International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 11-No.4 (2025) pp. 7943-7953
http://dergipark.org.tr/en/pub/ijcesen

ISSN: 2149-9144

Research Article

A New Method in Wastewater Treatment: Ecological Ladder Model (EMM)

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Article Info:

DOI: 10.22399/ijcesen.2366
Received : 09 February 2025
Accepted : 24 August 2025

Keywords
Constructed Wetland
Purification Model with Ecological Ladder
EMM
Burdur Lake

Abstract:
This article was prepared to introduce a new natural purification system designed by us. The model is theoretic. Ways to use the purified water for agricultural purposes have also been sought.For this purpose, we call the 'Ecological Ladder Model (EMM)' was done. The model can be revised in line with the results obtained from the application. It is estimated that it can also be applied to other water sources suffering from drought problems. The general features of the model are as follows:
The EMM model; is an ecological treatment system that imitates nature. The treatment period and the area of use for treatment are longer than other systems, and vary according to the flow rate of the water; however, it is an environmentally friendly system.The system; has 2 parts, one large (main unit) and one small (side unit). While the main unit is being cleaned, the side unit can be put into operation and run for a few days.The top of the system is open and swamp mud, filters, etc. can be changed with construction equipment. Since the wastewater with a natural flow from top to bottom comes to the lake by filtering under the effect of the slope, it will be purified and purified like a strainer in peatlands. For this, the topography of the land should have a slope of approximately 15-30%. Wastewater can be purified and released into the lake or used for agricultural purposes. Purification consists of 3 steps:
In the first stage, disease-causing microorganisms will be destroyed (with ozone/şap/essential oil plants),In the second stage, the chemical and physical properties of the water such as pH, hardness, O_2 will be made suitable (with claystone, marble dust, lime and gypsum rocks, etc.),In the third stage, there is an artificial wetland created from plants determined for the purpose from the aquatic flora of the area and the water will be purified by giving it to the plants, the water filtered from here will be tested with live indicators to see if it is drinkable and the purified water will be delivered to the lake or to the agricultural areas to be used. All of these features have been concretized with a technical drawing and turned into a visual plan. The disposal of the treatment sludge can be made into a valuable fertilizer by feeding it to Red California worms (*Eisenia fetida*). Burdur is the most important province in worm compost production. It also has very important experiences in agriculture and animal husbandry.

1. Introduction

Today, countries with a water potential per capita of less than 1,000 m^3/year are considered water poor. In countries considered water rich, it is 10,000 m^3/year and above per capita. Approximately 75% of the world's total water consumption is used in agricultural irrigation. Türkiye is divided into 25 hydrological basins. The average annual total flow of the basins is 186 billion m3. Lakes Eğirdir and Kovada are located in the 09 numbered 'Antalya Havzası'. The Göller Yöresi is located in the transition zone between the Mediterranean and Continental climate types. Humid air masses coming from the Mediterranean have created a microclimate around lakes Kovada, Beyşehir, and Burdur.
Humanity's destructive efforts were first directed at forests, then at rivers and lakes. Until recently, 14% of the world was covered with forests, but today the total amount of forested areas has decreased to 6%. Türkiye's forest area is 22,933,000 ha, which is close to 30% of its surface area. With studies conducted in recent years, Türkiye has risen from 46th to 27th place in terms of forest assets among world countries.

For this reason, Türkiye is one of the few countries in the world that has increased its forest areas. It is accepted that deforestation poses an environmental threat both in terms of climate change and biodiversity; forests are a 'Life Support System' for humans and all other living things [1].

In Isparta; Eğirdir, Kovada and Gölcük lakes and Karagöl. There are also about 20 lakes/ponds for irrigation purposes in the province.

In Burdur; Burdur Gölü, Akgöl, Yarışlı Gölü, Salda Gölü, Karataş Gölü, Kestel Gölü, Gölhisar Gölü, Çorakgöl and about 20 dam lakes/ponds;

In Konya; Akşehir Gölü and Akşehir Yaylabelen Dam;

In Afyonkarahisar; in addition to natural lakes such as Akşehir, Eber, Karamık, Acıgöl, there are about 40 irrigation ponds such as Karakuyu, Pınarbaşı, Bayat, Selevir, Örenler, Kırka, Emre, Taşoluk for irrigation purposes [2].

Water resources are greatly affected by geogenic and anthropogenic activities. The hydrogeochemical properties of groundwater are formed by groundwater quality and rock/mineral-water interactions in groundwater layers and sometimes by the mixing of two different water layers [3].

There are basically 3 factors that deteriorate the quality of water:

1) Anthropogenic factors: These include mining activities, illegal waste disposal, leakage of septic tanks (which is of little concern to the Göller Yöresi for now) and excessive use and non-disposal of pesticides in agricultural areas,

2) Geological factors: These include rock erosion, volcanism and rock-water interaction[3] in this group.

3)Environment (climatic and edafic)-living relationships: Agricultural and animal productions are weakening day by day. In 2022, the Ministry of Agriculture and Forestry paid direct crop loss support to registered farmers across the country. In 2023, grape production in the Lakes Region decreased significantly. In recent years, since tomatoes could not be grown in the field, greenhouse production was made up for even in the summer months. Water prices increased approximately 10-fold in the city center of Isparta from 2023 to 2024. Those who raise animals such as cattle suffered from water and feed costs and reduced production. In 2024, field mice and moles dug up the thirsty agricultural lands, especially in Keçiborlu, and ate the products. For this reason, those who planted chickpeas in particular could not produce even as much as the seeds they threw into the soil.

Watering the plant did not work either due to the dryness of the air. Because the dry air absorbed the water from the plants, and the plants turned yellow and dried out. Of course, climate changes such as a decrease in humidity in the air, drought and sudden warming of the weather led to food shortages and increased prices.

With the rapid increase in urbanization and industrialization, the metallurgical industry and parts production have begun to grow rapidly. Discharging wastewater from the metallurgical industry into the receiving environment without proper treatment leads to deterioration of water quality and rendering the receiving environment unusable for drinking and utility water. Our water resources are depleting day by day and our renewable energy resources are decreasing. The importance of wastewater treatment emerges at this point [4]. Management of urban biowaste poses serious social and economic challenges for all countries. Approximately 70 % of biowaste is taken to landfills without any treatment. The most effective way to reduce biowaste is to prevent food waste.

Lake Burdur and its surroundings are one of the 14 Ramsar sites in Türkiye. It is included in the list of 122 Important Plant Areas (IPA) and 360 Important Nature Areas with priority in protection. In recent years, Lake Burdur has regressed to the stage of drying out due to various reasons, its natural water flow has been completely cut off, and it has become a pit where wastewater from industrial establishments in and around Burdur city center is stored.

Due to these physical and chemical changes in the lake, clay dust rising from the areas where the lake recedes with wind, bad smells carried by the wind and mosquitoes have become a threat to settlements. The areas where the lake recedes are turned into fields and plowed by the local people, farms are established, farm manure is spread and dried, and uric acid leaks into the lake as a result of purification. A highway has been opened and is used from the dried area between Burdur and Senir town (Isparta). Although there is a commission on the protection of the area, the inadequacy of protection is obvious. Since 2013, our observations on the relevant area have continued and we are getting to know the area closely. In recent years, the water regime of the lake has been severely damaged by the increase in drought. Therefore, there is no other option but to purify the wastewater with a natural system and release it to the lake.The purpose of this article is to draw attention to the water regime and faulty practices in the Göller Yöresi which includes the provinces of Burdur and Isparta, and partly Afyonkarahisar, Konya, Denizli and Antalya, and to make recommendations to implementing persons and institutions.

2. Problems of the Study Area

1. Recently, there have been important environmental factors that threaten the habitats in Lake Burdur and its surroundings (**Fig. 1**). These

factors have brought Lake Burdur and its surroundings (Ramsar Site) to its current state. These factors are listed below:

2. The Burdur fault within the Burdur fault zone; extends approximately 300 km in the NE direction between Fethiye Gulf and Keçiborlu. In most places, it is not a single structural line, but in the form of intermittent parts developed parallel to each other. It is a zone with a width ranging from 3 to 10 km. Many earthquakes have occurred in Burdur prov. since 1914 [6, 7].
3. The fact that the central district and its surroundings consist of filling areas called 'alluvium' and that the main rock is made done up of water-permeable rocks such as conglomerate and limestone is also an important factor in the distribution of water to other areas. We need more information about the flow direction and reserves of underground water.
4. Lake Burdur is located in a closed basin (Burdur basin). The lake was fed by rainfall, seasonal and permanent streams and groundwater. The important streams feeding the lake include Bozçay, most of which is currently dry and located at the southwestern end of the lake, and Ulupınar, Bayındır, Büğdüz, Kurna Çerçin, Keçiborlu (Adalar Çayı) streams to the east [8].
5. For these reasons, the water level of Lake Burdur has decreased vertically by 13 m in the last 40 years and its surface area has decreased from 230 km³ to 150 km³. The water level has decreased from 858 m to 845 m. This trend shows that the lake is rapidly drying out and is in danger [6].
6. Excessive grazing and mowing are carried out in the surrounding area. This situation increases plant species resistant to grazing and mowing; suppresses non-resistant species. The weakening of the vegetation disrupts the shelters and habitats of wild animals. Animals subject to the microclimate of Lake Burdur are harmed by the application.
7. The unconscious use of barn manure and pesticides negatively affects the aquatic habitats around the lake. The awareness of the agricultural and animal husbandry sector should be raised on this issue; excessive use of pesticides and water should be prevented; however, the producer sector should be directly supported and guided by the Provincial Directorate of Agriculture and Forestry with seeds, financial support and contracted production.
8. The lake bed is shrinking due to the withdrawal of water; Drying lake beds are being ploughed by the surrounding field owners or villagers and converted into agricultural land. There are legal cases on the subject. In the drying areas, there are animal shelters, feedlots, farms and various agricultural crops. **Fig. 2**.
9. In some of these dams; the negative characteristics of this practice are naturally reflected in the Ramsar area. However, while the local people were happy with the practice since they made a profit in agriculture and fishing in the first years when the dams were built, they started to object and complain in the 2020s because the dams could not hold water.

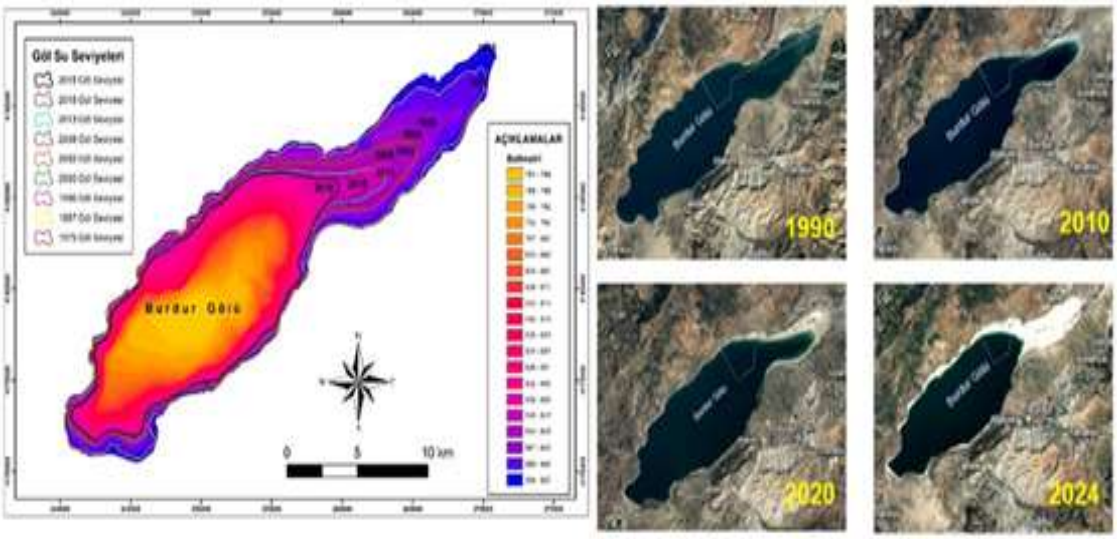

Figure 1. *Change in the surface area of Burdur Lake over the years from Google Earth* [5].

Figure 2a*. Main vegetation types in environs of Burdur Lake (hydropytic habitats: marshes and meadows).*

3. Material and Methods

Water scarcity has become a problem for the whole world. in recent years, some water sources in the Lakes Region have dried up and some are about to dry up. We have made various observations on Lake Burdur and its surroundings since 2013. These studies were generally carried out within the scope of projects supported by the Ministry of Agriculture and Forestry. The reports of the projects were submitted to the relevant ministry through the relevant companies. Flora and vegetation formations, ecosystem cycles, endemic plants, protection statuses and habitat types were examined. Priority areas for protection were determined, indicator plants and a monitoring system were suggested [9]. The protection of the Burdur Lake Ramsar site, which is in the establishment phase, is one of the important current

Figure 2b. *A view from Yarışlı Lake (Burdur) which in recent years, summers have dried up and turns into a clay base.*

environmental problems of the country. The feeding of the lake from natural sources has completely stopped. There is no other feeding source other than the domestic wastewater of the Organized Industrial Zone and Burdur city center. It has been revealed that there is a problem in the treatment of these wastewaters and that they pollute the lake due to the inadequacy of the
treatment. Therefore, a natural treatment method inspired by nature is needed for wastewater. Such a method has been designed and modeled theoretically by us and explained in various aspects in this article. Since the necessary explanations in the description the model have been made in the text of the article, they are not explained again here. There are significant wetlands around Burdur Lake. The flora of these areas has been previously determined by us [9-11].

4. Findings and Discussion

A large part of the lake is within the borders of Burdur and a part of it is within the borders of Isparta province. Isparta side is adjacent to the Keçiborlu district, and Burdur side is adjacent to the lake with its central district and villages. Most of Türkiye's oil rose gardens are also concentrated in this area. 12 of the 20 rose oil factories in total were established in Keçiborlu; a few of them were established in Burdur villages. Their wastewater also reaches the lake without being treated. This wastewater also requires an ecological treatment. In its current state, the lake is rapidly progressing towards becoming a rotten area. The shape and type of plants around it are changing, turning red, and shameless weeds are increasing. In order to suppress the bad smell, local governments recommend planting capers (*Capparis spinosa* and Lavender (*Lavandula x hybrida* or *L. angustifolia*) around the lake. This application may be important in terms of environmental regulation. Lavender essential oil is only for cleaning. Since Burdur Lake is connected to other underground water sources from the bottom, the drying of this lake or the withdrawal of its water from year to year will also negatively affect other water sources in the Lakes Region. The most important of these are Acıgöl, Eğirdir Lake, Beyşehir Lake, Çorakgöl, Salda Lake, Akşehir Lake and dams. The narrowing of the bed of Eğirdir Lake, which is the largest freshwater lake in 2024, the smell of algae coming from the drinking water, fish washing up on the shore, Çorakgöl (Yeşilova) drying up, 'Eber Lake' turning into a swamp; Akşehir Lake and even Beyşehir Lake on the verge of drying up cannot be considered separately from this issue. The decrease in water resources, being a water-poor country like Türkiye, is an economic problem. It is an invitation to collapse, famine, poverty, etc. The findings reveal that we need to discuss the issue in the light of science and give it more bureaucratic importance. According to the general opinion; groundwater is used for irrigation purposes more than surface water. Although groundwater is not easily polluted compared to surface water, it will be more difficult to clean pollutants when pollution occurs. The most important factor that pollutes groundwater is chemical pesticides used in the region [3, 12]. For this reason, we have to reduce the use of pesticides in agricultural areas.

According to the study of [13] animal husbandry is the main source of income in Burdur. The amount of fertilizer in animal husbandry enterprises is very high. Inappropriate storage of fertilizers harms the environment and the lake. When phosphorus secreted from fertilizers mixes with water resources, algae develop and this situation reduces the amount of oxygen in aquatic habitats and increases the mortality rate in fish populations. This negatively affects the biological diversity and water quality of the lake. An ecological treatment system is needed for this.The above-ground parts of the aromatical plant grown in the area can also be used in the treatment system explained in this article.

Although industrial and domestic wastewater are treated and discharged into the lake, a yellowish and foamy zone is formed in the area where the wastewater joins the lake. Life is quite poor here. It indicates the inadequacy of treatment. Burdur Lake is in serious danger especially due to the discharge of wastewater from factories, mines and marble quarries in its surroundings and also domestic wastewater from the central district of Burdur into the lake. More importance should be given to the treatment process. The wastewater that is proposed to support the treatment inadequacy and enters the lake should be subjected to biological treatment and artificial wetland treatment. For this purpose, a new treatment system that imitates the natural system has been designed by us. The artificial wetland that we call the Ecological Ladder Model (EMM) is described below.

The features of the Ecological Ladder Model Purification System (EMM) are as follows:

This model was designed by us for the first time to purify the wastewater of the city and organized industry, rose oil factories, etc. flowing into Lake Burdur. However, it can also be used in the purification of wastewater in other areas whose ecology and topography are similar to Lake Burdur. It is an ecological system that imitates nature. Therefore, the purification period and the area of use for purification are longer than other systems;

however, it does not harm the environment. The size of the area to be used varies according to the flow rate of the water. The system consists of 2 parts, one large (main unit) and one small (side unit). While the main unit is being cleaned, the side unit can be put into operation and operated for a few days. The top of the system is open and swamp mud, filters, etc. can be changed with construction equipment. Since the wastewater, which has a natural flow from top to bottom, comes to the lake by filtering due to the effect of the slope, it can be purified and purified like a strainer in peatlands. With these methods, the wastewater entering the lake is filtered from its surroundings due to the effect of the slope, so it is cleaned in a wide area and over a long period of time, like a strainer.The topography should be approximately 15-30 % slope. The wastewater source should be filtered from above and purified and delivered to the lake. The domestic wastewater of the city center should be purified by natural methods in several steps and then released to the lake. Purification consists of 3 steps:In the first stage in the EMM system, disease-causing microorganisms should be destroyed (with ozone, şap or essential oil plants),

In the second stage, the chemical and physical properties of the water such as pH, hardness, O_2 should be made suitable, In the third stage, the purified water should be tested with live indicators to see if it is drinkable and delivered to the lake.The steps should have a 5-10 % slope, the water passage channels should be curved, the steepness of the steps should be 2-5 m. 50 cm thick limestone (gravel, stone, dust, etc.) should be laid on the ground of all steps, the water should drain from a sloped land through approximately 5 m stone walls to the second step and from the second step to the third step. Distribution should be made from the third step wall to natural areas from above ground with a distribution network.In the first stage, the beginning should be 500 m wide, the end should be 750 m wide and approximately 1 km long; The middle step start should be 750, finish should be 1000 m, step length should be 1500 m. The last step start should be 1000 m wide, finish should be 1250 m wide, 2 km long.

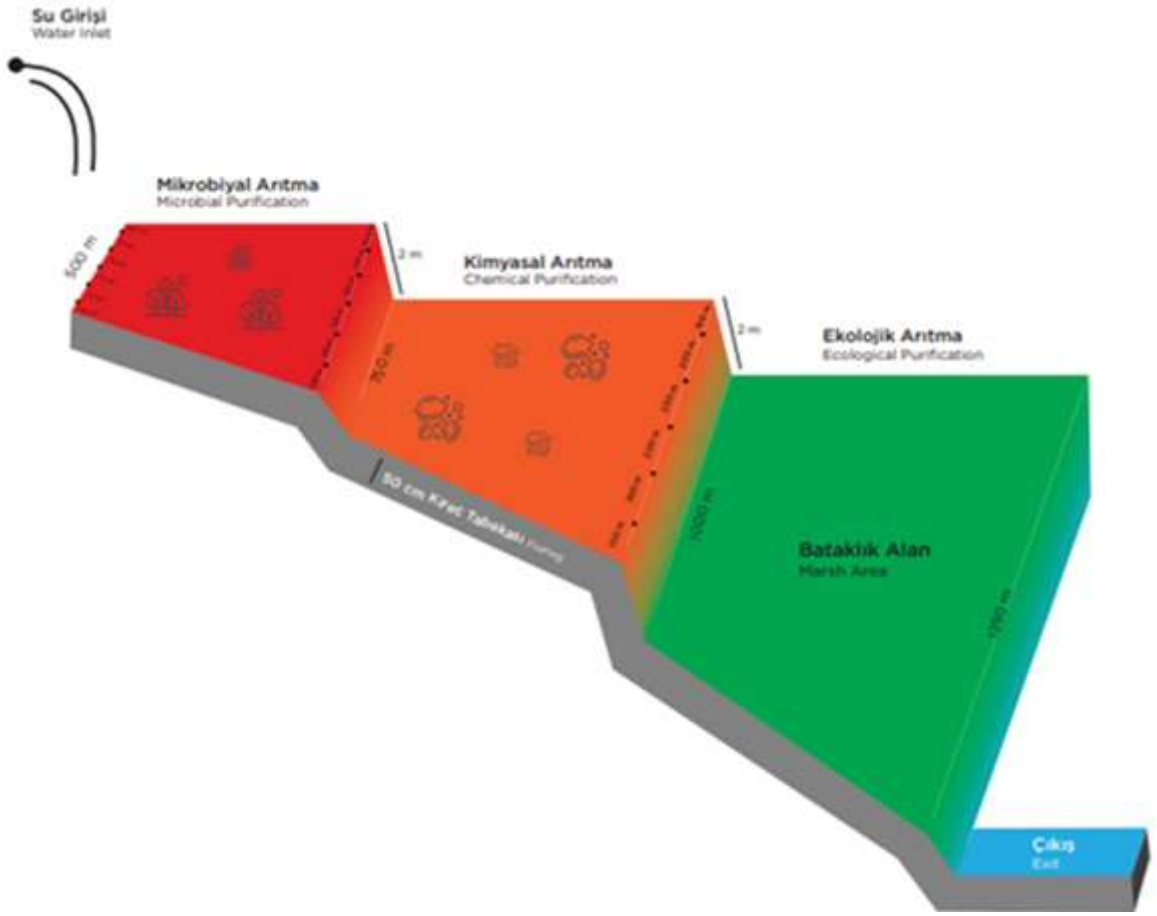

Figure 3a. *Side view of the ecological ladder model purification system (EMM).*

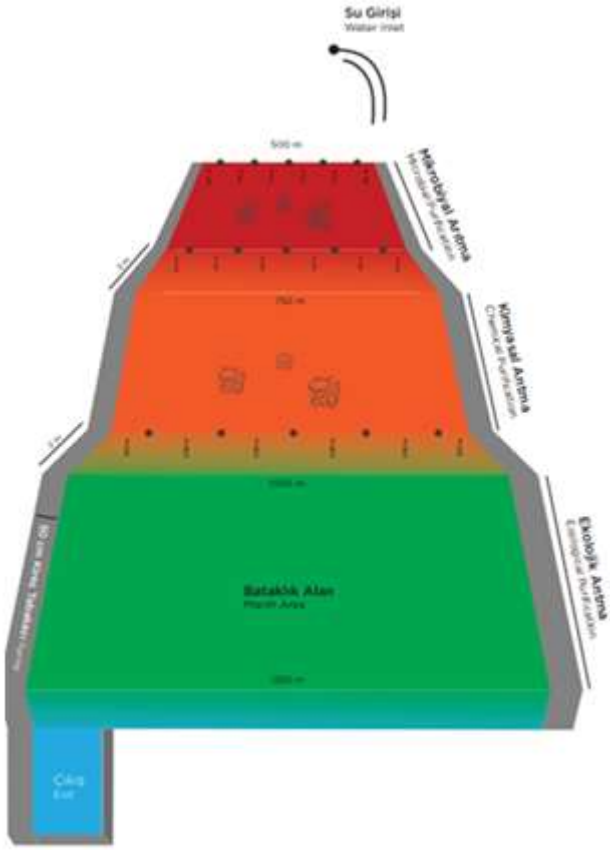

Figure 3b. *Front, vertical view the ecological ladder model purification system (EMM).*

After opening a depth of approximately 3 m for microbial treatment in the first stage, the ground should be covered with 50 cm thick limestone, claim and on top of this, folds/channels should be made with clay and limestone for water to flow. Compressed cotton, hemp, linen, etc. textile residues can be placed between the folds. A drip system of lavender, tyme, oregano oils etc.(specially şap chemicals) should be installed on these using a chlorination system method and flowed over the cotton, etc. section at certain intervals. Lavenders to be produced around the lake should be distilled for this purpose.Şap (in Türkish) alum, commonly known as potassium aluminum sulfate ($KAl(SO_4)_2 \cdot 12H_2O$), is a group of chemical compounds, usually consisting of hydrated double salts. It is widely used in water treatment, as an astringent, and in various industrial processes. The essential oils of essential oil plants such as lavender, thyme, laurel, juniper, cedar, flower, cone trunk, wood, leaf etc. should be placed and the system should be open. It should have two sections, the sections do not have to be equal. While one section is being cleaned, the other section should be working. Wastewater should preferably be given to the first stage at 100 m intervals, the flow rate and volume of the water should be weakened. The middle stage is for chemical treatment purposes.

A filter should be made by laying wood ash, gypsum rocks, soapwort roots or other organs, limestone rocks and gravel, marble dust; winding water channels should be created with basic rocks, the height of the channels (depth should be about 2.5 m) and should be covered with a layer of soil of about 1-2 m.

Filtration of polluted water and disposal of treatment sludge:

In terms of physical properties, metals with a density higher than 5 gr/cm³ are called 'heavy metals'. There are more than 60 metals, the most important of which are chromium (Cr), iron (Fe), copper (Cu), nickel (Ni), zinc (Zn), cobalt (Co), mercury (Hg), lead (Pb), cadmium (Cd). These metals are generally found in nature as silicates, carbonates, oxides and sulfur.Salty, gypsum rocks and limestone can be used to purify polluted waters in the region. These rocks can be turned into gravel and wood ash can be sprinkled between them to prepare purification sludge. Polluted waters can be filtered with this sludge. Sludges that have completed their economic life should be collected in a certain area and capped mushrooms, *Thlaspi* spp., *Helianthus annuus*, *Nicotiana tabacum*, *Brassica* spp., *Zea mays*, *Pteris vittara*, *Gypsohila* spp., *Euphorbia* spp., *Tagetes* spp., *Typha* spp., *Carex* spp., *Cyperus* spp. group plants should be produced in this sludge and then the

plants should be destroyed. Some plants such as *Urtica* spp., *Chenopodium* spp., *Polygonum sachalase* and *Alyssum* spp., have the ability to accumulate cadmium, copper, lead, nickel and zinc in their bodies. *Salvinia natans, Lemna minor*, mosses can be grown wherever there are water bodies or excessive humidity.

The last step of the ladder is ecological purification. It was deemed appropriate that the beginning of 1000 m should be the widest side (end) of the 1250 m step. This should be covered with marsh plants that purify the water. The recommended plants for Burdur Lake and its surroundings are as follows: *Phragmites australis* ve *Typha domingensis, Bolboschoenus maritimus, Schoenoplectus lacustris, Juncus heldreichianus* subsp. *orientalis, Juncus maritimus, J. gerardi, Scirpoides holoschoenus, Cyperus* spp., *Carex* spp., *Tamarix smyrnensis, Ononis spinosa* subsp. *leiosperma, Cardopatium corymbosum, Trifolium* spp., *Medicago, Lotus, Lotononis* spp., *Potentilla* spp., *Beta* spp., *Zea mays, Sorghum* spp., *Vicia* spp., *Lathyrus* spp., *Onobrychis* spp., *Phlomis* spp., *Teucrium* spp., *Mentha* spp. etc. seeds or diaspores should be transferred from the surrounding flora to the relevant area.

In addition, in the Burdur and Yarışlı Lake edges, the halophytes *Suaeda cucullata* (endemic), *Atriplex tatarica, Frankenia hirsuta, Chenopodium murale, Lemna minor, Puccinellia distans, Petrosimonia brachiata, Aeluropus litoralis, Halimione portulacoides, Halocnemum strobilaceum, Salsola* spp., *Suaeda* spp. are characteristic taxa of soda halophyte habitats. Diaspores of these plants will also come from the lake surroundings [9, 14].

Wild fruit trees such as *Elaeagnus angustifolia, Hippophae rhamnoides, Pyrus* spp., *Sorbus* spp., *Crataegus* spp., *Berberis* spp. etc. should be planted in the empty areas by the lake, which the public can also benefit from. *Capparis spinosa, Lavandula* spp. should be planted in sloping areas for a pleasant appearance [15, 16]. From here, a vertically stepped reservoir should be built and purified water should be collected and given to natural grass, pastures and marshes. From there, excess water will be filtered from the soil and delivered to the lake. The area should be fenced and closed to animals, humans and animal:

1. The organic matter accumulated in the microbial treatment area can be fed to Red California Worms (*Eisenia fetida*) and converted into a quality fertilizer in agriculture. Burdur is an important province in worm compost production. It can be destroyed in existing facilities or a worm compost production facility should be established next to the artificial wetland. Animal producers, especially those around Burdur Lake, should be encouraged to establish manure purify areas and to purify and dispose of wastewater at the production site.

2. The following plants are recommended for the purification of water from heavy metals. Mushrooms, *Helianthus annuus, Nicotiana tabacum, Brassica* spp., *Zea mays, Pteris vittara, Arundo donax, Juncus, Cyperus, Typha, Thlaspi* spp. are recommended as a method of production and destruction. In addition, by creating peatlands and filtering polluted water; by making panels with a mixture of gypsum, limestone and wood ash and filtering the water, microbiological purification and adjustment of acid-base balance can be done.

3. For surface waters; water collection basins should be created and pollution should be prevented. The eyes of springs and their immediate surroundings as well as wetlands should be protected and controlled.

4. Results and Recommendations

According to the Burdur Chamber of Industry and Commerce (2010), the most important sources of income in the Burdur province economy are as follows: Agriculture and livestock, and the food industry, which includes meat, dairy, and agricultural products, comes first with 41%; the marble-focused industrial sector comes second with 18%. Trade accounts for 12%, tourism 10%, forestry 9%, mining 8%, and technology 1% [23].

The entire the lake area is under the control of the state. The lands surrounding the lake belong to the treasury, private property, and village legal entities. Treasury lands, which cover 56.28% of the entire basin, include wetlands, forests, meadows, and steppe areas. Irrigated and dry agricultural lands on privately owned land outside residential areas constitute 39.59% of the basin, while areas around the lake belonging to the treasury and village legal entities constitute 4.13%.

This information has been used in the establishment of artificial wetlands. If this method designed for Burdur Lake can be applie d and the model is successful, it can be applied to other polluted streams with similar topography and ecological conditions to Burdur Lake by changing the necessary corrections and conditions.

The EMM model designed and published in this article is a model that can be used for many lakes or streams, especially Burdur Lake. We think that this method can be developed further and used in solving pollution problems in Istanbul and Izmir Bay. Lake Van, which is the 1st largest lake in Türkiye and the 10th largest in Europe, has a circumference of 470 km. Unfortunately, it has also been in danger of putrefaction and drying in recent years. Its situation

is the same as Lake Burdur. It has not entered the danger limit because it is a larger lake. Lake Van will also experience the same problem in the coming years.

The zone created by the wastewater that has been partially purified or directly given to the lake until today is clear. The area where the wastewater enters is foamy, yellowish, turbid, uninhabited and smelly and the lake can be cleaned by installing a pump and giving it to the EMM system from the area. The lake also has its own ecosystem cleaning capacity. If it is desired to clean stinky wetlands, it can be entered into the system with a pump in the same way and after being purified, it can be given to the lake or the sea. Bottom muds with a lot of organic matter, treatment sludges, etc. can be turned into organic agricultural fertilizer by feeding them to worms.

Burdur Lake, one of the 14 Ramsar sites in Türkiye, is currently under the threat of drying up for various reasons [17-20]**.** Our recommendations against these results and threats are as follows:

The obtained barn manure should be collected under appropriate conditions and burned with biological methods (purified from uric acid), then used in agricultural areas.

The water regime of the basin should not be interfered with any more. Purified water should be used for park and garden irrigation instead of clean water. Rainwater collection systems should be brought to cities and villages.

The potential salinity sources of groundwater are salt rocks. These rocks are broken down by effects of heat and cold or melted by rain and mixed with water; and thus the chemical structure of the water and therefore the soil is damaged. The wastewater generated after rose processing has a high flow rate and is loaded with pollution. The fact that this type of wastewater is spread to different regions makes treatment difficult in treatment plants. For this reason, alternative treatment methods are needed other than the existing treatment methods.

It is extremely important to protect the environment and natural resources from pollution. Cleaning polluted areas is equally important. Since there is an increasing water shortage in the region, it is inevitable to purify water resources that contain salt, arsenic or heavy metal pollution.

Drainage in meadow areas: Drainage was made in meadow areas in Düger and Bucak districts of Burdur province, approximately 20 years ago. It was a very wrong application. As a result of this application, the meadows were turned into pastures for a few years and the grass yield increased. Shepherds and those who were engaged in animal husbandry were satisfied with the application for short time. In the following years, these meadow areas were converted into steppes and then into drylands. The waters of the surrounding agricultural areas and the moisture under the soil were affected by these activities.

One fish species has been identified in Lake Burdur, and two fish, three reptile, and one amphibian species have been identified in its connected streams. Due to the salinity and unique ionic composition of the lake water, the Burdur mossfish (*Aphanius sureyanus*) is a single species, adapted to the lake and a point endemic. Due to its small size (maximum 5 cm long), this species has no economic value as a human food**.**

The Burdur Lake Basin is one of the world's most important bird habitats. A total of 210 bird species have been identified. Of these, 82 are waterbirds, 95 are passerines, 27 are diurnal, and 6 are nocturnal. The white-headed duck (*Oxyura leucocephala*), saker falcon (Falco cherrug), and Egyptian vulture (*Neophron percnopterus*) are classified as Endangered (EN), and the Dalmatian pelican (Pelecanus crispus) are Vulnerable (VU) (IUCN Redlist). The representation of bird species protected under the Bern Convention within the sub-basin reveals that 153 species are protected. Furthermore, according to the compilation of Türkiye's Key Biodiversity Areas, completed in 2006, 21 bird species have earned the lake KBA status.The Burdur Lake basin boasts a rich ecosystem diversity, encompassing wetlands, meadows, reed beds, streams, broad-leaved forests, coniferous forests, mixed forests, woodlands, afforestation, mountain steppes, rock formations, agricultural and residential ecosystems. This diversity highlights the importance of the Burdur basin, and particularly Lake Burdur and its surroundings, in terms of biodiversity and landscape beauty. Adjacent ecosystem types can support each other in the formation and maintenance of life cycles, providing multifaceted benefits for all living creatures, especially humans. Therefore, the basin must be protected holistically and water loss prevented.

The number of endemic plant species in the Burdur Lake basin is 17, respectively: *Jurinea pontica*, *Tripleurospermum callusum*, *Alkanna areolate* var. *areolata*, *Alyssum caricum*, *Alyssum pateri* subsp. *pateri*, *Bolanthus minuartioides*, *Cephalaria cilicica Euphorbia falcata*, *Euphorbia djimitensis*, *Hedysarum pestalozzae*, *Ballota nigra* subsp. *anatolica*, *Micromeria cristata* subsp. *cristata*, *Stachys cretica* subsp. *smyrnaea*, *Stachys iberica* subsp. *stenostachya*, *Wiedemannia orientalis*, *Eryngium kotschyii*, *Valerianella glomerata* etc. Due to intensive agriculture in and around Lake Burdur, meadow plant populations are uneven. Plant species belonging to the families Asteraceae, Brassicaceae, Boraginace, Caryophyllaceae, Chenopodiaceae, Fabaceae, Geraniaceae,

Lamiaceae, Malvaceae, Papaveraceae, Ranunculaceae, and Rosaceae form the cover in the meadow areas around the lake. These species also form the cover in mountain steppes and rocky and stony habitats in the highlands**.**

Lake Burdur was designated a Waterfowl Wildlife Protection Area (38,125 ha) in accordance with the Land Hunting Law in 1993. This protection status was changed to the Lake Burdur Wildlife Development Area (26,229 ha) in 2006. Half of the lake (12,600 ha) was included in the Ramsar Convention in 1994, and the entire area in 1998. In 1998, the Ministry of Culture also declared a First Degree Natural Protected Area. The boundaries of wetland protection zones, determined according to the Regulation on the Protection of Wetlands, came into force in 2006 and were updated in 2012. Since Burdur Lake is a Wildlife Development Area (26,299 ha) and a Ramsar site (25,577 ha according to GIS analysis), protection and management efforts are carried out by the Ministry of Forestry and Water Affairs. It has been stated that groundwater quality in urban areas is mostly controlled by the geogenic and geochemistry of the environment, urbanization rate, dumpsite leaks, industrialization, mines, bacteriological pollution, heavy metals and the effects of the seasons [3]. Since the cities in the Göller Yöresi are also growing rapidly, groundwater will be more polluted by surface water and diseases will increase more. It is thought that surface water is more prone to pollution compared to groundwater due to being exposed to all kinds of pollutants (landfill, domestic waste, dumps, septic tanks and oil spills, etc.); however, it is easier to clean.It has been stated that ornamental plants *Calendula officinalis* and *Althaea rosea* can be used in phytoremediation due to their tolerance to cadmium. The use of plants (*Tagetes patula, Syngonia* sp., *Pteris cretica and Pteris vittata*) in the removal of As (Arsenic/$NaAsO_2$) pollution in soil has given positive results. Hyperaccumulator plants are plants that accumulate more metal levels in their aboveground parts than in the soil, and are therefore used in the cleaning of heavy metal pollution (phytoremediation). These plants can accumulate heavy metals 100 to 1000 times more than other plants without showing any toxicity symptoms. Approximately 450 plant species (only 0.2% of angiosperms) have been described as hyperaccumulators [21, 22].

Şap (in Türkish) alum, commonly known as potassium aluminum sulfate ($KAl(SO_4)_2 \cdot 12H_2O$), is a group of chemical compounds, usually consisting of hydrated double salts. It is widely used in water treatment, as an astringent, and in various industrial processes.

The inadequacy of the measures taken is observed with the pollution and ecosystem deterioration in the lake over the years. There is a board to manage the area. It should be managed by a board that selects consultants from relevant institutions under the responsibility of the Nature Conservation and National Parks Burdur Branch Directorate. Those other than the responsible institution should only make suggestions for drying the area. The Burdur Lake revised wetland management project should be integrated with the previously implemented projects. An executive management plan that will form the basis for the implementation of the Burdur Lake Integrated Basin Management Plan and that produces scientific, legal and practical results should be created by the representatives of the relevant institutions; It should be implemented by the Nature Conservation and National Parks Burdur Provincial Directorate.The treatment model (EMM) described here is a theoretical design. It was designed specifically for Lake Burdur. It can also be applied to other areas. Design modifications can be made based on the geographic and ecological characteristics of the location, as well as the wastewater flow rate and pollution levels. The General Directorate of National Parks or local governments could undertake the project. Other regions around the world could also implement wastewater treatment processes in their own regions based on this project. Wastewater treatment systems must be progressively transformed to meet ecological requirements. Chemical treatment is a short-term, rapid solution, but it disrupts the ecological cycle. Hybrid facilities can also be established in some areas.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** This study was carried out within the scope of 2 projects: 1. The project titled “Biodiversity Inventory Monitoring Work of Terrestrial and Inland Water Ecosystems of Burdur Province” commissioned by the Ministry of Forestry and Water Affairs of the Republic of Türkiye. We would like to thank the General Directorate of Nature Conservation and National Parks for financially supporting the study; the contractor company AnaDOKU (Anatolian Nature and Culture Conservation Cooperative), 2. Burdur Lake Wetland Revised Management

Plan project. The contractor company Ançeo (Anatolian Forestry, Mapping, Construction. Trade and Industry Co. Ltd.) and the project work teams, especially the project manager Prof. Dr. İskender Gülle; We would also like to thank the SDÜ Rectorate for granting the necessary permissions for our work and facilitating the legal procedures; the 6th Regional Directorate of Nature Conservation and National Parks.

- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1] Karacabey, B., Özgür, H., Çevirme, M., Koç, M., Gültekin, G., Ertürk, T., İpek, N., Kocaeli, G.M., Bilge, S. (2021). Türkiye'de orman varlığı (2020). *Orman Genel Müdürlüğü, OGM Ofset*, Ankara.

[2] Anonymous, (2024). https://ekotaban.tarimorman.gov.tr/alan/2889

[3] Eyankware, M.O., Ogwah, C., Okeke, G.C. (2018). Geochemical evaluation of groundwater origin using source rock deduction and hydrochemical facies at Umuoghara Mining Area Lower Benue Trough, SE Nigeria, *International Research Journal of Earth Sciences*, 6,10: 1-11.

[4] Erşen, S.S., İşcen, C.F. (2024). Metal sanayi atık sularının yukarı akışlı anaerobik dolgulu yatak reaktörde arıtılabilirliği ve kinetik modellemesi. *Research Journal of Biology Sciences (BIBAD)*, 17(1): 12-27.

[5] Gülle, İ., Özçelik, H., Bellioğlu, G. et al. (2018). Burdur lake wetland revised management plan project. *TR. Ministry of Agriculture and Forestry, Nature Conservation and National Parks 6th Regional Directorate, by Ançeo (Anadolu Ormancılık, Haritacılık, İnş. Tic.ve San. Ltd. Şti.),* Ankara.

[6] Anonymous. (2012). TR. BAKA (Western Mediterranean Development Agency) *Report: problems, solutions, management and economic potential of Burdur lake, Isparta*.

[7] Anonymous, (2025). https://www.ramsar.org/country-profile/Turkiye .

[8] Ataol, M. (2010). The water level changings in Burdur Lake, *Coğrafya Bilimleri Dergisi, CBD* 8(1): 77-92.

[9] Özçelik, H., Çinbilgel, İ., Muca, B., Tavuç, İ., Koca, A. & Bebekli, Ö. (2016). Plant I-inventory of Burdur Province (Economic, Rare and Endemic Plants). *Burdur Belediyesi, Kültür Yayınları*.

[10] Özçelik, H., Çinbilgel, İ., Koca, A., Muca, B., (2014). Mermer Ocaklarının Burdur Florası Üzerine Etkileri, *Ulusal Mermer ve Taş Ocakları Onarım Teknikleri Sempozyumu*, 18-20 Eylül 2014, Bildiriler Kitabı: s. 191-204.

[11] Çetin, A., Erdoğan, N., Genç, H., (2013). Flora of the Burdur Lake Surroundings (Türkiye), Biological Diversity and Conservation, 6, 2: 55-76

[12] Jiang, Y., Li, R., Yang, Y., Yu, M., Xi, B., Li, M., Xu, Z., Gao, S., Yang, C. (2019). Migration and evolution of dissolved organic matter in landfill leachate-contaminated groundwater plume. *Resour. Conser. Recy.*,151(5), 104463

[13] Atılgan, A., Erkan, M., Saltuk, B. & Alagöz, T. (2006). Environmental pollution caused by manure in livestock farms in the mediterranean region. *Ekoloji*, 15(58): 1-7

[14] Yurdakulol, E., Öncel, I., Demirörs, M., Yıldız, A. & Keles, Y. (1996). Ecological and syntaxonomic investigation of salt marshes vegetation in the vicinity of Burdur and Acıgöl (Denizli/Turkey). *Ecologia Mediterranea*, 22 (1-2): 51-61.

[15] Gül, A., Özçelik, H., (2016). Determination of some ground cover plants growing naturally in Lakes region of Türkiye, *SDÜ. Fen dergisi*, 11, 2: 13-44.

[16] Özçelik, H., Koca, A., (2011). Türkiye'de Kebere (Capparis L. /Capparaceae) Cinsi ve Ekonomik Önemi, *2. Uluslararası Odun Dışı Orman Ürünleri Sempozyumu*, 8-10 Eylül 2011, Isparta, s. 32-40.

[17] Özçelik, H., Çinbilgel, İ., Muca, B., Koca, A., Tavuç, İ., Bebekli, Ö., (2014). Burdur İli Karasal ve İçsu ekosistem çeşitliliği: Koruma ve İzleme çalışmaları, *SDU Journal of Science (E.Journal)*, 9(2): 12-43.

[18] Özhatay, N., Byfield, A., Özçelik, H., (1998-2000). Türkiye Önemli Bitki Alanları, Fauna, *Flora International (FFI), Doğal Hayatı Koruma Derneği (DHKD*), İstanbul Üniv. Eczacılık Fak. İstanbul.

[19] Özhatay, N., Byfield, A. & Atay, S. (2005). 122 Important Plant Areas of Türkiye (ÖBA). *Fauna, Flora International (FFI), Doğal Hayatı Koruma Derneği (DHKD) and İst. Üniv. Eczacılık Fak. İstanbul.*

[20] Eken, G., Bozdağ, M., İsfendiyaroğlu, S., Kılıç, D.T. & Lise, Y. (2006). Natural areas of Türkiye I., II., *Mas Matbaacılık A.Ş.*, Ankara.

[21] Özay, C., Mammadov, R. (2013). Ağır Metaller ve Süs Bitkilerinin Fitoremediasyonda Kullanılabilirliği, *BAÜ Fen Bil. Enst. Dergisi*, 15, 1: 67-76.

[22] Yiğitbaşıoğlu, H. & Uğur, A. (2010). Environmental problems arising from land use characteristics in Burdur Lake Basin. *Ankara University Journal of Environmental Sciences*, 2, 2: 129-