If gray water is intended for storage advanced treatment technologies such as aerobic or anaerobic treatment, chemical coagulation, filtration, and advanced disinfection methods are applied. If gray water is intended for garden irrigation, it must undergo primary treatment such as screening, filtering, settling, or secondary treatment such as biological oxidation or disinfection.

Gray water undergoes three stages of treatment: physical, chemical, and biological. After the physical treatment process, most organic substances are removed. The second stage involves chemical and biological methods to treat floating and settling particles, while the third stage focuses on removing elements such as nitrogen and phosphorus. Gray water treatment may involve all or several of these stages, depending on the specific needs. Each stage is essential for ensuring human and environmental health. Gray water obtained after simple physical treatment methods is commonly used for garden irrigation. To prevent sediment from entering the gray water used for garden irrigation, a grid or sieve is employed before pumping the water.

2. Material and Method

Fenerbahçe Aquaculture Cooperatives located in Zühtüpaşa Neighborhood of Kadıköy district in Istanbul province has a total area of 342,884 m², including 102,394 m² of reclaimed land, 1,135 m² of state-owned land, and 233,244 m² of sea surface area. Currently, it has a capacity for 1,291 boats in the sea and 200 boats on land.

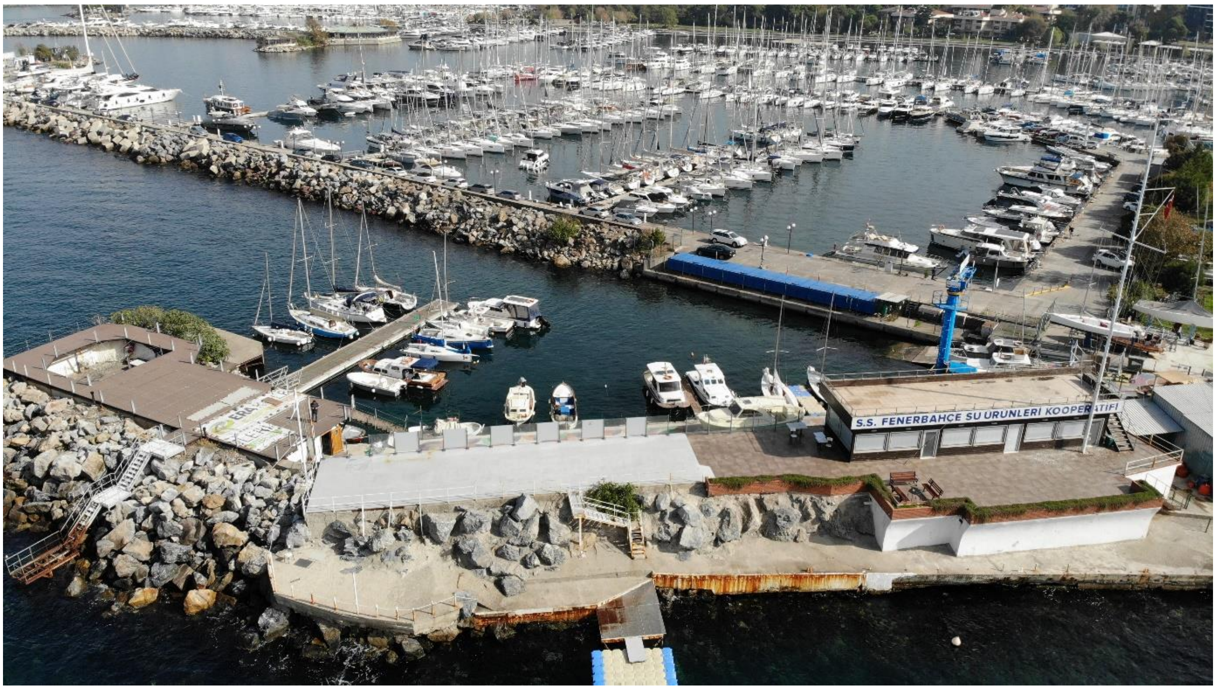

Figure 1. Image of Fenerbahçe Fisheries Port (Bileyici, 2024)

All structures within the port were identified, and appropriate water conservation methods for each area were evaluated and discussed. Techniques for irrigation in gardens and landscaping areas were addressed, along with measures for improving water efficiency both on board and around ships. Water losses within the port area were identified, and various water efficiency methods, particularly gray water treatment and rainwater harvesting, were applied, with calculations made to determine the amount of water saved.

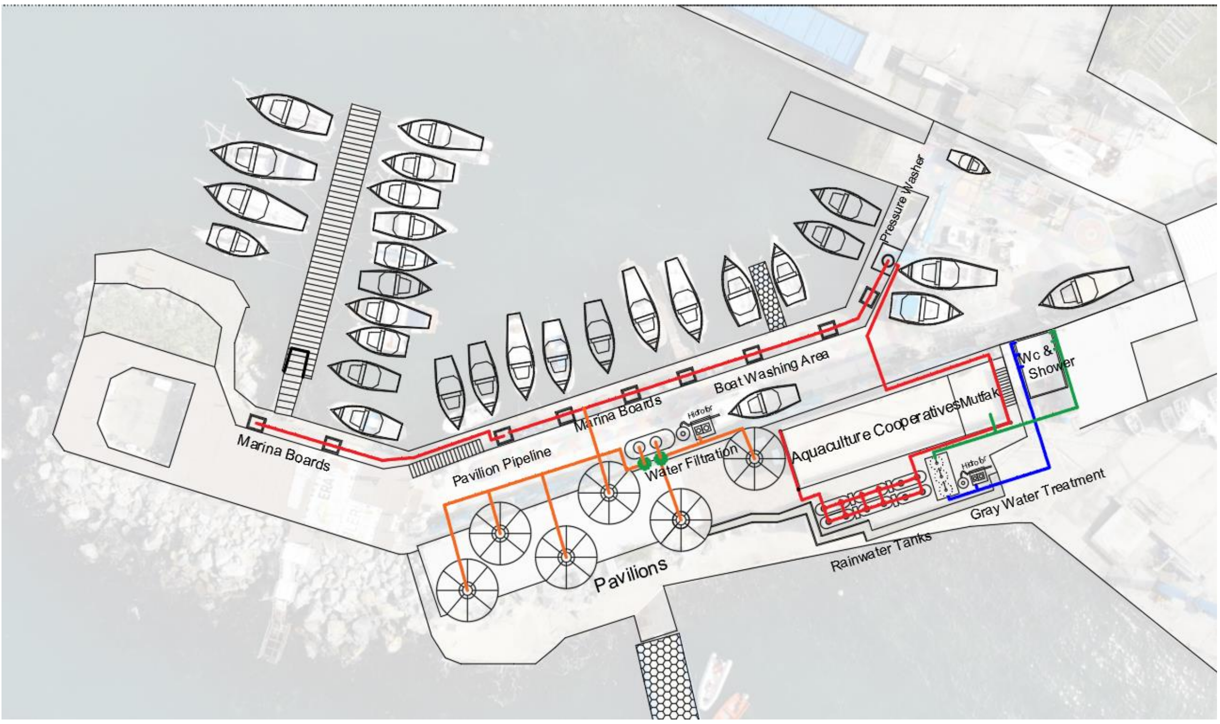

Figure 2. Fenerbahçe Port water Project (Bileyici, 2024)

2.1. Water Use Areas in Fishing Shelters and Small Ports

Fenerbahçe Fishing Shelter is a small harbor primarily used for boat maintenance and repair. After identifying the areas of water usage within the port, research was conducted to determine the most suitable water efficiency system for each area.

2.2. Dock Maintenance

Dock maintenance and repair are essential tasks that require regular attention. These activities involve researching, evaluating, and repairing damages caused by natural disasters (Tari, 2014). During dock maintenance and repair, it is crucial to conserve water wherever possible. The most suitable cleaning method should be selected based on the ground material characteristics of the port. If the flooring is coated with concrete, cleaning with seawater is cost-effective; however, if wood is used, it is preferable to use water purified through gray water technologies or obtained via rainwater harvesting methods, as saltwater is detrimental to wood structures. When using seawater for washing, portable water pumps can be employed.

2.3. Ship Maintenance and Repair

In ship maintenance and repair, the first step is to identify any damages and create a repair plan accordingly. Once repairs are completed, if the ship requires painting, certain preparatory steps must be taken. Initially, the material of the surface to be painted must be determined, and a suitable paint should be selected. The process begins with assessing the corrosion level of the surface and identifying any existing paint systems. If an old paint system is present, its type and thickness should be measured. Additionally, sharp corners, welding spatters, and welding errors in the sheet metal construction need to be addressed. The salinity level and presence of oil on the surface should also be checked (Tari, 2014). Prior to painting, ship surfaces must be thoroughly cleaned. If oil residues are found, it is recommended to use soluble detergents for cleaning, followed by rinsing with purified gray water or rainwater harvested water.

Figure 3. Boat washing area (Bileyici, 2024)

2.4. Water Use in Port Offices and Facilities

There are office and restaurant buildings in the inner port areas. In offices, the most water is used for cleaning and toilets, while the least water is used in the kitchen and for dishwashing.

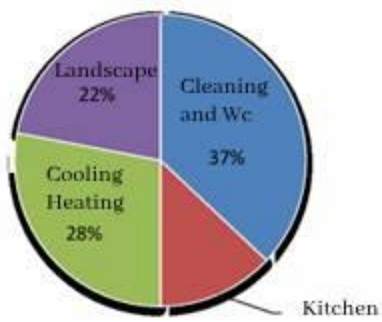

Figure 4. Water use in offices (Ekinci, 2015)

There are office and restaurant buildings in the inner port areas. In offices, the most water is used for cleaning and toilets, while the least water is used in the kitchen and for dishwashing.

2.5. Water Use in Harbor Landscaping

Water obtained from rainwater collection barrels or gray water treatment methods can be used to meet the water needs of the gardens located in the port.

Figure 5. Drip irrigation method (Bayramoğlu, Ertek & Demirel, 2013).

When planting, natural species that consume less water should be used. Ground covers should be preferred instead of large grass surfaces, and limited irrigation levels should be applied to plants during certain periods (Bayramoğlu et al., 2013). The restricted irrigation technique is widely used. When plants receive more water than they need, their productivity decreases, but restricted irrigation techniques have a productivity-increasing effect on plants.

3. Water Consumption and Gained Calculation

Water consumption and savings calculations were made according to the water usage areas in the port.

3.1. Water consumption in boat cleaning and maintenance:

Assuming that one boat is washed in an average of 30 minutes, the water requirement for washing a boat is: 15 L (amount of water flowing in 1 minute) * 30 minutes = 450 L

An average of 3 boats are washed per day in the marina area. The water requirement for washing 3 boats in 1 day is: 3 * 450 L = 1,350 L

The monthly water requirement is: 1,350 L * 30 days = 40,500 L

The yearly water requirement is: 40,500 L * 12 months = 486,000 L

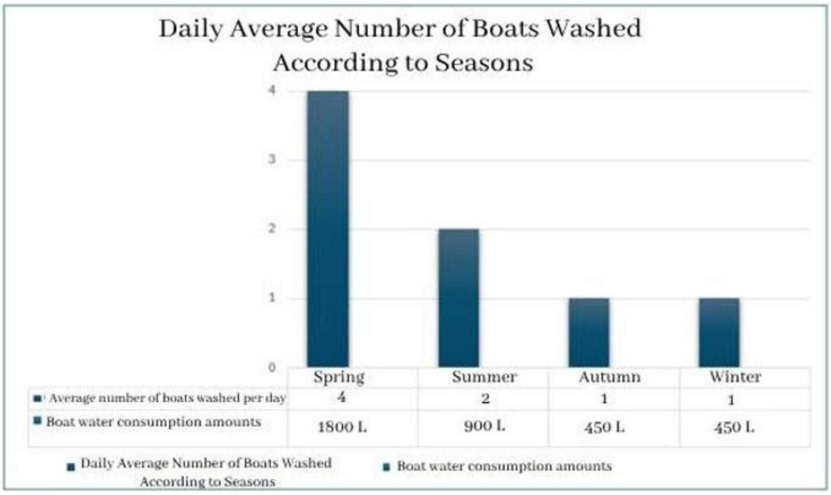

Figure 6. Daily average number of boats washed according to seasons (Bileyici, 2024)

3.2. Water consumption for washing the boat maintenance and repair area:

Water requirement calculation assuming that the 300 m² boat maintenance and repair area is washed approximately once a day:

Considering that 1 tap flows an average of 15 liters of water per minute and that an area of 300 m² is washed in an average of 1 hour:

15 * 60 min = 900 L of water required.

Water needs for 1 month: It is 900 * 30 = 27,000 L.

1-year water needs: It is 108,000 * 12 = 324,000 L.

3.3. Water consumption in dock cleaning and maintenance:

Assuming that an area of 300 m² is washed once a week:

Considering that 1 tap flows an average of 15 litres of water per minute and that an area of 300 m² is washed in an average of 2 hours:

15 * 120 min = 1800 L of water is required.

1-month water needs: 1800 * 4 = 7 200 L of water is required for dock cleaning and maintenance.

1-year water need: It is 7 200 * 12 = 86.400 L.

3.4. Water consumption in landscape care:

When calculating the irrigation requirements of green areas, it is assumed that 5 litres of water per square meter will be used for each irrigation (Eren et al., 2016). The green area located right next to the Fisheries Cooperatives building covers an area of 28 m².

28 m² * 5 L = 140 L

Assuming that it is watered once a week, the water requirement for 1 month is: 140 L * 4 (since 1 month is 4 weeks) = 560 L

Annual water requirement for landscape irrigation: 560 * 12 = 6720 L of water is required.

If watering is done 2 days a week, per year; 6270 * 2 = 12 540 L of water is needed.

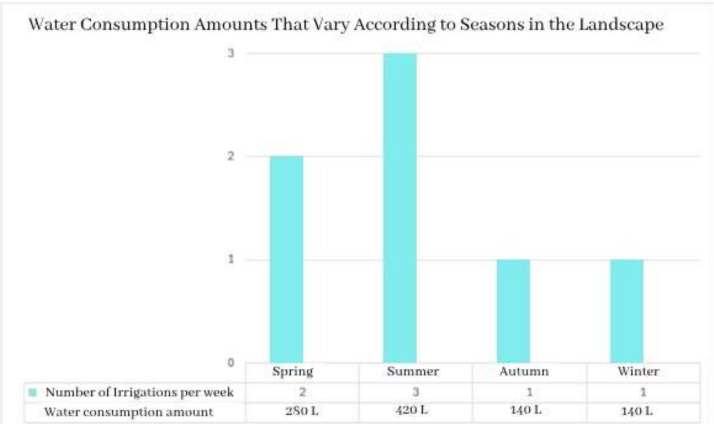

Figure 7. Water consumption amounts changing according to seasons in landscape irrigation in the fishing shelter (Bileyici, 2024)

3.5. Water consumption in the shower:

Assuming that the shower is used 8 times a day, the amount of water consumed per day is:

10 L (amount of water flowing from the tap in 1 minute) * 6 min (average shower time) = 60 L

60 * 8 = 480 L shows the amount of water flowing for a shower in a day.

Amount of water consumed in 1 month: 30 * 480 = 14 400 L.

Amount of water consumed in 1 year: It is 14 400 * 12 = 172 800 L.

3.6. Sink water consumption:

A faucet that flows 15 L of water in 1 minute will flow 10 L of water during this time, considering the hand washing time is 40 seconds.

Assuming that hands are washed an average of 40 times a day, the amount of water flowing from the sink is: 40*10L = 400 L

Amount of water consumed in the sink in 1 month: 400 * 30 = 12 000 L.

Amount of water consumed in the sink in 1 year: 12 000 * 12 = 144.000 L

3.7. Water Gained From Rainwater Harvesting

Rain harvesting plays an important role in reducing water scarcity. It is of great importance in protecting water resources. It provides an alternative water source in areas with low water quality. Rainwater harvesting can be accomplished by a variety of methods according to different needs and environments. At Fenerbahçe Fishing Shelter, roof surface rainwater harvesting, rainwater collection from pavilions and underground rainwater harvesting methods are applied. It ensures efficient collection and use of rainwater, thus contributing to the sustainable management of water resources.

3.8. Water Gained from Pavilions and Gray Water

Pavilions both provide rainwater storage and create a recreation area by providing shade. Each of the pavilions can store up to 650 L of water. The total storage potential of 6 pavilions is 6 * 650 = 3 900 L. An average of 46,800 L of water is saved annually from the pavilions. When we look at the total monthly rainfall in Istanbul by month throughout the year, it is seen that the highest rainfall is 98.6 mm in December. It is seen that the least rainfall is 22.2 mm in July. According to the chart, the average monthly total rainfall was measured as 662.5 mm. In other words, 662.5 L of precipitation falls per m².

The Aquaculture Cooperative building covers an area of 100 square meters. 662.5 * 100 = 66 250 L of water is collected from the roof of the Fisheries Cooperative building annually. If this number is multiplied by the safety coefficient of 0.75, taking into account rainfall irregularities, leaks and leaks caused by the roof; 66 250 * 0.75 = 49 687 L of water is collected. The amount of water obtained from showers and sinks for gray water treatment is 873,000 L per year. 785,700 L of the amount of water, that is, approximately 90 percent, can be purified.

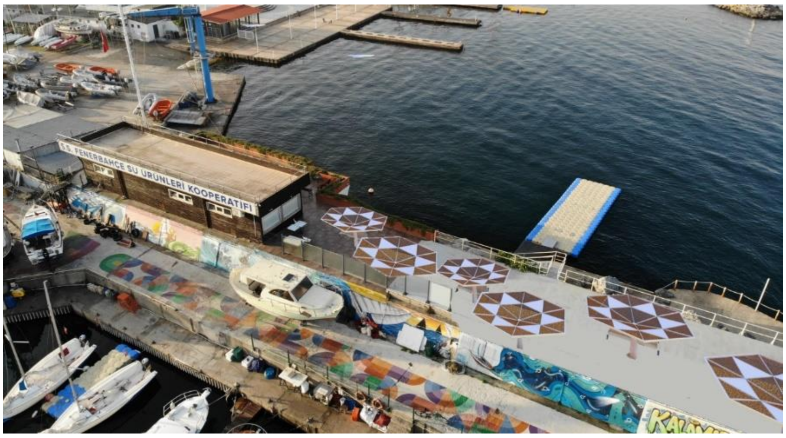

Figure 8. Placing pavilions at Fenerbahçe Port (Bileyici, 2024)

The total amount of water obtained from the gray water system, rainwater harvesting and pavilions is 883 693 L per year on average. 1 536 060 L of water is consumed in Fenerbahçe Fishing Shelter a year. Thanks to the water efficiency project, 57.5% of the total water need is met.

4. Results

In the water project carried out at Fenerbahçe Port, water losses were kept to a minimum by ensuring maximum water conservation. Using rainwater harvesting methods, the water collected in pavilions and water tanks is used for various purposes, such as boat cleaning and maintenance, dock cleaning, landscape irrigation, etc., thus reducing the use of mains water. The area where gray water is treated using biological and chemical treatment methods is very important. Systems have advantages and disadvantages compared to each other. Biological treatment methods are preferred over chemical treatment methods when using water for irrigation and washing purposes. Water purified from gray water in the port structure will be used for ship washing and irrigation purposes. When we examine biological treatment methods, it can be seen that the most advantageous system for the port structure is the rotating biological disc (RBD). Reasons such as the high investment costs of membrane bioreactors and the increased use of sequential batch bioreactors in industrial areas make rotating biological discs the most reasonable systems for the port structure. Since purified gray water will be used for purposes such as boat cleaning and maintenance, dock cleaning, and plant irrigation, gray water has been preferred because it is thought that the water obtained by biological treatment methods will meet all the mentioned needs. The investment cost of the rotating biological disc is not very high, and the area it occupies is quite small. Since there is not much space in the port where the system will be installed, the rotating biological disc is suitable. The water quality obtained from RBD is suitable for boat washing, dock cleaning, and landscape irrigation. Another advantage of the system is that it performs purification in a short time. It is easy to apply and has little maintenance. Water obtained from showers and sinks is ready for use after being purified in rotating biological discs.

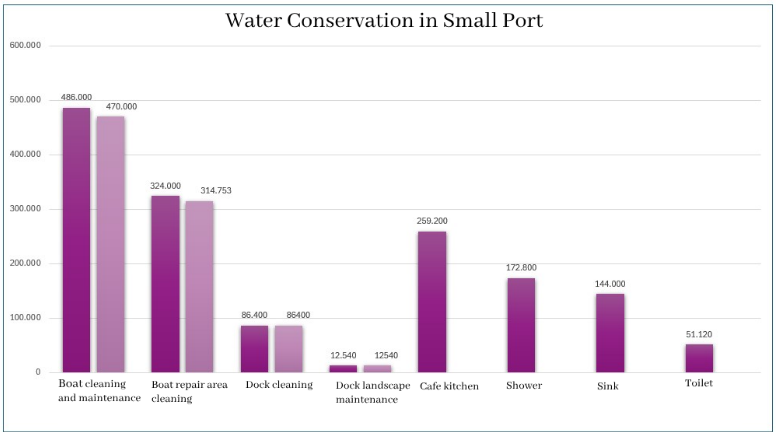

Figure 9. Water conservation in small ports (Bileyici, 2024)

When all the water obtained from pavilions, rain tanks, and gray water harvesting is used for port needs, 57% less mains water is used annually, and 883,693 liters of water are saved. Thanks to these systems, which are very simple to implement for small ports, water savings are achieved, and pavilions can also be used as shade elements. Thus, the pavilions give the port a more aesthetic appearance and functionally protect it from the sun in summer and rain in winter.

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Author Contribution and Conflict of Interest DeclarationInformation

All authors contributed equally to the article. There is no conflict of interest.

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