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Research Article

Setting Measures for Tackling Agricultural Diffuse Pollution of Küçük Menderes Basin

Küçük Menderes Havzası'nda Tarımsal Kaynaklı Yayılı Kirlilikle Mücadele Tedbirlerinin Belirlenmesi

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Abstract

We explained the methodology used in setting the basic and supplementary measures for diffuse pollutants at Küçük Menderes Basin. As the majority of diffuse pollutants arise from livestock breeding and agricultural activities, we focused to propose measures regarded with tackling the pollution from agricultural activities. The types and distribution of diffuse loads were expressed by total nitrogen and phosphorous parameters. We used the results of a yearlong surface water quality monitoring involving physico-chemical, chemical and biological parameters with specific pollutants and priority substances, set in the European Union Water Framework Directive as the AquaTool input data. The AquaTool model was run for attaining the outcomes of a series of measures determined according to the ecological sensitivity of each water body. The removal efficiency of pollution loads provided by the best management practices in agricultural activities and livestock breeding were compiled from literature, and typical removal rates were further determined for the basin. We produced nine alternative scenarios at first cycle for determining compliance measures for mitigating point and diffuse sources of pollution

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in surface water bodies, and water quality improvements observed in the Model were reported. A number of exemptions were defined for some of the water bodies that could not achieve the environmental objectives at the end of first implementation cycle. 759 proposed measures for tackling diffuse pollution were 81% of the total measures considered. Additionally, the measures for mitigating diffuse agricultural pollution were almost equal to half of the diffuse pollutant measures, and 40% of the overall measures listed.

Keywords: *Diffuse pollutants, basic measures, total nitrogen, total phosphorus*

Öz

Türkiye'nin batısında yer alan Küçük Menderes Havzası'nda özellikle yayılı tarımsal kirleticiler için temel ve tamamlayıcı tedbirlerin belirlenmesinde kullanılan metodolojiyi açıkladık. Havzadaki yayılı kirleticilerin büyük kısmı hayvancılık ve tarımsal faaliyetlerden kaynaklandığından, makalede tarımsal faaliyetlerden kaynaklanan kirlilikle mücadele ile ilgili tedbirlere odaklanılmıştır. Yayılı yüklerin tipleri ve dağılımı toplam azot ve fosfor parametreleri ile ifade edilmiştir. AquaTool girdi verileri olarak Avrupa Birliği Su Çerçeve Direktifi'nde belirlenen spesifik kirleticiler ve öncelikli maddelerle birlikte fiziko-kimyasal, kimyasal ve biyolojik parametreleri içeren bir yıllık yüzeysel su kalitesi izleme sonuçları kullanılmıştır. AquaTool modeli, her bir su kütlesinin ekolojik duyarlılığına göre belirlenen bir dizi önlemin sonuçlarına ulaşmak için çalıştırılmıştır. Tarımsal faaliyetlerde ve hayvancılıkta en iyi yönetim uygulamaları kullanılarak belirlenen kirlilik yüklerinin giderim verimi literatürden derlenmiş ve havza için tipik giderme oranları ayrıca belirlenmiştir. Yüzey suyu kütlelerinde noktasal ve yayılı kirlilik kaynaklarının azaltılmasına yönelik uygun tedbirlerin belirlenmesi için ilk döngüde dokuz alternatif senaryo üretilmiş ve AquaTool modelinde gözlenen su kalitesindeki iyileşmeler raporlanmıştır. İlk döngünün sonunda çevresel hedefe ulaşamayan su kütleleri için muafiyetler tanımlanmıştır. Yayılı kirlilikle mücadele için 759 önlem önerilmiş ve bu miktar havzada belirlenen tüm önlemlerin %81'ini oluşturmuştur. Ek olarak, yayılı tarımsal kirliliğin azaltılmasına yönelik önlemler, yayılı kirleticilerin önlenmesi ile ilgili tüm önlemlerin neredeyse yarısına ve listelenen genel önlemlerin %40'ına eşittir.

Anahtar kelimeler: *Yayılı kirleticiler, temel tedbirler, toplam azot, toplam fosfor*

Introduction

In Article 11 of European Union Water Framework Directive (EU WFD) the Member States should establish programme of measures (PoMs) for each river basin (European Commission [EC], 2000; EC, 2012). With the assessment of pressure-impact-risk analyses coupled with water quality analyses conducted within the framework of preparing the River Basin Management Plans (RBMPs), it is intended to achieve environmental objectives by setting the necessary basic and supplementary measures for tackling water pollution. It is aimed to take measures based on the requirements of the legislation in force for effective, efficient and sustainable water usage as well as the protection of water quality, and prevention of point/non-point (diffuse) pollution.

The implementation of the relevant current laws for the protection of water resources is basic before determining other measures. Directives related with urban wastewater, nitrate, industrial emissions, drinking water, bathing water are among those directives that need to be fully applied. The best environmental implementation for controlling the diffuse pollutants are the licenses based on the binding rule or the records (EC, 2012). Supplementary measures can bring stricter limit values than the measures specified in the EU legislation, and stricter controls may be required particularly for agricultural activities involving crop production and animal raising. When selecting the combination of supplementary measures for a water body, the criteria of technical appropriateness of the measures and the achievement of the objective within the determined time should be taken into account. Additionally, it is also necessary to reveal how to implement the measures more cost effective and consistent. If the implementation of the measure within the specified period results in uneven costs or if it is not technically feasible, an exemption may be defined for extending the period to the next planning cycle as depicted in EU WFD.

Different mechanisms are available in the process of setting measures in various countries. These mechanisms can be economic instruments, negotiated agreements, and methods for increasing water efficiency, training programs and research, development and implementation projects as experienced especially by developed countries of the Member States who have already completed their first cycle in the implementation of the measures. Recent studies from Europe refer to the lessons-learnt from the experiences of the first cycle implementation; a few examples from Germany (Evers, 2016; Taha et al., 2019), Denmark (Baattrup-Pedersen et al., 2018), England (Giakoumis & Voulvoulis, 2019) and the Netherlands (den Haan et al., 2019) may be cited.

Turkey as a candidate country of EU, has been preparing river basin management plans for main 25 river basins of the country. Detailed and up-dated information on Turkey's water resources have been compiled in the recently published book (Harmancıoğlu & Altınbilek, 2020) in which a chapter was devoted to river basin management efforts (B. Selek & Z. Selek, 2020). Turkey, forming a bridge between the two continents; Europe and Asia, lies within a strategic geographical location, bears variable geographical, topographical, hydrological, geological and climatic properties representing different characteristics in its water basins. Rapid population increase, inefficient use of water resources, climate change effects and environmental degradation due to human-induced activities necessitate implementation of sustainable management strategies against further deterioration of the basins.

In this study, the basic aim is to mention the methodology used to set the measures in handling diffuse pollution, especially diffuse agricultural pollution with a case study (Küçük Menderes Basin [KMB], located on the Aegean Sea coast) in main river basins of the country. RBMP of this basin has recently been prepared and approved by the Republic of Turkey, Ministry of Agriculture and Forestry (MAF) according to the requirements of the EU WFD (Küçük Menderes River Basin Management Plan [KMRBMP], 2020). Determination of the pollution sources that arise due to various land-use activities, evaluation of pressures/impacts/risks based on the ecological targets, review of existing evaluations of hot spots, investigating the suitability of the existing pollution control measures, reviewing the current regulations, policies and strategies have been addressed within this comprehensive study.

Method

Study Area

KMB locates in Western Turkey and drains off its water into Küçük Menderes River and other streams. The geographical location of the basin in Turkey and its surface water bodies are shown in Figure 1. It has a total area of 6963.25 km^2 and consists of 5 sub-basins with a total population of 3.5 million. The most important river of the basin is Küçük Menderes River. According to the Master Plan study of the basin (State Hydraulic Works [SHW], 2016), water potentials calculated by taking the weighted average-based values on the sub-basins are given in Table 1.

The Mediterranean climate, characterized by dry summers and mild, wet winters, dominates the majority of the KMB. Generally, drought is not experienced much in the basin. The total rainfall amount in the east and southeast of the basin presenting a sub-humid region is higher than the rainfall in the other parts of the region. The average basin temperature is calculated and determined as 16.8^0C. As seen from Table 1, the annual average precipitation has been determined as 693 mm; however, the average of the total evaporation values of the basin is calculated as 1.525 mm. According to CORINE 2018 land-use distribution data, almost half of the basin is covered by forests and semi-natural areas followed by agricultural areas occupying 40% of the total area. Residential and industrial areas constitute only 6% of the entire basin.

According to WFD, surface water resources should be divided into 3 groups such as natural, artificial and heavily modified according to their physical and morphological characteristics classified under 4 different categories of river, lake, coastal and transitional waters (EC, 2003). Based on this categorization, there are 38 rivers and 13 lakes in the basin. 19 of 38 river water bodies are classified as heavily modified because of their structural changes. Only two of the 13 lakes are classified as natural. The rest of the lakes consisting of dams and ponds are heavily modified. Five dams are operated for providing domestic water needs. As a result of in-depth investigation, it has been observed that the water bodies of KMB are highly contaminated physico-chemically and chemically as well as in terms of their biological quality elements. Detailed information on the characteristics of the basin can be found in KMRBMP (2020).

Figure 1

Geographical Location of the Basin and Its Surface Water Bodies

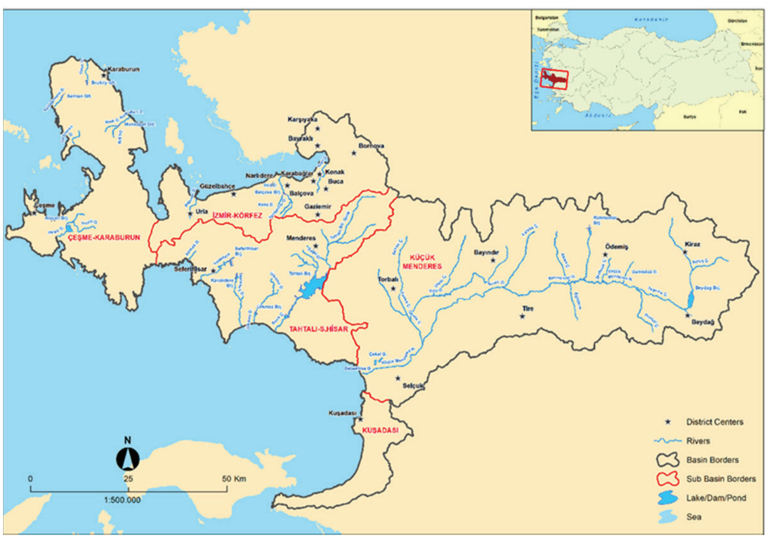


Table 1

Surface Water Potential of the Basin

Basin Hydraulic Properties	Unit	Values
Area	km^2	6963
Surface Water	hm^3/year	624
Current Water Consumption	hm^3/year	223
Current Water Potential	hm^3/year	401
Water Consumption with Source Development	hm^3/year	311
Annual Average Rainfall	mm	693
Average Flow Capacity	v_s/km^2	2.84
Average Flow/Rainfall Ratio	-	0.13

Monitoring and Modelling Studies

Current Pollution Profile of the Basin

According to the risk assessment profile of the surface water bodies in the RBMP, 29 water bodies are "at high risk" whereas 16 of the water bodies are "at moderate risk" in the basin. The current pollution regarding point and diffuse sources of pollutants are calculated and estimated, respectively. The distribution of these two major types of pollution is expressed by the two nutrient parameters of total nitrogen (TN) and total phosphorous (TP). The pollution loads and their distribution in the current situation are given in Table 2.

Table 2

Pollution Loads and Their Distribution in the Basin

Pollution Types	Total Point Pollutant Loads			Total Diffuse Pollutant Loads		
Parameter	COD	TN	TP	COD	TN	TP
Load (tons/year)	11548	1024	123	4474	7731	655
% Distribution	72	12	16	28	88	84

COD: Chemical Oxygen Demand; TN: total nitrogen; TP: total phosphorous

Evaluation of the data given in Table 2 clearly indicates that the basin suffers mainly from diffuse pollutants, as in the most of the watersheds of the country. Turkey is still an agricultural producing country even though it accelerates and deepens the industrialization efforts. Therefore, we emphasize to select the most suitable and efficient measures, either structural or non-structural, for meeting the environmental objectives. Accordingly, it is important to know the sources and the distribution of different types of diffuse loads in the whole basin. In Table 3 we show the distribution of diffuse loads based on the two significant parameters of TN and TP.

Agricultural activities due to fertile soil types of the Aegean Region coupled with favorable climatic conditions for intensive agriculture and livestock breeding make the basin a highly prioritized one regarding its high point and diffuse pollutant loads. In this basin, agro-industrial activities and mining operations are equally important economic activities due to high level of ease of moving goods and services, ease of access and connectivity. This transportation opportunity makes it very attractive region for economic activities. The major sources of diffuse loads arise from livestock breeding and agricultural activities in forestry, meadows, pastures, etc. The leading diffuse load generated by livestock breeding on the basis of two nutrient parameters (TN and TP) are 43% and 55%, respectively. This type of diffuse pollution is followed by agricultural activities where excess chemical fertilizer use constitutes the majority of diffuse loads. These ratios are 25% and 27% for TN and TP, respectively. This trend indicates the requirement of applying Best Management Practices (BMP) and Integrated Manure Management (IMM) in the PoM.

Table 3

Distribution of Diffuse Loads in the Basin

Land-use activities causing diffuse pollution	TN (% distribution)	TP (% distribution)
Fertilizer application	25	27
Livestock breeding	43	55
Meadows, pastures, forestry	24	14
Unsanitary Landfill	6	2
Septic Tanks	1	2
Atmospheric Deposition	1	-

Surface Water Quality Monitoring

Within the context of the RBMP of the basin, water quality monitoring studies have been lasted for 12 months (September 2017- September 2018). The results were used as input data in water quality modelling via AquaTool Model. 79 water quality monitoring points have been identified within its 56 surface water bodies, of which 38 are within rivers, 13 are on lakes/dams, 4 are on coast and 1 are within transitional water. The frequency of measurements is twice (spring and autumn) in this period for biological factors and from 1 to 12 times (every month) in this period for physic-chemical parameters and lastly from 1 to 4 times (each season) in this period for hydromorphological monitoring. Ecological status of the surface water bodies based on WFD is summarized in Table 4.

Table 4

Ecological Status of Its Surface Water Bodies

Status	River Water Body	Lake water body	Coastal water body	Total
Bad	20	1	0	21
Poor	3	1	1	5
Moderate	4	11	3	18
Dry	9	0	0	9
No Monitoring	2	0	0	2
Total	38	13	4	55

Modelling of Surface Water Bodies

AquaTool model is used for the development and analysis of decision support systems for the planning and management of the PoM. Modules that can be used within the Aquatool model program are listed below.

• SIMGES Module (Water allocation module)
• SIMGES Module (Water quality module)
• EVALHID Module (Rainfall runoff model - Hydrological model)

At the initial stage of the modelling studies, hydrological modelling was carried out in four sub-basins (one of the sub-basins does not bear any water bodies) and the model was calibrated. Hydrological modelling studies were conducted between 2000 and 2018, and temperature, precipitation and potential evapotranspiration data were used as input data. Following the hydrological modelling, we studied intensively on water quality modelling. At this stage, water pollution from point and diffuse sources were taken into consideration. There is no monitoring studies on industrial discharges, because the values of these discharges are accepted in compliance with the legislation. The results of the monitoring studies carried out for a yearlong were utilized for the calibration of the AquaTool model.

AquaTool model was operated until the end of 2031 with the monthly average flow rates of the last five years. The efficiency (output) of the results of the proposed measure scenarios based on the parameters exceeding the environmental objectives has been evaluated via the model. It is need to fulfil the environmental objectives for the water bodies in the upstream of the Küçük Menderes sub-basin; they cannot be achieved in some parameters despite all the measures taken as the sub-basin that is the most polluted one among the others. This situation is still valid even some supplementary measures were also proposed to protect the basin. This is an indication that industrial activities are also highly active in addition to agricultural activities in water bodies approaching downstream in this sub-basin. Although advanced treatment technologies were proposed for the industry, the pollutants that discharge to the same water mass exceed the carrying capacity of the water. At this stage, no other measures were proposed in the first cycle concerning the parameters that do not meet the environmental objectives. However, monitoring these specific parameters in the first cycle can be continued and additional measures may be introduced if found necessary in the second cycle. Exemptions have been defined for the first cycle in the KMRBMP.

Measures Identified In the Basin

First, gap analysis (between measured concentration and environmental objectives for the pollutant) was conducted to achieve the environmental targets. Then, each of the basic measures were applied and further tested with the AquaTool model. The need for supplementary measures were then determined, and each of these additional measures were applied separately. Every time, model was run to obtain the results and this procedure continued until the environmental objectives are met. The list of measures identified as appropriate for the basin is given in Table 5.

Table 5

The List of Measures Identified As Appropriate for the Basin

1st Cycle	S1	AAT construction in direct discharges
		Rehabilitation of Irregular Solid Waste Landfill
		Controlled use of animal manure
	S2	S 1 + Management of nutrient and pesticide use
	S3	S2 + Terracing in Agricultural Lands
	S4	S3 + Measures for Olive Cultivation Enterprises
		S3 + Measures for Gas Stations
	S5	S4 + Advanced Treatment in Industrial Facilities
	S6	S5 + Nutrient Removal of all OSBs
		S5 + Nutrient Removal in Urban AATs
	S7	S6 + Vegetative Barrier
	S8	S7 + Crop Rotation
	S9	S8 + Green Belt (Through the stream)
2nd Cycle	S10	S9 + Environmental Flow Measure

Methodology of Selecting Measures for Diffuse Pollutants

Within the period of determining the measures for diffuse pollutants, we aimed to select in compliance with both the overall WFD approach and the related national legislation such as;

- Regulation on Surface Water Quality,
- Regulation on Good Agricultural Practices,
- Code on the Good Agricultural Practices for the Prevention of Nitrate Pollution (CGAP).

National regulation on the Protection of Waters against Nitrate Pollution from Agricultural Sources states that nitrate sensitive areas should be determined initially to fix the respective measures and their order of application. The necessary measures to improve the water quality in sensitive water bodies have been determined at first. Additionally, good agricultural practices have been taken as a basis for the prevention of agricultural pollution in nitrate sensitive areas according to the national regulation on the Determination of Sensitive Water Bodies and the Areas Affecting Them and the Improvement of Water Quality. The Regulation on the Control of Solid Wastes also provides a basis for the closure and rehabilitation of existing unsanitary solid waste depots in the basin and for the establishment of solid waste sanitary landfills.

As the majority sources of diffuse pollutants arise from livestock breeding and agricultural activities, the measures concerning these practices will be the focus of this article.

Code on the Good Agricultural Practices

National regulation on Good Agricultural Practices was published in 2010 to conduct rules and procedures for an agricultural production method allowing traceability, sustainability and food safety in agriculture without harming the human health, animal health and environment. Organic substances positively affect physical, chemical and biological properties of soil For instance, water retention and aeration properties of soil are improved, the penetration of plant roots in soil gets easy and the water penetration into soil increases. 92% of Turkey’s soil is lack of sufficient organic matter; whereas, farmyard manure contains many nutrients for macro and micro plants like nitrogen, phosphorus, calcium and sulphur (Konca & Uzun, 2012).

The removal efficiency of TN and TP loads provided by the Best Management Practices (BMP) for agricultural activities are compiled from literature and displayed in Table 6. Typical removal rates were further selected for KMB during the selection of the PoMs.

The main measures proposed for agricultural production for KMB as mentioned in the Code of Good Agricultural Practices were as follows;

- The high slope (12-20%) and extremely high slope (>20%) areas for terrace farming in the basin
- Management of nutrient and pesticide uses
- Riparian forest buffers on lakes and river banks
- Vegetative barrier practices
- Crop rotation (alternation)

Table 6

Removal Efficiency of Nutrients in the Best Management Practices (BMPs) For Agricultural Land-Use Activities (Tavşan, 2008)

BMPs	Nutrient Removals (%)		Reference
	TN	TP	
Management of Nutrients	21	6	USEPA (2003)
Management of Nutrients	20-90		Novotny (2003)
Organic Agriculture	40-64	No data available for P removal	Scialabba and Hatam (2002)
Organic Agriculture	46 (clayed soil) 10 -35 (sandy soil)	No data available for P removal	Eila et al. (2005)
Terracing	56-92		Ritter and Shirmohammadi, (2001); Cestti et al. (2003)
Terracing	30-70		Novotny (2003)
Change in the Surface Flow Direction (diversions)	20-45		Novotny (2003)
Riparian Forest Buffers on Lake and River Sides	80-90	50-75	Novotny (2003)
Vegetative Filter Strips	50-80	50-80	Grismer et al. (2006)
Vegetative Filter Strips	35-90	5-50	Novotny (2003)
Vegetative barriers	70	70	Blanco-Canqui et al. (2004)
Conservation tillage	No data available for N removal	50	Fawecett (2005)
Conservation tillage	50-80	35-85	Novotny (2003)
Crop rotation (clover-potato)	No data available for N removal	12-33	Lauringson et al. (2004)
Crop rotation	50	30	Novotny (2003)
Strip cropping systems	No data available for N removal	50	Novotny (2003)
Crop Pattern	No data available for N removal	30-50	Novotny (2003)

Terracing.

Terracing is a method of soil protection applied to prevent accumulation and erosion as a result of surface flow caused by precipitation on sloping land (Wheaton & Monke, 2001). Terraces change the land slope and reduce the surface flow rate (Novotny, 2003). Thus, it reduces the erosion rate in the upper layer of soil, the amount of sediment drifted by erosion and the amount of pollutants that may be related to them in surface flow (Cestti et al., 2003; Novotny, 2003). Terracing prevents 94-95% of soil loss, 56-92% of nutrient loss, and 73-88% of surface flow volume (Ritter & Shirmohammadi, 2001; Cestti et al., 2003). According to Novotny (2003), these rates can rise up to 95% for sediment and vary between 30-70% for nutrients. Terraces block the surface flow and store sediments and pollutants by holding them.

Terracing within the agricultural areas is determined as a basic measure to prevent the movement of priority substances, certain pollutants and nutrients towards water resources in KMB. For this purpose, firstly the slope categorization of the basin has been determined. In this categorization, agricultural production areas have been categorized based on this:

- Low slope (<6%),
- Medium slope (6% -12%),
- High slope (12% -20%) and
- Extremely high slope (> 20%).

For each agricultural land, terracing is considered at high and extremely high slope (including pastures, olive groves and continuously irrigated vegetable land). The reduction rates of TN and TP from the diffuse sources were differently foreseen according to the slope. Criteria to take measures for terracing were as follows:

1. In the water bodies there must be pollutants that cannot be associated with point sources,
2. The slope of agricultural areas (including pasture, olive grove and irrigated vegetable land) must be greater than 12%,
3. The ratio of total water bodies within the total agricultural land having the slope above 12% should be at least 5% or more.
4. If it is required, green belt should also be considered for these water bodies as a policy.

Nutrient Management.

If an excessive amount of nutrients is present in the soil, they will be moved from the soil to the water environment through erosion, surface flow, penetration and evaporation and become harmful (United States Environmental Protection Agency [USEPA], 2007). Nutrient management is one of the '*control at source'* practices that aim to optimize the crop productivity and quality, to reduce the manure costs and protect the water and soil quality (Hilliard & Reedky, 2000), and to reduce the formation of excess nutrients and their access to water resources (Natural Resources Conservation Services [NRCS], 2002; Cestti et al., 2003; Novotny, 2003; NRSC, 2007; USEPA, 2007).

Suitable time, quantity, and application methods should be used to minimize the environmental losses while maximizing crop productivity. Time and frequency of application are mainly determined by the climatic conditions that affect the growth of crops, nutrient requirement and transfer of nutrients (USEPA, 2007). Nutrient management and application are particularly effective in controlling dissolved forms of nutrients and provide 20-90% removal in N and P (Novotny, 2003).

Within the scope of nutrient management, the provincial directorate of the MAF allocates budget to inform and train farmers about the suitable time, quantity and frequency of nutrient application. In this way, it is expected to plan the manure use and decrease the N by 20% and P by 10%. In this context, training and awareness raising activities will be conducted throughout the basin.

Pesticide Management.

Pesticide management is a burden of practices that minimize the pollution caused by the chemicals used to control the creatures that give harm to the crops (Novotny, 2003). In this field, management is achieved in two ways; '*control at source'* and '*structural control'*.

<u>*Control at source:*</u> This management way involves (Novotny, 2003);

- Proper application ratios,
- Modern application equipment,
- Suitable timing and frequency,
- Selection of suitable pesticides (the least toxic and most easily biodegradable) for crops.

The selection of pesticides, prohibited or approved is determined by the legislations and they are updated regularly in parallel with other practices and experiments around the world. The General Directorate of Food and Control of the MAF have developed a database on the Plant Protection Products. In the related website, the information such as active substance types required for the harmful organism, application dose and the dates are existed (https://bku.tarim.gov.tr).

Structural Controls: Protective buffer zone applications (green belt, vegetative barriers, etc.) from "Good Agricultural Practices" are also used for pesticide and nutrient control. Thanks to the protective buffer zones, removal is achieved for different pesticide species at the ratios of 10 to 95% (United States Department of Agriculture [USDA], 2000). The pesticides exceeding Environmental Quality Standards (EQS) in each water body have been identified. The measures taken for the pesticide species detected in the water bodies were as follows:

1. Pesticide species detected in water bodies are compared with the "Prohibited Pesticides List" of MAF.
2. Some pesticides have been encountered in water resources of the basin in a large number and quantity. These non-prohibited species will be replaced with their substitutes.
3. Pesticide species that cannot be removed by items (1) and (2) will be captured by the measures such as terracing, vegetative barrier or green belt.

Vegetative Barriers.

Vegetative barriers are narrow parallel bands that consist of plants cultivated on a steep, hard and dense way in the areas close to the land border. Their difference from classical plant filter bands is that they are narrower (less than 1.5 m in width) and they have a steep and hard vegetation throughout the year. Their benefits are listed as follows (Los, 2001; USEPA, 2007);

- They control erosion, hold the sediments in surface flow, and prevent them from reaching the receiving water environment.
- They allow the sediments to accumulate in the upper slopes of the barriers, by slowing down the speed of the water coming in surface flow.
- They increase the efficiency of other protective applications.
- They reduce the total amount of water in surface flow by increasing the water filtration capacity.

It is recommended to apply vegetative barrier on the riverbanks of the agricultural areas to provide effective N and P removal of water bodies in KMB. The guidance of agricultural engineers is needed in the cultivation of plants that are dense, evergreen, less water consuming, specific to the region and taller than the plants in the cultivated agricultural land. In this way, not only nutrients, but also specific and priority pollutants will be held in these barriers. The removal efficiency will be 70% based on TN and TP parameters as suggested by Blanco-Canqui et al. (2004). It can be applied at a width of 1 m to the borders of agricultural land. Its application is easy and very little space is needed. Therefore, vegetation barriers are proposed for some water bodies where terracing is not sufficient.

Crop Rotation.

Crop rotation is the cultivation of different crops on the same land in an annual or periodically planned sequence. By this application, the quality of soil is improved while the natural degradation of weeds, insects and other residues reduces the need of manure. The inclusion of foliage (grass, green grass) or legumes in crop rotation will improve soil quality and reduce erosion (Cestti, 2003; Xie et al., 2015). Moreover, since legumes meet their own N needs and provide extra N to the soil by fixation, the manure usage in the cultivated crop will be quite low (Cestti, 2003). In Estonia, for example, it was observed that the P requirement in the soil decreased by 12-33% in a crop rotation by first planting alfalfa and then potatoes (Lauringson, 2004). According to Novotny (2003), TN and TP can be reduced by 50 % and 30%, respectively. One of the most important benefits of crop rotation is the control of the organisms that may give damage to the crops and soil without using pesticides (Xie et al., 2015) and improves surface water quality by reducing sediment loss, pesticide applications and dissolved or soil-bound particulate nutrients and pesticide losses (Cestti, 2003).

Crop rotation in KMB is recommended when the basic measures in the basin are insufficient to achieve the EQS. In addition to this, the criteria of selection of crops are directly related with the water availability in the provinces and districts in KMB and also the crops in rotation should be selected taking into consideration the Agricultural Basin Production and Support Model of Turkey, started in 2017.

Lake and River Bank Forest Buffer Zones (Green Belt-Buffer Zones).

Lake and riverside forest buffers are afforestation areas close to the riversides, and forms a transition between water and soil. The most effective type of the riverside buffers (riparian buffers) is forests. They contribute to the improvement of water quality while being a habitat for wild animals and fishes. Tree roots absorb the nutrients and other pollutants carried by surface flow. In this way, tree roots grow the fastest and the holding water capacity of roots increases (Campbell et al., 2004). According to Novotny (2003), riverside buffers remove 80-90% of sediments, 50-75% of TP and 80-90% of TN.

In some water bodies in the basin, green belt has been proposed as a basic measure within the scope of "Good Agricultural Practices". This measure has been carried out in the limited amount of areas considering some criteria listed below because of two main problems: Its high cost and high compensation paid to property owners for land expropriation.

1. If the water body is a lake used for supplying drinking water, a 10 m wide forest buffer surrounding the lake is proposed.
2. If the water body is a river and if terracing cannot be done due to slope and if vegetation barrier measure cannot be applied as it passes through the agricultural land, a 5 m wide forest buffer at each site along the part of stream passing the agricultural land is proposed.
3. If the water body is also a river and if it is passing through an active mining site, a 5 m wide forest buffer is proposed at each site along the part of the river passing the mining site.

On the other hand, the green belt measure was not proposed for those water bodies, which have been already surrounded by green belts as a result of deciding with analysing the satellite images. Upon an in-depth review of the nutrient removal rates to be attained via various BMPs, Table 7, including the removal rates selected for the KMB, was prepared. In Figure 2, a map of basic control measures for reducing the agricultural diffuse in the basin was shown (except for animal manure control).

Animal Manure Control.

For the reason that increase in the impairment effects of chemical fertilizers used in agricultural activities on the human health, ecological agricultural practices, based on the animal manure use that has the same functions with the chemical ones have been developed at the second half of the last century. The fertility of agricultural areas cannot be sustained, especially with the use of chemical fertilizers. Using poultry manure, for example, positively affects the structure of soil, and provides the necessary nutrients for growing the plants (Soyergin, 2003).

If the necessary attention and care are not paid after the removal of the cow manure and if the required precautions are not taken, the loss of liquid faeces containing 50% of the plant nutrients before moving to the field becomes an important problem. If not enough bearing is used, it may leak from the cowshed floor and can be significantly lost under the manure pile. Moreover, if the manure taken from the cowshed is left in open air and in loose piles, the loss may reach a significant size (Soyergin, 2003).

The amount of use of commercial (synthetic) fertilizers in agricultural areas in Turkey varies by the amount and types of the planted crops, climatic conditions, and soil features. Data on the amount of synthetic fertilizers used in 2016 has been obtained from the 4. Regional Directorate of MAF. On the other hand, the amount of manure generated in the basin that shows an important potential in terms of the use of organic manure in agricultural applications is obtained again from the same directorate. The number of cows and cattle, sheep and goats, and poultry based on a village is used to determine the natural nitrogen manure that can be used in sustainable agricultural practices.

Figure 2

Map of the Control Measures for Reducing Agricultural Diffuse in the Basin (Except For Animal Manure Control)

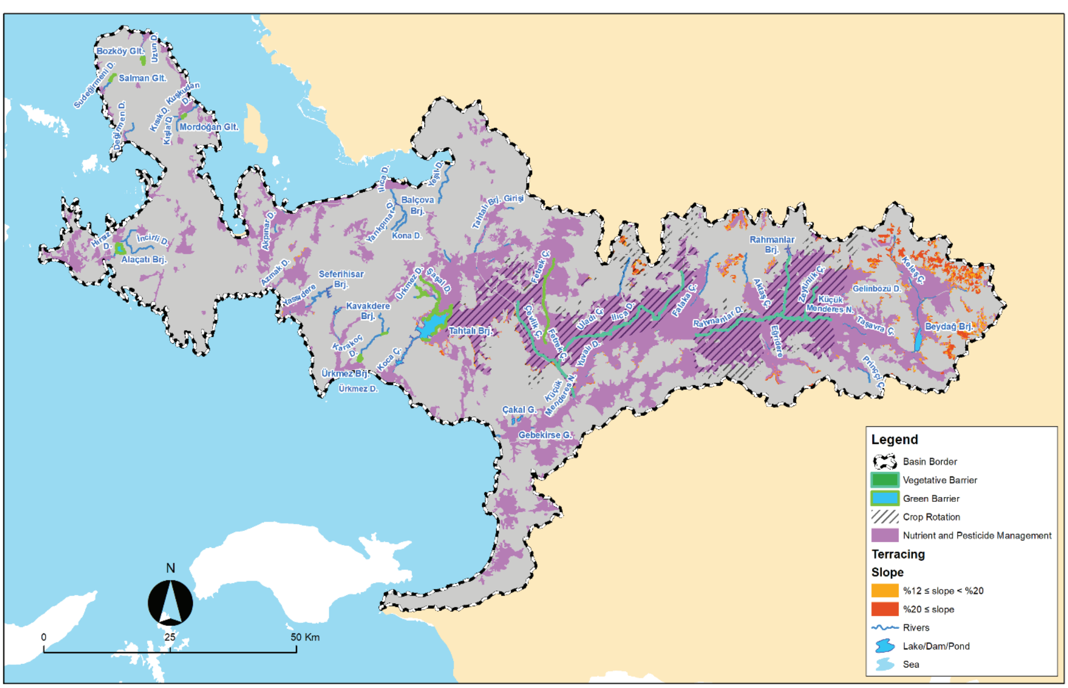


Table 7

Selected Removal Rates for BMPs

	Range of TN removal (%)	Selected TN removal (%)	Range of TP removal (%)	Selected TP removal (%)
Nutrient Management	20-90	30	20-90	20
Crop Rotation	50	50	30	30
Green Barrier	80–90	70	50–75	70
Vegetative Barrier	70	70	70	70
Terracing	30–70	70*	30–70	70*

**The ratio of agricultural land to be terraced/total agricultural land is considered.*

Within the scope of good agricultural practices, manure management planning should be established in nitrate sensitive regions that produce 1600 kg N/year and more, and in non-nitrate sensitive regions that produce 3500 kg N/year and more. The unit N loads given in Table 8 are used the calculation of the N amount produced by the livestock breeding.

Table 8

Unit N Load Arising From Livestock Activities (MoEF, 2010)

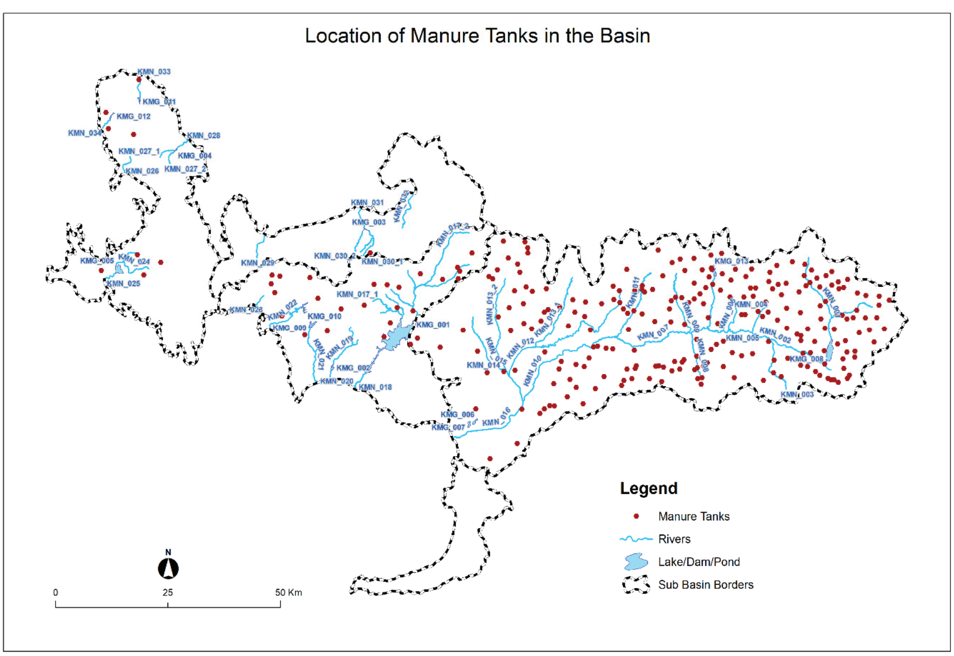
Animal Category	Nitrogen (kg/ton animal/day)
Cattle and cows	0.3
Sheep and goat	0.42
Poultry	0.52

Nitrogen unit (kg/day) is calculated based upon cows and cattles, taken as 500 kg, sheep and goats as 45 kg and poultry as 2 kg (MoEF, 2010). The total amount of organic N in manure is calculated annually based upon the unit loads of the settlements/villages and the number of animals. If sufficient measures are not taken during or after animal manure collected from barns, some of its value will be lost prior to carrying it to agricultural fields, and this amount is determined as 15% in the calculations. In addition to that, the organic substance of the manure, which has to be kept for a while in the sealed tank before starting an application, will be lost over time and this amount is accepted as 35%. Considering these losses, the amount of natural manure that can be safely applied has been determined based upon each water body. It is foreseen that the losses will decrease in the following years with the awareness raising activities, developments in application techniques and the measures to be taken during its transportation.

The settlements where animal manure will be correctly applied, are marked on Figure 3. Even if the animal manure is applied on agricultural areas, the use of chemical manure is still need to meet the N requirement of soil. The amount of chemical fertilizer after the application of animal manure has decreased compared with the chemical fertilizer amount used at present. The total amount of N from animal manure and chemical fertilizer based upon water bodies is given in Table 9. The amount of natural manure to be generated from animal breeding activities in the basin has the potential to significantly reduce the use of chemical fertilizers when it is used within the context of good agricultural practices. Fertilizer need of some water bodies can be met only with animal manure, but in the first cycle, the farmers' tendency to continue using chemical fertilizer is taken into consideration and the assessment is made based on the entire basin. Accordingly, the average use of animal manure throughout the basin was calculated as approximately 52%.

Figure 3

Settlements Where It is Recommended to Place Manure Tanks



Results and Discussion

In this study, initially gap analysis was conducted to achieve Environmental Quality Standards (EQSs). Then, each applied measure was tested by the AquaTool model. At the stage of the determination of measures, basic measure scenarios were entered into the model and the need for supplementary measures was determined by evaluating the results obtained. In the second stage, complementary measures were entered respectively, and lastly the program for measures was created.

The total number of the measures including point and diffuse sources of pollutants together with hydromorphological and geothermal measures, and measures on coastal bodies, on mining areas was 932. Out of this huge number of measures, diffuse pollutant measures recommended were 759 constituting 81% of the total measures considered. Within this profile, agricultural measures were 373 that are almost equal to half of the diffuse pollutant measures, and 40% of the overall measures listed. The list of measures regarding with agricultural diffuse pollution is given in Table 10.

The majority of diffuse pollutant measures were structural measures (except nutrient and pesticide measurement); therefore, the related ones are either basic or supplementary depending on the sensitivity of the water body. As the river basin management plans are the initial trials of the country, their implementation and results will be observed and evaluated within the first cycle.

Agricultural diffuse pollution mitigation poses a significant policy challenge across Europe and particularly in the UK. Prevailing legislation and volunteer studies in the UK are not enough to get necessary environmental outcomes due to several reasons (Collins et al., 2016). Thus, it is important to identify specific measures for on-farm towards whose farmers express positive attitudes for higher nutrient uptake rates. Accordingly, an attitudinal survey was carried out among farmers in England on those measures. The results suggest that mitigation measures that farmers are motivated to implement in the future to improve the environmental performance of agriculture in England and Wales are those that cost lowest per hectare of arable land. This outcome of the survey conducted in England actually holds true all over the world, no matter the development level of the country. In that sense, understanding farmer receptiveness and attitudes towards on-farm diffuse pollution mitigation options is critical in developing a comprehensive approach to control negative impacts of farming on environmental quality as underlined by Blackstock et al. (2010) and Buckley (2012).

Table 9

Animal Manure and Chemical Fertilizer Uses Based Upon Good Agricultural Practices in Water Bodies

Water body	Total chemical fertilizer usage in present condition (ton/year)	Total amount of natural manure (ton/year) **	Total amount of applicable natural manure (ton/year)	Required chemical fertilizer amount after the application of animal manure (ton)	Use of animal manure (%)
KMN_011	675	227	227	448	34
KMN_013_1	940	180	180	760	19
KMN_012	2,023	875	875	1,149	43
KMN_010	1,268	1,119	1,119	148	88
KMN_002*	1,154	1,014	1,014	140	88
KMG_008*	120	238	120.3	-	100
KMN_017_2	652	135	135	517	21
KMN_033	0.9	6	0.9	-	100
KMN_026	4.5	26	4.5	-	100
KMN_013_2	1,110	90	90	1,021	8
KMN_001	1,374	2,871	1,374	-	100
KMN_015	2,010	229	229	1,781	11
KMG_001	472	36	36	436	8
KMN_021	106	58	58	48	55
KMN_017_1	372	40.6	40.6	331	11
KMG_010	27	26.7	26.7	0.3	99
KMN_023	53	107.5	52.7	-	100
KMN_022	30	4.6	4.6	25	15
KMN_016	1,207	352.1	352.1	855.2	29
KMG_006	40.8	2.9	2.9	37.8	7
KMN_007	2,153	3,240	2,153	-	100
KMN_008	633	286	286	347	45
KMN_024	5.9	14.8	5.9	-	100
KMN_003*	466	287	287	179	62
KMN_006	597	265	265	331	44
KMG_013	407	76	76	331	19
KMN_004	381	463	381	-	100
KMN_009	698	230	230	468	33
KMN_005*	400	579	400	-	100
Total	19,379	13,080	10,027	9,353	52

*Sensitive Water Body

**The losses foreseen for the 1st cycle are not taken into consideration

Table 10

Number of Agricultural Measures for Non-Point (Diffuse) Pollutants

Agricultural measures for non-Point (Diffuse) Pollutant	Number of Measures	Unit	Basic (B)/ Supplementary (S)
Application of animal manure in a controlled way to agricultural land	279	settlement	B/S
Terracing	17	water body	B/S
Nutrient and pesticide management	57	water body	B/S
Setting vegetative barrier	5	water body	B/S
Conducting crop rotation	6	water body	B/S
Setting green belt	9	water body	B/S
Total	373		

Nowadays, social science linked watershed management recognized the need for voluntary action by farmers in the context of environmental regulation and government subsidies to reduce agricultural diffuse pollutants as proved by Collins et al. (2016) who have conducted a detailed survey among a group of farmers. Therefore, coping with agricultural diffuse pollutants seems to be a long-lasting issue especially in developing countries that face economic constraints in implementing the measures.

Within the context of measures program, basic measures to be followed in all the water bodies and supplementary measures in the required ones were proposed. It is expected that the strict implementation of these measures in the first cycle of the river basin management plan will improve or tend to improve the quality of surface water bodies. Measures for reducing point and non-point pollutants in surface water bodies at the first cycle covering the years 2020-2025 and at the second cycle covering the years 2026-2031, were proposed and improvements observed in water quality via the AquaTool model were reported. By applying the so-called measures in the first and second implementation cycles, the model has given the final ecological and chemical status of the water bodies as shown in Table 11. As can be seen from the table, a total number of 27 water bodies still "*do not meet the good status*".

Table 11

Ecological and Chemical Status of the Water Bodies after Implementing the Measures in Two Cycles (2020-2025 and 2026-2031)

Ecological Status			Chemical Status		
Status	Monitoring results	Modelling Results (after implementing the measures)	Status	Monitoring results	Modelling Results (after implementing the measures)
Bad	21	15	Failed	38	27
Poor	5	2			
Moderate	14	10	Passed	6	10
Good	4	10			
Dry	9	9	Dry	9	9
No Monitoring	2	2	No Monitoring	2	2
No modelling		7	No modelling	-	7
Total	55	55	Total	55	55

Conclusion

The ultimate goal in national and international legislation is to achieve '*good water*' status in all water bodies. As stated in all relevant regulations, guidance documents and practices some strategies need to be developed in order to prevent and control the pollution of water bodies. In this context, the measures program was prepared by taking into consideration the results of the monitoring program conducted from September 2017 to August 2018 for surface water bodies. Within the scope of the preparation of KMRBMP, surface water bodies were studied in a holistic manner. The measures to be taken to improve the surface water bodies interacting with each other in the basin were evaluated.

Both basic and supplementary measures were proposed and tested via the AquaTool model for the first and second implementation cycles covering the years 2020-2025 and 2026-2031. Despite the so-called measures taken within these two cycles, 27 water bodies out of 55 failed in satisfying the '*good ecological and chemical status*'. This situation implies that even though a series of basic and supplementary measures were considered, a considerable number of water bodies do not meet the requirements. Therefore, it is important to apply and realize all the referred measures in time to reach a better environmental condition in the basin in future.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Küçük Menderes Havzası'nda Tarımsal Kaynaklı Yayılı Kirlilik Tedbirlerinin Belirlenmesi

Küçük Menderes Havzası, Türkiye'nin batısında Gediz ve Büyük Menderes Havzaları arasında, sularını Küçük Menderes Nehri ve diğer akarsularla Ege Denizi'ne boşaltan alanı kapsamaktadır. Toplam alanı 6963.25 km^2 ve toplam nüfusu 3,5 milyonun üzerinde olan 5 alt havzadan oluşmaktadır. Havzanın en önemli nehri Küçük Menderes Nehri'dir. Havza toplam alanının %40'ı tarım alanları ile kaplıdır. Yerleşim ve sanayi alanları tüm havzanın %6'sını oluşturmaktadır. Avrupa Birliği Su Çerçeve Direktifi (AB SÇD)'nin sınıflandırmasına göre, havzada 38 nehir ve 13 göl bulunmaktadır. 38 nehir suyu kütlesinden 19'u büyük ölçüde değiştirilmiş su kütlesi sınıfına dahildir. 13 göl suyu kütlesinden sadece ikisi doğal göl sınıfındadır. Göllerin geri kalanı büyük ölçüde değiştirilmiş, baraj veya gölet inşa edilmiştir. Havzada evsel su ihtiyacının karşılanması için 5 baraj işletilmektedir. Havza için hazırlanan nehir havza yönetim planında: İnsan faaliyetlerinden kaynaklı kirlilik yükleri, ekolojik hedeflerle ilgili baskı ve etkiler, mevcut sıcak noktalar, mevcut kirlilikle kontrol yöntemleri ve önlemler, mevcut yasal düzenlemeler, politikalar ve stratejiler gözden geçirilmiştir. Havza yönetim planı sonuçlarına göre Küçük Menderes Havzası su kütlelerinin fiziko-kimyasal ve kimyasal olarak ve de biyolojik kalite unsurları açısından oldukça kirlenmiş oldukları görülmüştür. Havzada 9 nitrata hassas alan ile 16 kentsel hassas alan bulunmaktadır. Bu çalışmada, Küçük Menderes Havzası'ndaki su kütleleri ile ilgili özellikle yayılı kaynak kirliliğinin önlenmesi için gereken temel ve tamamlayıcı tedbirlerin belirlenmesi için kullanılan metodoloji anlatılmıştır.

Çalışmada yayılı kirlilik kaynaklarına yönelik tedbirlerin belirlenmesinde, tedbirlerin AB SÇD ile uyumlu olması gözetilmiş, Yerüstü Su Kalitesi Yönetmeliği, İyi Tarım Uygulamaları Hakkında Yönetmelik ve Sularda Tarımsal Faaliyetlerden Kaynaklanan Nitrat Kirliliğinin Önlenmesine Yönelik İyi Tarım Uygulamaları Kodu Tebliği temel alınmıştır. Su kütlelerinde yayılı azot ve fosfor yüklerine karşı alınacak tedbirler ile belirlenen nitrata hassas bölgeler için tedbirler ortaya konmuştur.

Havza yönetim planında öncelikle mevcut kirlilik profili ortaya konmuştur. Risk değerlendirme çalışmasının sonuçlarına göre toplam 29 su kütlesi "yüksek risk altında" ve 16 su kütlesi "orta risk altında" olarak bulunmuştur. Risk değerlendirmede noktasal ve yayılı kaynaktan gelen yükler değerlendirilmiştir. Yayılı kaynak kirliliğine neden olan en önemli iki kirletici parametre, toplam azot (TN) ve toplam fosfor (TP)'dur. Havzadaki veriler değerlendirildiğinde, havzanın özellikle yayılı kaynak kirliğine bağlı TN ve TP açısından oldukça kirlenmiş olduğu görülmüştür. TN ve TP açısından kirlenmenin dağılımı sırasıyla %88 ve %84 olarak belirlenmiştir. TN ve TP açısından kirlilik kaynakları başta hayvancılık, aşırı ve kontrolsüz gübre kullanımı olmak üzere arazi kullanım şekli, fosseptikler ve katı atık sahaları olduğu tespit edilmiştir.

Havza yönetim planında izleme çalışmaları Eylül 2017-Eylül 2018 arasında 12 ay boyunca yapılmıştır. İzleme sonuçlarına göre havzada 21 kötü, 6 zayıf, 18 orta, 9 kuru durumda olan ve 2 adet izlenemeyen su kaynağı bulunmaktadır. Çalışmada su kaynaklarının yönetim alternatiflerinin belirlenmesi ve gerekli verilerin düzenlenmesi için AQUATOOL programı kullanılmıştır.

Mevcut durum dikkate alınarak havzada noktasal ve yayılı kaynakların kontrolü için tedbirler belirlenmiştir. Öncelikle boşluk analizi yapılmıştır; yani ölçülen konsantrasyonlar ile çevresel hedefler arasındaki farklar belirlenmiştir. Böylece alıcı ortamın istenen su kalitesine ulaşmak için gerekli olan

ayrı uygulanmıştır. Her seferinde tedbirlerin sonuçlarını elde etmek için model yeniden çalıştırılmış ve bu prosedür çevresel hedeflere ulaşılıncaya kadar devam etmiştir. Havzada 1. ve 2. döngü için farklı kombinasyonlardaki tedbirler toplam 10 başlık altında değerlendirilmiştir.

Yayılı kirletici kaynakların büyük çoğunluğu hayvancılık ve tarımsal faaliyetlerden kaynaklandığından çalışmada, bu uygulamalara ilişkin tedbirler üzerinde durulmuştur. Küçük Menderes Havzası için tarımsal üretim için önerilen temel tedbirler şunlardır:

- Yüksek eğimli ve çok yüksek eğimli tarımsal üretim alanlarında teraslama
- Besi maddesi ve pestisit yönetimi,
- Göl ve nehir kıyısına tampon bölgeler,
- Bitkisel bariyer uygulamaları,
- Ürün rotasyonu.

Tüm bu tedbirler eğim, besi maddesi ve pestisit kullanım miktar ve davranışları, ürün bilgileri, su kütlesi özellikleri vb. dikkate alınarak havzada her bir su kütlesi için ayrı ayrı belirlenmiştir.

Hayvan gübresinin kontrollü kullanımı önemli tedbirlerdendir. Havza bazında ortalama hayvan gübresi kullanımı yaklaşık %52'dir. Yapılan hesaplamalarda havzadaki hayvancılık faaliyetlerinden üretilecek doğal gübre miktarı, iyi tarım uygulamaları kapsamında kullanıldığında kimyasal gübre kullanımını önemli ölçüde azaltma potansiyeline sahip olduğu görülmüştür.

Sonuç olarak havzada önerilen toplam tedbir sayısı (noktasal ve yayılı kaynaklar ile birlikte hidromorfolojik ve jeotermal önlemler ile madencilik ve kıyı alanlarındaki önlemler de dahil) 932'dir. Tavsiye edilen yayılı kaynak tedbirlerinin sayısı, toplam tedbirlerin %81'ini oluşturan 759'dur. Bu profilde tarımsal tedbirler, yayılı kaynak kirliliği için önerilen tedbirlerin neredeyse yarısına eşit olup 373'tür ve yayılı kaynak tedbirlerinin %40'ıdır. Yayılı kirletici tedbirlerinin çoğu yapısal tedbirlerdir; bu nedenle, su kütlesinin özelinde belirlenen tedbirler hassasiyetine bağlı olarak temel veya tamamlayıcıdır. Yönetim planlarının bu şekilde hazırlanması ülkenin ilk denemeleri olduğundan, bunların uygulanması ile ortaya çıkan faydalar ilk döngüde gözlemlenecek ve değerlendirilecektir.

Tedbirler programı dahilinde tüm su kütlelerinde uygulanması gereken temel ve tamamlayıcı tedbirler belirlenmiştir. Nehir havzası yönetim planının ilk döngüsünde bu önlemlerin sıkı bir şekilde uygulanmasının yerüstü suyu kütlelerinin kalitesini iyileştirmesi veya iyileştirme eğiliminde olması beklenmektedir. 2020-2025 yıllarını kapsayan birinci döngü ve 2026-2031 yıllarını kapsayan ikinci döngü sonunda yerüstü kütlelerinde noktasal ve noktasal olmayan kirleticiler için belirlenen tedbirlerin uygulanması sonucunda ulaşılacak bu sonuçlar AquaTool ile modellenmiştir. Elde dilen sonuçlara göre tüm havzada tedbirler sonunda hedefe yani "iyi durum" a ulaşamayan 27 su kütlesinin bulunacağı belirlenmiştir. Bu sonuçlar havzada önerilen tüm zorunlu ve tamamlayıcı tedbirlerin zamanında uygulanmasının önemini göstermektedir. Böylelikle havza ilk iki döngü sonrasında günümüzdeki durumdan daha iyi koşullara kavuşmuş olacaktır.

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Research Article

New Records for the Turkish Freshwater Algal Flora in Twenty Five River Basins of Turkey, Part III: Miozoa, Haptophyta

Türkiye'deki 25 Nehir Havzasından Türkiye Tatlı Su Alg Florası İçin Yeni Kayıtlar, Bölüm III: Miozoa, Haptophyta

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Abstract

Turkish lakes have different morphometry and hydrology as a result of different climate types and noticeable altitude differences, which provide different habitats for algal diversity. In the last 40 years,

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the total number of algae taxa in the flora of Turkey has increased due to the studies on phytoplankton taxonomy and ecology. This study aims to describe new planktonic algal taxa for the Turkish freshwater algal flora. A total of 63 Miozoa and 2 Haptophyta taxa were determined in the project conducted from 2017 to 2019 in lakes of 25 river basins of Turkey. Our study was done as a part of the Project, namely "Establishment of Reference Monitoring Network in Turkey", financially and technically supported by the Ministry of Agriculture and Forestry, Directorate General for Water Management. In each lake, phytoplankton was sampled with water samplers from three depths (surface, middle, and bottom) of the euphotic zone, and then the water samples taken from these three depths were mixed for obtaining subsamples. Plankton net with a pore diameter of 50 µm was also used for sampling. Identification of the algal taxa was performed with various compound and inverted microscopes in many laboratories. During this study, 26 Miozoa and 2 Haptophyta taxa were found as new records for the freshwater algal flora of Turkey.
Keywords: *Miozoa, Haptophyta, Turkish freshwater, algae, new record*

Öz

Türkiye gölleri, Türkiye farklı iklim tiplerine ev sahipliği yaptığından ve coğrafik olarak yükseklik farklılıkları bulundurduğundan dolayı farklı morfometrik ve hidrolojik yapıya sahip olup, bu durum alglerin biyoçeşitliliği için farklı habitat tipleri sağlamaktadır. Son 40 yılda, fitoplankton taksonomisi ve ekolojisi alanında yapılan çalışmalar sebebiyle Türkiye florasındaki toplam alg taksonu sayısı artmıştır. Bu çalışma, Türkiye tatlı su alg florası için yeni planktonik alg taksonlarını tanımlamayı amaçlamaktadır. 2017 ve 2019 yılları arasında Türkiye'deki 25 nehir havzasında yapılan çalışmada Miozoa divizyosuna ait 63, Haptophyta divizyosuna ait 2 takson tanımlanmıştır. Bu çalışma Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü (SYGM) tarafından finansal ve teknik olarak desteklenen "Türkiye'de Referans İzleme Ağının Kurulması" adlı proje kapsamında gerçekleştirilmiştir. Her gölde fitoplankton öfotik derinliğin 3 farklı bölgesinden (yüzey, orta, dip) su örnekleyicisi ile alınarak örneklenmiştir. Daha sonra bu üç derinlikten alınan su örnekleri karıştırılarak su numunesi alınmıştır. 50 µm göz açıklığına sahip plankton kepçesi de örnekleme sırasında ayrıca kullanılmıştır. Alg taksonlarının teşhisi farklı laboratuvarlardaki ışık ve ters mikroskoplar kullanılarak gerçekleştirilmiştir. Çalışmada, Türkiye tatlı su alg florası için Miozoa divizyosuna ait 26 takson, Haptophyta divizyosuna ait 2 yeni takson bulunmuştur.
Anahtar kelimeler: *Miozoa, Haptophyta, Türk tatlı suları, alg, yeni kayıt*

Introduction

The number of studies on phytoplankton taxonomy and ecology, which is accepted as one of the biological quality elements according to the EU Water Framework Directive (WFD) (EC Parliament & Council, 2000), have increased in recent years in Turkey. Due to the compatibility process with European Union, several projects have been implemented, taking into account biological quality components funded by the Ministry of Agriculture and Forestry, Directorate General for Water Management (DGWM), and General Directorate of State Hydraulic Works (DSİ). Many water quality monitoring studies on different river basins, some lake management planning studies, and some index development projects to determine water quality using biological quality components have been completed (Directorate General for Water Management [DGWM], 2020). This study is also a part of the

"Establishment of Reference Monitoring Network in Turkey" project which is financially and technically supported by DGWM. In this project, 275 lakes in 25 river basins were studied, and a total of 1363 phytoplankton taxa were detected. Among these taxa, 63 Miozoa, and 2 Haptophyta taxa were determined.

Until now, more than 3550 Miozoa and 773 Haptophyta taxa were listed in previous studies in the world (Guiry & Guiry, 2020). Most of the species of Miozoa are free-swimming, unicellular organisms, and members of this group in fresh waters are found in plankton of both large bodies of water such as lakes and reservoirs, and smaller water bodies such as pools. Members of Haptophyta which have a unique organelle haptonema, are common in marine waters. Few planktonic species are known from freshwater habitats (John et al., 2003).

In the flora of Turkey, 235 Miozoa and 5 Haptophyta taxa were recorded in previous studies. However, only 45 Miozoa taxa were identified and no species were found in Haptophyta as freshwater taxa (Taşkın et al., 2019; Maraşlıoğlu & Gönülol, 2020). Due to the effects of four different types of climate, and noticeable altitude differences, Turkish lakes have different morphometry and hydrology that support distinct algal diversity. In recent years, many new records were given for the algal flora of Turkey (Aysel et al., 1993; Öztürk et al., 1995a, 1995b; Şahin, 2000, 2002, 2007, 2009; Yağcı & Turna, 2002; Atıcı, 2002; Baykal et al., 2009; Sevindik et al., 2010, 2011, 2015, 2017; Özer et al., 2012; Akar & Şahin, 2014; Yüce & Ertan, 2014; Varol & Fucikova, 2015; Varol & Şen, 2016; Maraşlıoğlu & Soylu, 2018), and the total number of taxa have increased (Taşkın et al., 2019; Maraşlıoğlu & Gönülol, 2020). The present study aims to contribute to the algal flora of Turkey. Therefore, 26 Miozoa and 2 Haptophyta were described in this paper as new records for Turkish freshwater algae.

Materials and Methods

Study Area

Turkey has 25 river basins (Figure 1), and inland water bodies in these basins, consist of 200 natural lakes, 806 reservoirs, and 1000 ponds (Foreign Relation Office of General Directorate of State Hydraulic Works [DSİ], 2014). Considering the areas of river basins, the annual amount of water produced per unit area is the lowest in Akarçay Basin with 64,430 m^3/km^2, and the highest in Doğu Karadeniz Basin with 618,850 m^3/km^2 (Foreign Relation Office of DSİ, 2014). However, Lakes Region (Burdur Basin), South Marmara (Susurluk Basin), Lake Van and its surroundings

(Lake Van Basin), Lake Tuz, and its surroundings (Konya Basin) were the regions where the natural lakes are gathered (Hoşgören, 1994).

Figure 1

River Basins of Turkey

A total of 275 lakes, including reservoirs, were sampled during the study in 25 river basins. The number of studied lakes in the river basins was given in Table 1.These lakes are grouped in 22 lake typologies based on altitude (R), lake depth (D), lake size (A), and geology (J) (DGWM, 2015), and they are located between the longitudes of 26º 19´ and 43º 54´E and the latitudes of 35º 56´ and 42 º 00´N. The altitudes of the sampled lakes vary between sea level (Lake Gala) and 2757 m (Lake Çamlu).

Table 1

Number of Studied Lakes in 25 River Basins

Basins	The number of studied lakes	Name of lake
Burdur	6	Acıgöl L., Burdur L., Karataş L, Salda L., Tefenni P., Keçiborlu Güneykent Uzundere P.
Akarçay	10	Akşehir L., Eber L., Akdeğirmen R., 26 Ağustos TP L., Karamık R., Ağzıkara P., Tınaztepe P., Gezler P., Şehit Uz. Çvş. Nurullah Oymak P., Tazlar Satı Gelin P.
Sakarya	23	Taşkısığı L., Akgöl 2 L., Çubuk L., Poyrazlar L., Sapanca L., Işık Dağı Karagöl L., Çavuşcu L., Mogan L., Üçlerkayası P., Çubuk Karagöl L., Eymir L., Akgöl 1 L., Küçük Akgöl L., Avdan L., Kayuslu L., Karamurat L., Cüneyt Sönmez P., Çılgınlar P., Yıldırım Evci P., Ovacık L., Sülüklü L., Çamkoru TP P., Anagöl L.
Batı Karadeniz	14	Nazlı L., Büyük L., Derin L., Parçayır L., Abant L., Dipsiz L., Gölcük L., Keçi L., Yeniçağa L., Kuyudüzü L., Erze L., Koca L., Kuru L. Natural Park, Sazlı L.
Doğu Karadeniz	7	Gaga L., Sera L., Ulugöl L., Uzungöl L., Çamlu L., Çakır L., Limni L.
Yeşilırmak	14	Akgöl L., Aşağıtepecik (Gölova) L., Boraboy P., Büyük L., Düden L., Kaz L., Ladik L., Uyuz L., Karacaören Mevki L., Dipsiz L. 2, Sarıçiçek L., Yenihayat R., Dipsiz L. 1, Zinav L.
Kızılırmak	23	Gölbel L., Ulaş L.-2, Büyük Lota L., Hafik L., Küçük Lota L., Tödürge L., Arı L., Aygır L., Bakkal L., Dipsiz L., Elekci L., Ulaş L.-1, Ulaş L.-3, Deniz L., Yeşilgöl 1 L., Bardakçılı Mevki L., Yenidanişment Mevki L., Palanga L., Sugiylan Mevki L., Kayabaşı L., Kuru L., Sıraç L., Kızılçam L.
Meriç-Ergene	5	Gala L., Sığırcı L., Pamuklu L., Üsküp Sulama P., Domuz L.
Marmara	9	Habibler Mevki P., Great Dipsiz L., İznik L., Koca L., Karamaden L., Danamandıra L.-1, Danamandıra L.-2, Small Dipsiz L., Sinekli L.
Antalya	9	Eğirdir L., Kovada L., Gölcük L., Cemalalanı L., Duruca L., Eğri L., Küllü L., Titreyen L., Düden L.
Batı Akdeniz	13	Gölhisar L., Girdev L., Avlan L., Dalaman Wetlands, Denizcik L., Kocagöl L., Kusuru L., Köycegiz L., Küçükdalyan L., Yeşilgöl L., Yazır L., Baranda L., Pozan L.

Table 1

(Continued)

Basins	The number of studied lakes	Name of lake
Büyük Menderes	13	Nazlı L., Büyük L., Derin L., Parçayır L., Abant L., Dipsiz L., Gölcük L., Keçi L., Yeniçağa L., Kuyudüzü L., Erze L., Koca L., Kuru L. Natural Park, Sazlı L.
Gediz	6	Gölcük L., Demirköprü R., Marmara L., Gördes R., Karagöl L., Küçükler R.
Kuzey Ege	5	Boz L., Güzelhisar R., Karagöl L., Sevişler R., Tepe L.
Küçük Menderes	6	Çatal L., Tahtalı R., Alaçatı R., Belevi L., Gebekirse L., Ürkmez R.
Konya	18	Sarıot L., Beyşehir L., Tuz L., Süleymanhacı L., Gök (Kozanlı) L., Meke L. (Meke Maarı), Gavur L., Dipsiz L., Acıgöl L. 2, Bakı L., Uyuz L., Acıgöl L. 1, Kayı L., Düden L., Kovalı L., Köpek L., Küçük L., Sülüklü L.
Susurluk	9	Manyas L., Uluabat L., Adsız-1 L., Gölbaşı L., Gölcük L., İkizcetepeler R., Karagöl L., Kilimli L., Nilüfer R.
Aras	3	Aktaş L., Çıldır L., Aygır L.
Çoruh	8	Adsız L., Boğa L., Balık L., Şavşat Karagöl L., Çil L., Borçka Karagöl L., Tortum L., Ürünlü P.
Fırat-Dicle	17	Kaz L., Ahır L., Haçlı L., Korlu L., Hazar L., Karagöl L., Yeşildere P., Palandöken P., Güroymak R., Kalecik R., Kapıaçmaz P., Dedeyolu P., Güzelyurt Sulama P., Hasancık P., İncesu P., Otlukbeli L., Siverek Yeleken P.
Van	7	Akgöl L., Erçek L., Bostaniçi P., Arin L., Aygır L., Van L., Nazik L.
Asi	8	Reyhanlı (Yenihisar) L., Yayladağ R., Tahtaköprü R., Karagöl L., Adsız L., Yarseli R., Üçpınar P., Sapkanlı P.
Ceyhan	18	Gölbaşı L., Kartalkaya R., Kara L., B. Yapalak P., Korkmaz P., Zorkun P., Merk P., Yamaçoba P., Kızılıniş P., Arıklıkaş P., Karacaören P., Meletmez P., Postkabasakal P., Bağtepe P., Zerdali P., Kozan Aydın P., Yumurtalık Zeytinbeli P., Yumurtalık Ayvalık P.
Doğu Akdeniz	12	Aygır L., Uzun L., Değirmendere P., Cemilli Çevlik P., Hacınuhlu Kelce P., Akın P., Kızılöz P., Başyayla P., Göktepe P., Bağbaşı R., Yassıbağ P., Hadım-İnönü P.
Seyhan	12	Bahçelik R., Tufanbeyli Demiroluk P., Adsız L., Pekmezli-Çatalçam P., Tufanbeyli Doğanbeyli P., Gümüşören R., Şıhlı P., Dölekli P., Kılıçlı P., Topacık P., Hüsniye P., Çavuşlu P.
Total	275	

L: Lake; P: Pond; R: Reservoir; R: Reeds

Sampling and Identification

Phytoplankton was sampled three times (spring, summer, and fall) a year between 2017 and 2019 at the one, two, or three monitoring stations in each lake. Station numbers were determined as one for lakes which have a surface area smaller than 50 ha, two for lakes which have a surface area between 50 and 500 ha and, three for lakes which have a surface area higher than 500 ha (Yer Üstü Suları, Yer Altı Suları ve Sedimentten Numune Alma ve Biyolojik Örnekleme Tebliği, 2015). One of the selected stations was determined at the deepest point of the lake. Phytoplankton was sampled with water samplers from three depths (surface, middle, and bottom) of the euphotic zone, and then the water samples taken from these three depths were mixed for obtaining subsamples. Plankton net with a pore diameter of 50 µm was also used for sampling. Samples were fixed with Lugol's solution. Identification of the algal taxa was performed with various compound and inverted microscopes according to the Huber-Pestalozzi (1976) and John et al. (2003). Identified taxa were checked with the checklist of Aysel (2005), Taşkın et al. (2019), and the database of Turkish algae (Maraşlıoğlu & Gönülol, 2020), and then determined as new taxa for Turkish freshwater algal flora. The currently accepted nomenclature and distribution of taxa have been given according to Guiry & Guiry (2020). Taxa were photographed with a camera attached to various microscopes.

Results

A total of 28 taxa (26 Miozoa, and 2 Haptophyta) are described below.

Phylum: Miozoa
Class: Dinophyceae
Order: Suessiales
Family: Suessiaceae
Genus: *Biecheleria*

Species: *Biecheleria ordinata* (Skuja) Moestrup 2018 (Figure 2a)
Synonyms: *Gymnodinium ordinatum* Skuja 1939*, Woloszynskia ordinata* (Skuja) Thompson 1950
Description: Cells flattened dorsoventrally, symmetrical when viewed from the front, broad oval, 18 µm long, 14 µm wide, and about 8 µm thick. Epivalva slightly larger, with a regular semicircular apex. Hypovalva somewhat smaller and slightly pointed dome-shaped towards the rear. Cingulum rather deep, very little below the middle or almost median. Sulcus limited to the hypovalva, well developed.
Ecology: This is freshwater species. The water quality indicator is sensitive.

Distribution: *Europe*: Britain, Netherlands, Romania, Scandinavia, Slovakia, Spain, Sweden. *North America*: Northwest Territories. *Australia and New Zealand*: Queensland, New Zealand.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz, Sakarya, and Akarçay basins.

Family: Borghiellaceae
Genus: *Borghiella*
Species: *Borghiella woloszynskae* (Pascher) Moestrup 2018 (Figure 2b)
Synonyms: *Gymnodinium woloszynskae* Pascher 1923*, G. veris* Lindemann 1925
Description: Cells oval, 20 µm long, 18 µm wide. Epivalva conical with slightly convex edges. Hypovalva large, broadly rounded at the Antapex. Cingulum equatorial, broad, almost circular, slightly winding to the left. Sulcus limited to the hypovalva, also fairly wide, deeply incised, has a comb-like ridge on its right side.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Germany. *North America*: Northwest Territories. *Asia*: Japan.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Fırat-Dicle basins.

Order: Dinophyceae ordo incertae sedis
Family: Dinophyceae familia incertae sedis
Genus: *Glenoaulax*

Species: *Glenoaulax inaequalis* (Schmarda) Diesing 1866 (Figure 2c)
Synonym: *Glenodinium inaequale* Schmarda
Description: Cells ovoid, 22 µm long, 18 µm wide. Epivalva considerably reduced in size than Hypovalva. Epivalva head-shaped to low dome-shaped, narrower, only about 1/3 as high as the Hypovalva. Hypovalva rounded, asymmetrical, bluntly pointed towards the Antapex. Cingulum quite broad; Sulcus widened backward.
Ecology: This is freshwater species. The water quality indicator is sensitive/tolerant.
Distribution: --
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Order: Gymnodiniales
Family: Gymnodiniaceae
Genus: *Gymnodinium*

Species: *Gymnodinium albulum* Lindemann 1928 (Figure 2d)
Synonym: *Gymnodinium profundum* Schiller 1932

Description: Apical part of the cell hemispherical, the same width or wider than the antapical part. Antapex narrowly rounded. Cingulum equatorial, circular, broad. Sulcus uncertain. Cells 17 µm in diameter.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Austria, Baltic Sea, Black Sea, Britain, Germany, Mediterranean, Scandinavia, Spain. *North America*: Maryland, Northwest Territories. *Asia*: Russia (Far East).
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Fırat-Dicle basins.

Species: *Gymnodinium eurytopum* Skuja 1948 (Figure 2e)
Synonym: --
Description: Cells broadly ellipsoidal, slightly flattened, 25 µm long, 20 µm wide. Cingulum well defined, sharply demarcated towards the Epivalva, almost equatorial, slightly twisted to the right. Sulcus almost restricted to the Hypovalva, rather deep, little pronounced towards the front. Epivalva almost hemispherical, somewhat less arched on the left than on the right. Hypovalva hemispherical.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Black Sea, Latvia, Portugal, Scandinavia, Slovakia, Sweden.
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Species: *Gymnodinium inversum* Nygaard 1929 (Figure 2f)
Synonym: --
Description: Cells ellipsoidal, very little flattened dorsoventrally, 30 µm long, wide 27 µm. Epivalva and Hypovalva broad, irregularly rounded, Hypovalva considerably larger than Epivalva. Cingulum broad, not very deep, twisting to the left. The sulcus is rather narrow, extends to the Antapex, and protrudes into the Epivalva. Nucleus broadly oval lies partly under the Cingulum.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Black Sea, Britain, Denmark, Scandinavia, Slovakia. *North America*: Northwest Territories.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Fırat-Dicle basins.

Species: *Gymnodinium inversum* var. *elongatum* Nygaard 1950 (Figure 2g)
Synonym: --
Description: Cells elongate, longer than type, 35 µm long, wide 26 µm. Epivalva and Hypovalva equal in size. Epivalva subconical, narrowly rounded at the Apex, Hypovalva semi-oval. Nucleus central, broadly elliptical.

Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Denmark, Scandinavia.
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Species: *Gymnodinium lantzschii* Utermöhl 1925 (Figure 2h)
Synonym: *Gymnodinium minimum* Lantzsch 1914
Description: Cells small, rounded, 15 µm long, 13 µm wide. Apical part is rounded at the front, conical, with convex borders, Antapical part broad and flat rounded, slightly smaller than the Apical part. Cingulum clear, apparently twisted to the left. Sulcus only indicated. Nucleus central.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands, Austria, Baltic Sea, Black Sea, Germany, Scandinavia, Switzerland. *Australia and New Zealand*: Australia.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Fırat-Dicle basins.

Species: *Gymnodinium mitratum* Schiller 1932 (Figure 2i)
Synonym: --
Description: Cells oval, not flattened, circular in cross-section, 25 µm long, 15 µm wide. Apex half-ovoid, longer than the Antapex. Cingulum exactly circular, somewhat behind the equator, fairly broad and deep, the upper edge somewhat protruding. Sulcus relatively wider than Cingulum, not reaching Antapex. Nucleus oval.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Austria, Germany, Mediterranean, Romania. *North America*: Mexico (Atlantic, Pacific). *Middle East*: Egypt. *Asia*: China.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Akarçay basins.

Species: *Gymnodinium palustre* Schilling 1891 (Figure 2j)
Synonyms: *Gymnodinium carinatum* Schilling 1891*, G. zachariasii* Lemmermann 1900
Description: Cells elongated elliptical, 30 µm long, 20 µm wide. Apex considerably larger, elongated, bell-shaped, regularly rounded. Antapex short and broad. Cingulum circular, broad, and ± deeply sunk. Sulcus forming a deep, narrow groove. Nucleus central.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Mediterranean, Black Sea, Britain, Denmark, Germany, Poland, Slovakia, Sweden. *North America*: Laurentian Great Lakes. *Asia*: Japan.

Occurrence: It has been detected in freshwater habitats (lakes) in the Doğu Akdeniz basin.

Species: *Gymnodinium saginatum* Harris 1940 (Figure 2k)
Synonym: --
Description: Cells very rounded, 24 µm long, 20 µm wide. Epivalva and Hypovalva equal in size, separated by a narrow, deep cingulum; Sulcus rather narrow, extends to the base of Hypovalva; cell wall quite firm.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain.
Occurrence: It has been detected in freshwater habitats (lakes) in the Konya basin.

Species: *Gymnodinium tatricum* Woloszynska 1919 (Figure 2l)
Synonym: --
Description: Cells oval, very slightly flattened, with broadly rounded Epi- and Hypovalva, 37 µm long, 30 µm wide. Epivalva semi-oval, Hypovalva not entirely hemispherical. Epivalva larger and somewhat less flattened dorsoventrally than Hypovalva. Cingulum broad, slightly twisting to the left. Sulcus incised deep into the Hypovalva, with a ridged left margin. Nucleus large, oval.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Austria, Poland, Slovakia.
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Genus: *Nusuttodinium*

Species: *Nusuttodinium acidotum* (Nygaard) Takano & Horiguchi 2014 (Figure 2m)
Synonym: *Gymnodinium acidotum* Nygaard 1950
Description: Cells broadly pear-shaped, slightly flattened dorsoventrally, 31 µm long, 29 µm wide. Epivalva conical, with a narrowly rounded Apex. Hypovalva about the same size briefly pointed at the Antapex. Cingulum equatorial, broad, slightly winding to the left. Sulcus straight, running in the middle line of the cell, narrow, reaching to Antapex. Nucleus median, ellipsoidal.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands, Denmark. *North America*: Northwest Territories, Louisiana, Missouri. *Asia*: Taiwan, Japan.
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Species: *Nusuttodinium aeruginosum* (Stein) Takano & Horiguchi 2014 (Figure 2n)

Synonym: *Gymnodinium aeruginosum* Stein 1883
Description: Cells elongated, dorsoventrally flattened, 20 µm long, 16 µm wide. Epivalva larger and slimmer, bell-shaped, rounded. Hypovalva also bell-shaped, but broader, often slightly indented Antapex. Cingulum completely encircles the body, slightly post-median, deeply sunk. Sulcus spanning far into the Apical part, reaching to the rear end.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Baltic Sea, Black Sea, Austria, Czech Republic, Britain, France, Italy, Germany, Romania, Netherlands, Portugal, Scandinavia, Slovakia, Denmark, Sweden, Finland. *North America*: Québec, Tennessee, Maryland. *South America*: Argentina, Brazil. *Asia*: China, Japan, Taiwan, Tajikistan. *Australia and New Zealand*: New South Wales, New Zealand, Queensland, Tasmania.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya, Akarçay, and Fırat-Dicle basins.

Order: Peridiniales
Family: Peridiniales incertae sedis
Genus: *Glenodinium*

Species: *Glenodinium paululum* Lindemann 1928 (Figure 2o)
Synonym: --
Description: Cells oval, dorsoventrally hardly flattened, 17 µm long, 9 µm wide. Epivalva conically pointed. Cingulum is relatively broad, circular, slightly subequatorial. Sulcus very indistinct, on the Epivalva it is only slightly developed, on the Hypovalva the Sulcus region slopes downwards.
Ecology: This is freshwater species. The water quality indicator is sensitive/tolerant.
Distribution: *Europe*: Baltic Sea, Black Sea, Romania, Scandinavia.
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Family: Peridiniaceae
Genus: *Parvodinium*

Species: *Parvodinium africanum* var. *tatricum* (Woloszynska) Moestrup 2018 (Figure 2p)
Synonym: *Peridinium africanum* var. *tatricum* (Woloszynska) Schiller 1935
Description: Cells elongated ovate, somewhat slimmer than the type, 32 µm long, 24 µm wide. The median Apical plate is enclosed by the 4 Apical plates. Hypovalva with three blunt corners, each with a short spine. Right Antapical plate large. On the

Hypovalva, the left edge of the lower cingulate ring is covered with few delicate spines. The right edge of the Sulcus has a larger sting. Nucleus oval, central.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Slovakia, Poland, Russia. *Asia*: Taiwan.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Fırat-Dicle basins.

Species: *Parvodinium centenniale* (Playfair) Carty 2008 (Figure 3a)
Synonym: *Peridinium centenniale* (Playfair) Lefèvre 1932
Description: Cells almost spherical, very weakly flattened dorsoventrally, 45 µm long, 41 µm wide. Epivalva hemispherical, considerably larger than Hypovalva. Cingulum strongly twisted to the left, with noticeably thick margins. Sulcus spanning very little over the Epivalva, slightly widening towards the rear.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands, Slovakia, Spain, France, Poland. *Australia and New Zealand*: New South Wales, Queensland, Tasmania. *Central America*: Belize. *Africa*: Ivory Coast, Madagascar. *South-east Asia*: Indonesia, Sumatra.
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Species: *Parvodinium lubieniense* (Woloszynska) Carty 2008 (Figure 3b)
Synonym: *Peridinium lubieniense* Wolszynska 1916
Description: Cells oval, hardly flattened dorsoventrally, 33 µm long, 28 µm wide. Apex opening present. Cingulum broad, very slightly twisting to the left. Sulcus extends little to the Epivalva, widens very little backward, and does not reach to Antapical pole. Epivalva bell-shaped, somewhat larger than Hypovalva. Hypovalva conical, with 5 post-equatorial plates + 2 Antapical plates of equal size. Nucleus oval, central.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands, Scandinavia, Spain, Sweden, Black Sea, France, Germany, Poland, Romania, Ukraine.
Occurrence: It has been detected in freshwater habitats (lakes) in Akarçay and Fırat-Dicle basins.

Genus: *Peridinium*

Species: *Peridinium gatunense* Nygaard 1925 (Figure 3c)
Synonym: *Peridinium cinctum* var. *gatunense* (Nygaard) Nygaard 1932
Description: Cells round, slightly wider than long, 42 µm long, 40 µm wide, very little flattened dorsoventrally. Epi- and Hypovalva roughly the same size, both are truncated, conical, with a humped contour. Cingulum strongly twisted to the left,

broad, at the edges wide hyaline ridges. Sulcus very little, encompassing the Epivalva, widening little backward, not reaching the Antapical pole. Antapical plates are always very large and often of the same size.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands, Sweden, Ukraine. *Australia and New Zealand*: New South Wales, Northern Territory, Tasmania, Western Australia. *America*: Laurentian Great Lakes, Québec, Tennessee, Belize, Cuba, Argentina, Brazil. *Middle East*: Iraq. *Asia*: China, Myanmar (Burma), Singapore.
Occurrence: It has been detected in freshwater habitats (lakes) in Susurluk, Kızılırmak, Batı Karadeniz, Burdur, Seyhan, Doğu Akdeniz basins.

Species: *Peridinium gatunense* f. *majus* Lefèvre (Figure 3d)
Synonym: --
Description: Larger than type, 75 µm long, without hyaline crests on the edges of the Cingulum.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: --
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Species: *Peridinium gutwinskii* Woloszynska 1912 (Figure 3e)
Synonym: --
Description: Cells oval, almost circular in cross-section, 35 µm long, 30 µm wide. Apex opening present. Epivalva conical. Cingulum deep, divides the cell into an almost equally large Epivalva and Hypovalva. Sulcus extends to the Epivalva, expands backward, but does not reach to the rear margin.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands. *South America*: Brazil. *South-west Asia*: Khandesh. *Australia and New Zealand*: Northern Territory.
Occurrence: It has been detected in freshwater habitats (lakes) in the Asi basin.

Species: *Peridinium volzii* var. *cyclicum* Lindemann (Figure 3f)
Synonym: --
Description: Differs from the main type only in the mutual location of the Apical plates. The ventral and median apical Plates are as long as wide; they are arranged more circularly and smaller than the type. Cell 56 µm long, 50 µm wide.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: --
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Family: Peridiniopsidaceae
Genus: *Peridiniopsis*

Species: *Peridiniopsis armata* (Levander) Stein & Borden 1980 (Figure 3g)
Synonym: *Glenodinium armatum* Levander 1900
Description: Cells almost spherical, 19 µm long, 18 µm wide, with a short sting on the left side of the rear edge. Epivalva significantly larger than Hypovalva. Cingulum slightly twisting to the left. Sulcus limited to the Hypovalva, running to the rear end. Nucleus oval, located in Antapical part.
Ecology: This is freshwater species. The water quality indicator is sensitive/tolerant.
Distribution: *Europe*: Baltic Sea, Scandinavia. *North America*: Laurentian Great Lakes, Québec. *Middle East*: Iraq. *Asia*: Russia (Far East).
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Burdur basins.

Species: *Peridiniopsis kulczynskii* (Woloszynska) Bourrelly 1968 (Figure 3h)
Synonym: *Peridinium kulczynskii* Woloszynska 1916
Description: Cells oval, slightly flattened dorsoventrally, Apex opening present, 36 µm long, 31 µm wide. Cingulum twisting to the left. Sulcus slightly overlapping the Epivalva, expanded on Hypovalva, reaching to the rear end. Valves in the same size. Epivalva and Hypovalva rounded. Nucleus oval, central.
Ecology: This is freshwater species. The water quality indicator is sensitive/tolerant.
Distribution: *Europe*: Denmark, Poland. *North America*: Laurentian Great Lakes, Kansas. *Middle East*: Iraq.
Occurrence: It has been detected in freshwater habitats (lakes) in Burdur and Seyhan basins.

Species: *Peridiniopsis pygmaea* var. *brigantina* (Lind.) Moestrup & Calado 2018 (Figure 3i)
Synonym: *Peridinium pygmaeum* f. *brigantinum* Lindemann 1923
Description: Differs from the main type in the considerable reduction in the size of the 3 Apical plates. Cell 50 µm long, 36 µm wide.
Ecology: This is freshwater species. The water quality indicator is sensitive/tolerant.
Distribution: --
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Family: Protoperidiniaceae
Genus: *Protoperidinium*

Species: *Protoperidinium achromaticum* (Levander) Balech 1974 (Figure 3j)
Synonym: *Peridinium achromaticum* Levander 1902
Description: Cells rhombic, dorsoventrally slightly flattened, marginalized at the rear end, 28 µm long, 30 µm wide. Apex opening present. Cingulum almost circular. Sulcus limited to the Hypovalva, broad, carrying a small spine on the right, ending on the posterior end of the Hypovalva with a clearly defined, arched ridge. Epivalva conical. Nucleus elongated kidney-shaped, central.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Latvia, Netherlands, Baltic Sea, Black Sea, Britain, Helgoland, Scandinavia. *North America*: Mexico. *South America*: Brazil. *South-west Asia*: Lebanon. *Asia*: Caspian Sea, China, Russia (Far East), Tajikistan. *Australia and New Zealand*: Australia.
Occurrence: It has been detected in freshwater habitats (lakes) in the Susurluk basin.

Phylum: Haptophyta
Class: Coccolithophyceae
Order: Prymnesiales
Family: Chrysochromulinaceae
Genus: *Chrysochromulina*

Species: *Chrysochromulina parva* Lackey 1939 (Figure 3k)
Synonym: *Erkenia subaequiciliata* Skuja 1948
Description: Cells ovoidal, 5 µm wide and 3 µm thick; flagella two per cell, 10 µm long; chloroplasts two.
Ecology: This is freshwater species. The water quality indicator is tolerant.
Distribution: *Arctic*: Svalbard (Spitsbergen). *Europe*: Black Sea, Britain, Germany, Netherlands, Romania, Scandinavia, Slovakia, Sweden, Spain. *North America*: Arkansas, Northwest Territories, Ontario, Québec. *South America*: Brazil. *Asia*: India, China. *Middle East*: Israel.
Occurrence: It has been detected in freshwater habitats (lakes) in the Antalya basin.

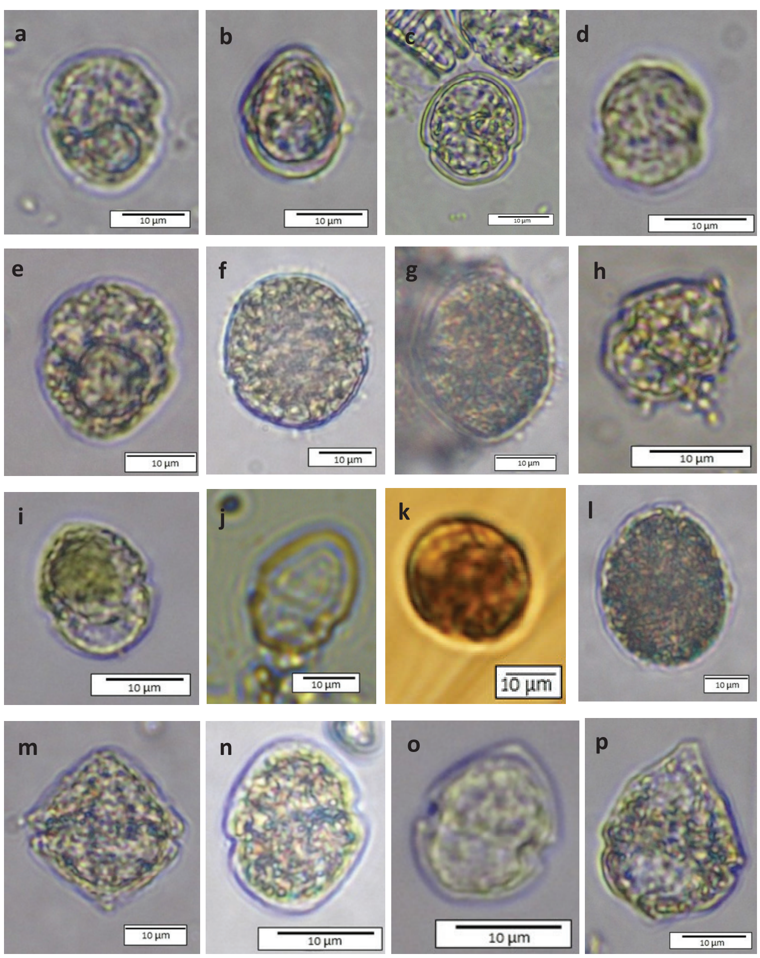
Order: Coccolithales
Family: Hymenomonadaceae
Genus: *Hymenomonas*

Species: *Hymenomonas roseola* Stein 1878 (Figure 3l)
Synonym: *Hymenomonas stagnicola* (Chodat & Rosillo) Kamptner
Description: Motile cells metabolic, ellipsoidal, 25 µm long, 12 µm wide; slightly emarginate at anterior end; flagella two per cell; haptonema short; coccoliths circular with a jagged top.

Ecology: This is brackish water species. The water quality indicator is tolerant.
Distribution: *Europe*: Britain, Czech Republic, Germany, Netherlands, Romania, Scandinavia, Slovakia, Sweden. *Caribbean Islands*: Cuba.
Occurrence: It has been detected in brackish water habitats (lakes) in the Antalya basin.

Figure 2

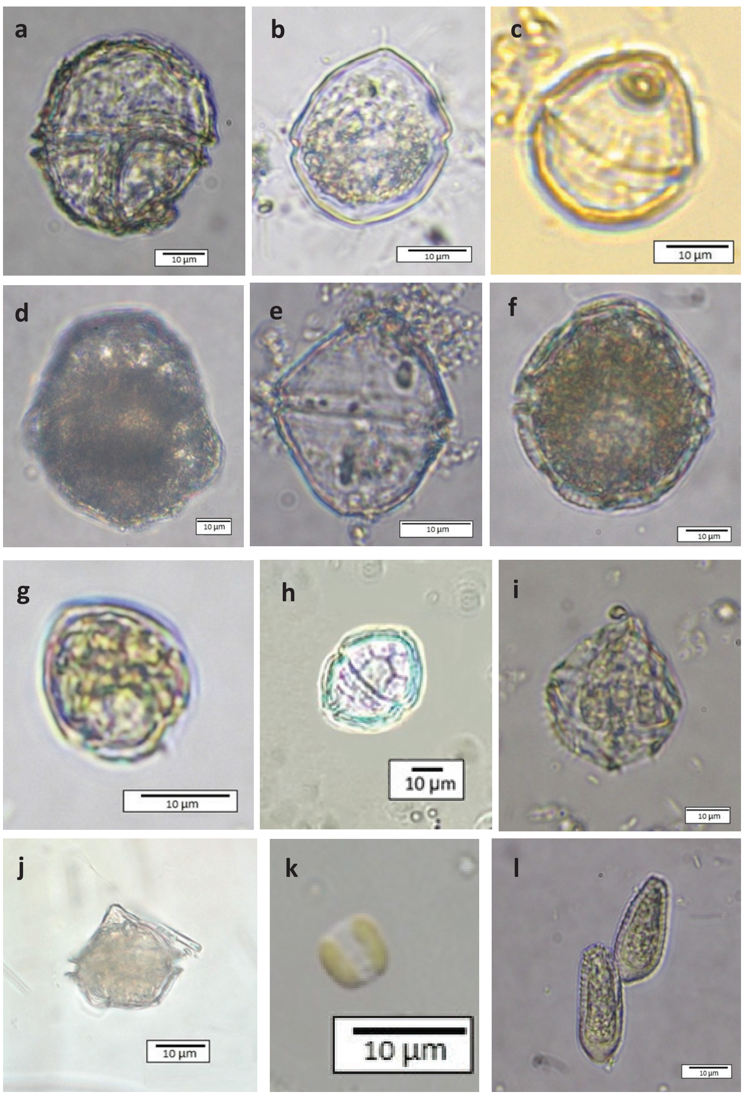
Sixteen New Records of Miozoa Taxa



Note. a. *Biecheleria ordinata*, b. *Borghiella woloszynskae*, c. *Glenoaulax inaequalis,* d. *Gymnodinium albulum,* e. *Gymnodinium eurytopum,* f. *Gymnodinium inversum,* g. *Gymnodinium inversum* var. *elongatum,* h. *Gymnodinium lantzschii,* i. *Gymnodinium mitratum,* j. *Gymnodinium palustre,* k. *Gymnodinium saginatum,* l. *Gymnodinium tatricum,* m. *Nusuttodinium acidotum,* n. *Nusuttodinium aeruginosum,* o. *Glenodinium paululum,* p. *Parvodinium africanum* var. *tatricum.*

Figure 3

Ten New Records of Miozoa and Two New Records of Haptophyta Taxa



Note. a. *Parvodinium centenniale,* b. *Parvodinium lubieniense,* c. *Peridinium gatunense,* d. *Peridinium gatunense* f. *majus,* e. *Peridinium gutwinskii,* f. *Peridinium volzii* var. *cyclicum,* g. *Peridiniopsis armata,* h. *Peridiniopsis kulczynskii,* i. *Peridiniopsis pygmaea* var. *brigantina,* j. *Protoperidinium achromaticum,* k. *Chrysochromulina parva,* l. *Hymenomonas roseola.*

Discussion and Conclusion

A total of 28 taxa were determined as new records for Turkish freshwater algae in the divisions of Miozoa, and Haptophyta.

Miozoa contributes to the new records with 26 taxa and these taxa are into genus *Biechleria, Borghiella, Glenoaulax, Gymnodinium* (9*), Nusuttodinium* (2), *Glenodinium, Parvodinium* (3), *Peridinium* (4)*, Peridiniopsis* (3*),* and *Protoperidinium.* The species of Miozoa are found in marine waters as well as fresh waters as planktonic and rarely parasitic species (Keshri et al., 2013; Gómez, 2012). Rawson (1956) determined the members of Miozoa in mesotrophic waters. Their ecological states are generally sensitive, but *Glenoaulax inaequalis, Glenodinium paululum, Peridiniopsis armata, Peridiniopsis kulczynskii,* and *Peridiniopsis pygmaea* var. *brigantina* are sensitive/tolerant.

Although all of them were recorded in Europe, some species were found in Australia and New Zealand, Asia, North and South America. Only *Parvodinium centenniale* were determined in Africa (Guiry & Guiry, 2020). The identified members are freshwater species in Kızılırmak, Burdur, Seyhan, Batı Akdeniz, Konya, Susurluk, Sakarya, Yeşilırmak, Batı Karadeniz, Akarçay, Doğu Akdeniz, Fırat-Dicle, and Asi basins.

The two taxa (*Chrysochromulina parva* and *Hymenomonas roseola*) were recorded as new records in Haptophyta. These taxa were the first record identified in freshwater and brackish water habitats in Turkey. Both species were found in the Antalya basin. *C. parva* is a cosmopolitan species and has been observed almost worldwide (Kristiansen, 1971; Diaz & Lorenzo, 1990; Wujek & Saha, 1991). Hansen et al. (1994) have reported that this species can grow in mass development, and this feature caused to toxic effects for fishes. *C. parva* has been found in the Arctic, Europe, North America, South America, China, and Middle East (Guiry & Guiry, 2020). *H. roseola* inhabits highly eutrophic waters such as polluted rivers but this species have been observed in various ponds and small lakes (Lackey, 1939; Huber-Pestalozzi 1941; Bourrelly, 1968). The species generally prefers the brackish waters. The distribution of *H. roseola* is in Europe and the Caribbean Islands (Guiry & Guiry, 2020).

In conclusion, 28 new records were added to the freshwater algal flora of Turkey with this study. It was observed that these taxa were distributed in different regions of the world. The number of new records for the algal flora of Turkey is expected to increase in the future.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Türkiye'deki 25 Nehir Havzasından Türkiye Tatlı Su Alg Florası İçin Yeni Kayıtlar, Bölüm III: Miozoa, Haptophyta

Avrupa Birliği Su Çerçeve Direktifi'ne (SÇD) göre biyolojik kalite bileşenlerinden biri olarak kabul edilen fitoplankton üzerine Türkiye'de yapılan taksonomik ve ekolojik çalışmaların sayısı her geçen gün artmaktadır. Avrupa Birliği'ne uyum çerçevesinde Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü (SYGM) ve bağlı kuruluşu Devlet Su İşleri (DSİ) tarafından biyolojik kalite bileşenleri de dikkate alınarak gerçekleştirilen çok sayıda proje bulunmaktadır. Birçok farklı nehir havzasında yapılan su kalitesi izleme çalışmaları, bazı göl yönetim planı çalışmaları, biyolojik kalite bileşenleri kullanılarak su kalitesini belirlemek için geliştirilen indeks geliştirme projeleri tamamlanmıştır. "Türkiye'de Referans İzleme Ağının Kurulması" Projesinin bir parçası olan bu çalışma Su Yönetimi Genel Müdürlüğü tarafından mali ve teknik olarak desteklenmiştir. Proje kapsamında 25 nehir havzasında 275 göl çalışılmış ve toplam 1363 fitoplankton taksonu tespit edilmiştir. Bu taksonlardan 63 tanesi Miozoa, 2 tanesi Haptophyta divizyolarına aittir.

Bugüne kadar dünya genelinde yapılan çalışmalarda 3550 Miozoa ve 773 Haptophyta taksonu tanımlanmıştır. Miozoa divizyosunun birçok türü serbest yüzen, tek hücreli organizmalardır ve bu grubun üyeleri tatlı sularda hem göl ve baraj gölü gibi büyük hacimli su kütlelerinde hem de gölet gibi daha küçük hacimli su kütlelerinde bulunmaktadır. Haptonema denen eşsiz bir organele sahip Haptophyta divizyosu üyeleri ise denizel ortamlarda yaygındırlar. Tatlı su habitatlarında az sayıda planktonik türün varlığı bilinmektedir.

Dört farklı iklim tipinin etkisi altında olması ve coğrafik olarak farklı yüksekliklerin bulunması sebebiyle Türkiye'de bulunan göllerin morfometresi ve hidrolojisi de farklılıklar göstermektedir ve bu durum alg biyoçeşitliliğini de desteklemektedir. Son yıllarda Türkiye alg florası için çok sayıda yeni kayıt bildirilmiştir ve tespit edilen toplam alg sayısı artış göstermiştir. Bu çalışmanın amacı da Türkiye alg florasına tespit edilen yeni kayıtlar ile katkıda bulunmaktır.

Türkiye'de bulunan 25 nehir havzasında 200 kadar doğal göl, 806 kadar baraj gölü ve 1000 kadar göletin var olduğu tespit edilmiştir. 25 nehir havzasında gerçekleştirilen bu çalışmada ise baraj gölleri de dahil olmak üzere 275 göl örneklenmiştir. Çalışılan göllerin 22 göl tipolojisinde gruplandığı belirlenirken, 26º19´ - 43º54´D ve 35º56´ - 42º00´K koordinatları arasında bulundukları tespit edilmiştir. Üzerinde çalışma yapılan göllerin coğrafi olarak deniz seviyesi (Gala Gölü) ile 2757 m (Çamlu Gölü) arasındaki farklı yüksekliklerde dağılım gösterdikleri görülmektedir.

2017 ve 2019 tarihleri arasında her bir gölde yılda üç defa (ilkbahar, yaz, sonbahar) olmak üzere bir, iki ya da üç farklı istasyondan fitoplankton örneklenmiştir. Göl yüzey alanı 50 hektardan küçük göller için bir, 50 ve 500 hektar arası olan göller için iki, 500 hektardan büyük göller için üç örnekleme istasyonu seçilmiştir. İstasyonlardan biri gölün en derin noktasında seçilmiştir. Öfotik bölgenin (Secchi diski derinliği × 2.5) üç farklı derinliğinden (yüzey, orta ve dip) su örnekleyicisi ile alınan su örnekleri karıştırılarak alt su numunesi alınmıştır. 50 µm göz açıklığına sahip plankton kepçesi de örnekleme sırasında ayrıca kullanılmıştır. Alg taksonlarının teşhisi farklı laboratuvarlardaki ışık ve ters mikroskoplar kullanılarak gerçekleştirilmiş ve mikroskoplara bağlı kameralar vasıtasıyla fotoğrafları çekilmiştir. Taksonların yeni kayıt olup olmadığı Türkiye'deki güncel literatürlerde yer alan kayıtlarla karşılaştırılıp tespit edilmiştir. Aynı zamanda takson isimlerinin güncelliği kontrol edilip türlerin dünyadaki dağılımı da belirlenmiştir.

Bu çalışmada Türkiye tatlı su algleri için yeni kayıt olarak 26 Miozoa ve 2 Haptophyta taksonu tanımlanmıştır. Miozoa divizyosunda bulunan taksonlar *Biechleria, Borghiella, Glenoaulax, Gymnodinium* (9*), Nusuttodinium* (2), *Glenodinium, Parvodinium* (3), *Peridinium* (4)*, Peridiniopsis* (3*),* ve *Protoperidinium* cinsleri içinde dağılım göstermiştir. Miozoa türlerinin denizel ekosistemlerin yanında tatlı su ekosistemlerinde de planktonik ve nadiren de parazitik olarak dağılım gösterdikleri bilinmektedir. Aynı zamanda daha çok mezotrofik ortamları tercih ettikleri tespit edilmiştir. Yeni kayıt olarak tespit edilen Miozoa taksonlarının büyük çoğunluğunun ekolojik durumu hassas olarak tespit edilmekle birlikte, *Glenoaulax inaequalis, Glenodinium paululum, Peridiniopsis armata, Peridiniopsis kulczynskii* ve *Peridiniopsis pygmaea* var. *brigantina* taksonlarının hassas/toleranslı oldukları belirlenmiştir.

Her ne kadar tespit edilen taksonlar dünya geneline bakıldığında genellikle Avrupa'da kayıt edilse de bazı türlerin Avustralya, Yeni Zelanda, Asya, Kuzey ve Güney Amerika'da da rapor edildiği görülmektedir. Sadece *Parvodinium centenniale* türü Afrika'da bulunmuştur. Türkiye'de bu taksonlar Kızılırmak, Burdur, Seyhan, Batı Akdeniz, Konya, Susurluk, Sakarya, Yeşilırmak, Batı Karadeniz, Akarçay, Doğu Akdeniz, Fırat-Dicle ve Asi havzalarında kayıt edilmiştir.

Sadece *Chrysochromulina parva* ve *Hymenomonas roseola* olarak iki takson Haptophyta divizyosunda tespit edilmiştir. Her iki tür de Antalya Havzasında bulunmaktadır. *C. parva* kozmopolitan bir türdür ve dünya üzerinde birçok farklı bölgede rapor edilmiştir. Kuzey kutbu, Avrupa, Kuzey Amerika, Güney Amerika, Çin, orta doğu bu türün tespit edildiği bölgelere örnek olarak verilebilir. Ayrıca bu türün aşırı çoğalma gösterebildiği ve bu durumun balıklar için toksik etki oluşturabildiği bildirilmiştir. *H. roseola* kirli nehirler gibi çok ötrofik ortamlarda bulunabilmektedir fakat aynı zamanda birçok farklı gölet ve küçük gölde de tespit edilmiştir. Aynı zamanda acı su ortamlarını da tercih edebilmektedir. *H. roseola* türünün Avrupa'da ve Karayip Adalarında dağılım gösterdiği görülmektedir.

Sonuç olarak, bu çalışma ile birlikte 28 yeni kayıt Türkiye tatlı su alg florasına eklenmiştir. Bu taksonların dünyanın farklı bölgelerinde de dağılım gösterdikleri tespit edilmiştir. İlerleyen yıllarda yapılan çalışmalarda Türkiye alg florası için yeni kayıtların sayısının artması beklenmektedir.

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Research Article

New Records for the Turkish Freshwater Algal Flora in Twenty Five River Basins of Turkey, Part IV: Ochrophyta

Türkiye'deki 25 Nehir Havzasından Türkiye Tatlı Su Alg Florası İçin Yeni Kayıtlar, Bölüm IV: Ochrophyta

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Abstract

Turkish lakes have different morphometric and hydrological features as a result of different climates and noticeable altitude differences in Turkey that are necessary conditions to occur different habitats for algal diversity. The total number of algae taxa in the flora of Turkey has increased due to the growing number of studies on phytoplankton taxonomy and ecology in the last 40 years. This study aims to describe new planktonic algal taxa for the Turkish freshwater algal flora. A total of 56 Ochrophyta taxa were determined in this study, conducted from 2017 to 2019 in lakes lies in 25 river basins of Turkey. In 275 lakes, samples of phytoplankton were collected with water samplers from three depths (surface, middle, and bottom) of the euphotic zone, and then subsamples were obtained by mixing the water samples taken from these three depths. The plankton net with a pore diameter of 50 µm was also used for collecting samples of phytoplankton. The algal taxa was identified by using different types of compound and inverted microscopes in many laboratories. 30 Ochrophyta taxa of which were determined in this study, were reported as a new record for the first time for the freshwater algal flora of Turkey.

Keywords: *Ochrophyta, freshwater algae, new record, Turkey*

Öz

Türkiye gölleri, Türkiye farklı iklim tiplerine ev sahipliği yaptığından ve coğrafik olarak yükseklik farklılıkları bulundurduğundan dolayı farklı morfometrik ve hidrolojik yapıya sahip olup, bu durum alglerin biyoçeşitliliği için farklı habitat tipleri sağlamaktadır. Son 40 yılda, fitoplankton taksonomisi ve ekolojisi alanında yapılan çalışmaların artması sebebiyle Türkiye florasındaki toplam alg taksonu sayısı artmıştır. Bu çalışma, Türkiye tatlı su alg florası için yeni planktonik alg taksonlarını tanımlamayı amaçlamaktadır. 2017 ve 2019 yılları arasında Türkiye'deki 25 nehir havzasında bulunan göllerde yapılan çalışmada Ochrophyta divizyosuna ait 56 takson tanımlanmıştır. 275 gölde yapılan bu çalışmada fitoplankton örnekleri öfotik derinliğin 3 farklı bölgesinden (yüzey, orta, dip) su örnekleyicileri ile toplanmıştır. Daha sonra bu üç derinlikten alınan su örnekleri karıştırılarak su numuneleri alınmıştır. 50 µm göz açıklığına sahip plankton kepçesi de örnekleme sırasında ayrıca kullanılmıştır. Alg taksonlarının teşhisi farklı laboratuvarlardaki ışık ve ters mikroskopları kullanılarak gerçekleştirilmiştir. Çalışma sırasında, Türkiye tatlı su alg florası için ilk defa Ochrophyta divizyosuna ait 30 yeni takson bulunmuştur.

Anahtar kelimeler: *Ochrophyta, tatlı su algi, yeni kayıt, Türkiye*

Introduction

The number of studies on phytoplankton taxonomy and ecology, accepted as one of the biological quality elements according to the EU Water Framework Directive (WFD) (European Parliament & Council, 2000), has notably increased in recent years in Turkey. Due to Turkey's EU accession process, several projects, specified for biological quality components and funded by Directorate General for Water Management (DGWM) and General Directorate of State Hydraulic Works (DSİ) of the Ministry of Agriculture and Forestry, have been implemented successfully. Many studies for monitoring water quality of different river basins, a few studies for development and implementation of lake-management plans, and some index development projects to determine water quality by using biological quality components have been completed (DGWM, 2020). This study is an outcome of one of these projects.

Planktonic Ochrophyta species are mostly unicellular or colonial flagellates, predominantly occurring in freshwater (John et al., 2003). Chrysophyceae, Synurophyceae, and Xanthophyceae are the main plankton groups that are found in a freshwater environment. They were mostly reported in relatively unpolluted freshwaters and good indicators of water quality (Harper et al., 2012).

Until now, in previous studies, more than 4325 Ochrophyta taxa were listed in the world (Guiry & Guiry, 2020), while 223 Ochrophyta taxa were recorded in the flora of Turkey. However, only 51 taxa were identified as freshwater taxa (Taşkın et al., 2019; Maraşlıoğlu & Gönülol, 2020). In consequence of four different types of climate and noticeable altitude differences in Turkey, its lakes have different morphometric and hydrological features that are appropriate conditions for different algal species. In recent years, many new records were given for the algal flora of Turkey. A total of 250 new taxa were reported in Bacillariophyta (23), Chlorophyta (84), Charophyta (68), Cryptophyta (7), Cyanobacteria (22), Euglenozoa (25), Miozoa (11), Ochrophyta (8), and Rhodophyta (2) divisions. These records were mainly found in Susurluk, Sakarya, Fırat - Dicle, Yeşilırmak, Marmara, Doğu Karadeniz, Çoruh, Burdur, and Antalya basins. It has been seen that the contribution to new records is highest in Sakarya and Fırat - Dicle basins which have the largest surface area (Aysel et al., 1993; Öztürk et al., 1995a, 1995b; Şahin, 2000, 2002, 2007, 2009; Yağcı & Turna, 2002; Atıcı, 2002; Baykal et al., 2009; Sevindik et al., 2010, 2011, 2015, 2017; Özer et al., 2012; Akar & Şahin, 2014; Yüce & Ertan, 2014; Varol & Fucikova, 2015; Varol & Şen, 2016; Maraşlıoğlu & Soylu, 2018; Şahin & Akar, 2019a, 2019b; Morkoyunlu & Aktaş, 2020). As a consequence of these studies, the total number of taxa have increased in Turkey (Taşkın et al., 2019; Maraşlıoğlu & Gönülol, 2020). Similar studies were done and new records were recorded in different parts of the world (Khondker et al., 2006; Alfasane & Khondker, 2007; Oliveira et al., 2013; Bartozek et al., 2018; Akhtar et al., 2019).

This study is one of the outcomes of the "Establishment of Reference Monitoring Network in Turkey" project, financially and technically supported by DGWM. In this project, 275 lakes in 25 river basins were studied, and a total of 1363 phytoplankton taxa were detected. 56 of total taxa were determined as Ochrophyta and 30 of the total number of Ochrophyta were recorded as new records for Turkish freshwater algae.

Materials and Methods

Study Area

Turkey has 25 river basins (Figure 1), and inland water bodies in these basins consist of 200 natural lakes, 806 reservoirs, and 1000 ponds (Foreign Relation Office of DSİ, 2014). The natural lakes are mainly distributed in Burdur, Susurluk, Van and Konya basins (Hoşgören, 1994).

Figure 1

River Basins of Turkey

A total of 275 lakes, including reservoirs in 25 river basins, were sampled during the study. These lakes are given in Table 1. These lakes are grouped in 22 lake typologies based on altitude, lake depth, lake size, and geology (DGWM, 2015), and they are located between the longitudes of 26º19´ and 43º54´E and the latitudes of 35º56´ and 42º00´N. The altitudes of the lakes vary between from sea level (Lake Gala) and 2757 m (Lake Çamlu).

Table 1

Lakes Where the Research Was Conducted in the 25 River Basins

Basins	The number of studied lakes	Name of lake
Burdur	6	Acıgöl L., Burdur L., Karataş L, Salda L., Tefenni P., Keçiborlu Güneykent Uzundere P.
Akarçay	10	Akşehir L., Eber L., Akdeğirmen R., 26 Ağustos TP L., Karamık R., Ağzıkara P., Tınaztepe P., Gezler P., Şehit Uz. Çvş. Nurullah Oymak P., Tazlar Satı Gelin P.
Sakarya	23	Taşkısığı L., Akgöl 2 L., Çubuk L., Poyrazlar L., Sapanca L., Işık Dağı Karagöl L., Çavuşcu L., Mogan L., Üçlerkayası P., Çubuk Karagöl L., Eymir L., Akgöl 1 L., Küçük Akgöl L., Avdan L., Kayuslu L., Karamurat L., Cüneyt Sönmez P., Çılgınlar P., Yıldırım Evci P., Ovacık L., Sülüklü L., Çamkoru TP P., Anagöl L.
Batı Karadeniz	14	Nazlı L., Büyük L., Derin L., Parçayır L., Abant L., Dipsiz L., Gölcük L., Keçi L., Yeniçağa L., Kuyudüzü L., Erze L., Koca L., Kuru L. Natural Park, Sazlı L.
Doğu Karadeniz	7	Gaga L., Sera L., Ulugöl L., Uzungöl L., Çamlu L., Çakır L., Limni L.
Yeşilırmak	14	Akgöl L., Aşağıtepecik (Gölova) L., Boraboy P., Büyük L., Düden L., Kaz L., Ladik L., Uyuz L., Karacaören Mevki L., Dipsiz L. 2, Sarıçiçek L., Yenihayat R., Dipsiz L. 1, Zinav L.
Kızılırmak	23	Gölbel L., Ulaş L.-2, Büyük Lota L., Hafik L., Küçük Lota L., Tödürge L., Arı L., Aygır L., Bakkal L., Dipsiz L., Elekci L., Ulaş L.-1, Ulaş L.-3, Deniz L., Yeşilgöl 1 L., Bardakçılı Mevki L., Yenidanişment Mevki L., Palanga L., Sugiylan Mevki L., Kayabaşı L., Kuru L., Sıraç L., Kızılçam L.
Meriç-Ergene	5	Gala L., Sığırcı L., Pamuklu L., Üsküp Sulama P., Domuz L.
Marmara	9	Habibler Mevki P., Great Dipsiz L., İznik L., Koca L., Karamaden L., Danamandıra L.-1, Danamandıra L.-2, Small Dipsiz L., Sinekli L.
Antalya	9	Eğirdir L., Kovada L., Gölcük L., Cemalalanı L., Duruca L., Eğri L., Küllü L., Titreyen L., Düden L.
Batı Akdeniz	13	Gölhisar L., Girdev L., Avlan L., Dalaman Wetlands, Denizcik L., Kocagöl L., Kusuru L., Köycegiz L., Küçükdalyan L., Yeşilgöl L., Yazır L., Baranda L., Pozan L.

Table 1

(Continued)

Basins	The number of studied lakes	Name of lake
Büyük Menderes	13	Nazlı L., Büyük L., Derin L., Parçayır L., Abant L., Dipsiz L., Gölcük L., Keçi L., Yeniçağa L., Kuyudüzü L., Erze L., Koca L., Kuru L. Natural Park, Sazlı L.
Gediz	6	Gölcük L., Demirköprü R., Marmara L., Gördes R., Karagöl L., Küçükler R.
Kuzey Ege	5	Boz L., Güzelhisar R., Karagöl L., Sevişler R., Tepe L.
Küçük Menderes	6	Çatal L., Tahtalı R., Alaçatı R., Belevi L., Gebekirse L., Ürkmez R.
Konya	18	Sarıot L., Beyşehir L., Tuz L., Süleymanhacı L., Gök (Kozanlı) L., Meke L. (Meke Maarı), Gavur L., Dipsiz L., Acıgöl L. 2, Bakı L., Uyuz L., Acıgöl L. 1, Kayı L., Düden L., Kovalı L., Köpek L., Küçük L., Sülüklü L.
Susurluk	9	Manyas L., Uluabat L., Adsız-1 L., Gölbaşı L., Gölcük L., İkizcetepeler R., Karagöl L., Kilimli L., Nilüfer R.
Aras	3	Aktaş L., Çıldır L., Aygır L.
Çoruh	8	Adsız L., Boğa L., Balık L., Şavşat Karagöl L., Çil L., Borçka Karagöl L., Tortum L., Ürünlü P.
Fırat-Dicle	17	Kaz L., Ahır L., Haçlı L., Korlu L., Hazar L., Karagöl L., Yeşildere P., Palandöken P., Güroymak R., Kalecik R., Kapıaçmaz P., Dedeyolu P., Güzelyurt Sulama P., Hasancık P., İncesu P., Otlukbeli L., Siverek Yeleken P.
Van	7	Akgöl L., Erçek L., Bostaniçi P., Arin L., Aygır L., Van L., Nazik L.
Asi	8	Reyhanlı (Yenihisar) L., Yayladağ R., Tahtaköprü R., Karagöl L., Adsız L., Yarseli R., Üçpınar P., Sapkanlı P.
Ceyhan	18	Gölbaşı L., Kartalkaya R., Kara L., B. Yapalak P., Korkmaz P., Zorkun P., Merk P., Yamaçoba P., Kızıliniş P., Arıklıkaş P., Karacaören P., Meletmez P., Postkabasakal P., Bağtepe P., Zerdali P., Kozan Aydın P., Yumurtalık Zeytinbeli P., Yumurtalık Ayvalık P.
Doğu Akdeniz	12	Aygır L., Uzun L., Değirmendere P., Cemilli Çevlik P., Hacınuhlu Kelce P., Akın P., Kızılöz P., Başyayla P., Göktepe P., Bağbaşı R., Yassıbağ P., Hadım-İnönü P.
Seyhan	12	Bahçelik R., Tufanbeyli Demiroluk P., Adsız L., Pekmezli-Çatalçam P., Tufanbeyli Doğanbeyli P., Gümüşören R., Şıhlı P., Dölekli P., Kılıçlı P., Topacık P., Hüsniye P., Çavuşlu P.
Total	275	

L: Lake; P: Pond; R: Reservoir; R: Reeds

Sampling and Identification

Phytoplankton was sampled three times (spring, summer, and autumn) a year in 2017, 2018, and 2019 at the one, two, or three monitoring stations in each lake. The number of stations to be sampled were determined as one station for lakes that have a surface area smaller than 50 ha, two stations for lakes having a surface area between 50 and 500 ha, and three stations for lakes with a surface area higher than 500 ha ((Yer Üstü Suları, Yer Altı Suları ve Sedimentten Numune Alma ve Biyolojik Örnekleme Tebliği, 2015). One of the selected stations was determined at the deepest point of the lake. In 275 lakes, samples of the phytoplankton were collected with a water sampler from three depths (surface, middle, and bottom) of the euphotic zone (Secchi disk depth × 2.5), and then subsamples were obtained by mixing the water samples, taken from these three depths. Plankton net with a pore diameter of 50 µm was also used for collecting samples of phytoplankton. All samples were fixed with Lugol's solution. The algal taxa were identified by using different types of the compound and inverted microscopes in many laboratories according to the identification books of Huber-Pestalozzi (1962) and John et al. (2003). Identified taxa were checked with the checklist of Aysel (2005), Taşkın et al. (2019), and the database of Turkish algae (Maraşlıoğlu & Gönülol, 2020), and then determined as new taxa for Turkish freshwater algal flora. The currently accepted nomenclature and distribution of taxa have been given according to Guiry and Guiry (2020). The new records were photographed with the cameras attached to the microscopes.

Results

A total of 30 Ochrophyta taxa are described below.

Phylum: Ochrophyta
Class: Bikosea
Order: Bicoecida
Family: Bicoecidae
Genus: *Bicosoeca*

Species: *Bicosoeca planctonica* Kisselev 1931 (Figure 2a)
Synonym: --
Description: Lorica bell-shaped, with a button-shaped bulge at the base, yellowish, composed of about 10 rings stacked in parallel, 14 µm long, width at the mouth 13 µm.
Ecology: This is freshwater species. The water quality indicator is tolerant.
Distribution: *Europe*: France, Romania, Scandinavia, Slovakia, Sweden.

Occurrence: It has been detected in freshwater habitats (lakes) in the Yeşilırmak basin.

Class: Chrysophyceae
Order: Hibberdiales
Family: Stylococcaceae
Genus: *Bitrichia*

Species: *Bitrichia chodatti* (Reverdin) Chodat 1926 (Figure 2b)
Synonym: *Diceras chodatii* Reverdin 1917
Description: Cells surrounded by a hyaline lorica with 2 curved processes, one often more curved than the other, 35 µm and 20 µm long respectively. Chloroplast single and without an eyespot. Cells 14 µm long, 6 µm wide.
Ecology: This is freshwater species. The water quality indicator is tolerant.
Distribution: *Europe*: Netherlands, Slovakia, Baltic Sea, Britain, Germany, Scandinavia, Spain. *North America*: Northwest Territories, Québec. *Middle East*: Israel.
Occurrence: It has been detected in freshwater habitats (lakes) in the Yeşilırmak basin.

Order: Chromulinales
Family: Chromulinaceae
Genus: *Chromulina*

Species: *Chromulina annulata* Conrad 1930 (Figure 2c)
Synonym: --
Description: Cells ovate, 1.5 times longer than wide, broadly rounded at the back, 5 µm long, 3 µm wide. Flagella apical, 1.5 times longer than the body. Chloroplast single, without an eyespot.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: --
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Species: *Chromulina ovalis* Klebs 1893 (Figure 2d)
Synonym: --
Description: Cells ellipsoidal, 8 µm long, 5 µm wide. Flagella 1.5 times longer than the body. Chloroplast single, with an eyespot, and without a pyrenoid.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Black Sea, Britain, Germany, Latvia, Netherlands, Romania, Slovakia, Spain, Sweden. *North America*: Northwest Territories. *South America*:

Argentina. *Asia*: India, China, Japan, Taiwan. *Australia and New Zealand*: New South Wales, Queensland.
Occurrence: It has been detected in freshwater habitats (lakes) in the Çoruh basin.

Species: *Chromulina sphaeridia* J. Schiller 1929 (Figure 2e)
Synonym: --
Description: Cells regularly spherical, 7 µm in diameter. Flagella 2.5 times longer than the body. Chloroplast two, without an eyespot.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Slovakia.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Sakarya basins.

Species: *Chromulina wislouchiana* Bourrelly 1957 (Figure 2f)
Synonym: *Chrysoglena verrucosa* Wislouch 1914
Description: Cells irregularly ellipsoidal, 20 µm long, 12 µm wide, with walls densely covered with rounded warts. Flagella one per cell. Chloroplast single and large, with an eyespot and without a pyrenoid.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Genus: *Ochromonas*

Species: *Ochromonas granulosa* H. Meyer 1897 (Figure 2g)
Synonym: --
Description: Cells solitary, naked, with two unequal flagella. Cells ovoid, with tapered tail, 15 µm long, 8 µm wide. Chloroplast two, small, reduced, with an eyespot. Main flagellum as long as body-length.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Germany
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Akarçay basins.

Family: Dinobryaceae
Genus: *Chrysococcus*

Species: *Chrysococcus minutus* (F. E. Fritsch) Nygaard 1932 (Figure 2h)
Synonym: *Trachelomonas volvocina* f. *minuta* Fritsch 1918

Description: Lorica spherical, 5,5 µm in diameter, brown. Chloroplast single; one eyespot.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *South-west Asia*: India. *Arctic*: Svalbard (Spitsbergen). *Europe*: Baltic Sea, Britain, Germany, Netherlands, Romania, Scandinavia, Spain, Sweden. *North America*: Arkansas. *Australia and New Zealand*: New South Wales, Tasmania.
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Genus: *Dinobryon*

Species: *Dinobryon cylindricum* var. *alpinum* (O. E. Imhof) H. Bachmann 1911 (Figure 2i)
Synonym: --
Description: Lorica 35 µm long, not cylindrical but more vase-shaped; colonies many-celled and rather dense.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, France, Germany, Scandinavia, Spain, Sweden. *North America*: Arkansas, Northwest Territories, Québec. *South America*: Argentina. *Australia and New Zealand*: New Zealand, Tasmania.
Occurrence: It has been detected in freshwater habitats (lakes) in the Susurluk basin.

Species: *Dinobryon korshikovii* Matvienko ex Kapustin 2019 (Figure 2j)
Synonym: *Dinobryon elegans* Korshikov 1926
Dinobryon elegantissimum Bourrelly 1957
Description: Lorica solitary, the campanulated posterior region gradually attenuated, lateral margins slightly convex with marked undulations, 40 µm long, 10 µm wide.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands, Britain, Bulgaria, Scandinavia. *South America*: Brazil. *North America*: Québec. *Asia*: Japan.
Occurrence: It has been detected in freshwater habitats (lakes) in Küçük Menderes and Büyük Menderes basins.

Genus: *Kephyrion*

Species: *Kephyrion littorale* J. W. G. Lund 1942 (Figure 2k)
Synonym: --
Description: Lorica ovoid to bowl-shaped, with a thickening around the mouth, 7 µm long, 5 µm wide, brownish; single flagellum.

Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Germany, Netherlands, Romania, Scandinavia, Slovakia, Sweden. *Asia*: China, Tajikistan.
Occurrence: It has been detected in freshwater habitats (lakes) in Yeşilırmak and Doğu Karadeniz basins.

Species: *Kephyrion rubri-claustri* Conrad 1939 (Figure 3a)
Synonym: --
Description: Lorica barrel-shaped with an equatorial bulge, 6.5 µm long, 5 µm wide; single flagellum.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Baltic Sea, Black Sea, Britain, Germany, Netherlands, Romania, Scandinavia, Slovakia, Spain, Sweden, Ukraine. *Asia*: Taiwan, Tajikistan.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz, Sakarya, and Akarçay basins.

Genus: *Kephyriopsis*

Species: *Kephyriopsis ovum* Pascher & Ruttner (Figure 3b)
Synonym: --
Description: Lorica transversely truncated ovoid, a little longer than wide, mostly with a clear thickening ring, 10 µm long, 9 µm wide.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Netherlands
Occurrence: It has been detected in freshwater habitats (lakes) in the Asi basin.

Genus: *Pseudokephyrion*

Species: *Pseudokephyrion cinctum* (J. Schiller) Gerlinde Schmid 1939 (Figure 3c)
Synonym: *Kephyriopsis cincta* J. Schiller 1926
Description: Lorica cylindrical, brownish, rounded at the basal end, slightly narrowing towards the apical end, 9 µm long, 6 µm wide; flagella 2, unequal.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Slovakia. *North America*: Arkansas.
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Species: *Pseudokephyrion entzii* W. Conrad 1939 (Figure 3d)
Synonym: --

Description: Lorica elongated, brownish, rather thin-walled, broadly rounded at the basal end, then rising almost cylindrically, only slightly widening towards the apical end, 5 µm long, 4 µm wide; flagella 2, unequal.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Arctic*: Svalbard (Spitsbergen). *Europe*: Britain, Czech Republic, Germany, Netherlands, Scandinavia, Slovakia, Sweden. *North America*: Northwest Territories, Québec. *Asia*: Tajikistan.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Karadeniz, Sakarya, Yeşilırmak, Akarçay, Fırat-Dicle and Asi basins.

Species: *Pseudokephyrion minutissimum* Conrad (Figure 3e)
Synonym: --
Description: Lorica very small, brown, quite thick, smooth, basal part almost hemispherical, apical part with a wider narrowed mouth, 5 µm long, 4 µm wide; single flagellum.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Romania. *North America*: Québec. *Asia*: Russia (Far East), Tajikistan.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya, Fırat-Dicle, and Asi basins.

Species: *Pseudokephyrion ovum* (Pascher & Ruttner) Conrad 1939 (Figure 3f)
Synonym: --
Description: Lorica bowl-shaped, 8 µm long, 5 µm wide, brownish; single flagellum.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Germany, Netherlands, Spain, Sweden. *North America*: Northwest Territories. *Asia*: Tajikistan.
Occurrence: It has been detected in freshwater habitats (lakes) in Yeşilırmak and Doğu Karadeniz basins.

Species: *Pseudokephyrion pilidium* Schiller 1929 (Figure 3g)
Synonym: --
Description: Lorica conical, rounded at the back, side walls below the wide mouth initially concave, then slightly convex, 12 µm long, 9 µm wide; flagella 2, unequal.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Germany, Netherlands. *North America*: Arkansas.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Fırat-Dicle basins.

Species: *Pseudokephyrion pseudospirale* Bourrelly 1957 (Figure 3h)
Synonym: --
Description: Lorica ovoid, broadest at the middle, 7.5 µm long, 5 µm wide, with a helical thickening making 3 turns, brownish; chloroplast single; flagella 2, unequal.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Germany, Netherlands, Slovakia. *North America*: Arkansas. *Asia*: India. *Antarctic and Antarctic islands*: Signy Island.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Fırat-Dicle basins.

Species: *Pseudokephyrion ruttneri* (Schiller) Gerlinde Schmidt 1939 (Figure 3i)
Synonym: *Kephyriopsis ruttneri* Schiller 1929
Description: Lorica cylindrical with an apical constriction, transparent, 7 µm long, 5 µm wide, flagella 2 per cell.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Spain.
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Order: Paraphysomonadales
Family: Paraphysomonadaceae
Genus: *Chrysosphaerella*

Species: *Chrysosphaerella longispina* Lauterborn 1896 (Figure 3j)
Synonym: --
Description: Cells with their narrowed basal ends are united to form spherical colonies, which are held together by a gel. Cells ovoid, 8 µm long, 6 µm wide. Colony diameter 60 µm. Flagella 20 - 30 µm.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Germany, Ireland, Netherlands, Romania, Russia (Europe), Scandinavia, Sweden. *North America*: Arkansas, Laurentian Great Lakes, Newfoundland, Ontario, Québec, Virginia. *South America*: Argentina. *Asia*: India, Russia (Far East). *Australia and New Zealand*: New Zealand.
Occurrence: It has been detected in freshwater habitats (lakes) in the Asi basin.

Class: Synurophyceae
Order: Synurales
Family: Mallomonadaceae
Genus: *Mallomonas*

Species: *Mallomonas anglica* (N. Carter) Huber-Pestalozzi 1941 (Figure 3k)
Synonym: *Pseudomallomonas anglica* N. Carter 1937
Description: Cells ellipsoidal, 20 µm long, 8 µm wide. Flagella 22 µm long, with a large bluish basal grain at the base. Two chloroplasts, no stigma, no pyrenoid.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Netherlands.
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Species: *Mallomonas caudata* Iwanoff [Ivanov] 1899 (Figure 3l)
Synonym: --
Description: Cells elliptical, 25 µm long, 10 µm wide. Bristles densely covering cells, curved and coarsely serrated. Scales large, elliptical, without any visible structure.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Baltic Sea, Britain, France, Germany, Greece, Netherlands, Romania, Russia (Europe), Scandinavia, Slovakia, Spain, Sweden, Ukraine. *North America*: Arkansas, Florida, Laurentian Great Lakes, Newfoundland, Northwest Territories, Ontario, Québec, Tennessee. *South America*: Argentina, Brazil. *Middle East*: Iraq. *Asia*: India, Vietnam, China, Korea, Russia, Taiwan, Tajikistan. *Australia and New Zealand*: Queensland, New South Wales.
Occurrence: It has been detected in freshwater habitats (lakes) in the Çoruh basin.

Species: *Mallomonas majorensis* Skuja 1939 (Figure 3m)
Synonym: --
Description: Cells ovoid, 15 µm long, 9 µm wide. Flagella 7 µm. Bristles completely absent.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain, Netherlands, Romania, Slovakia, Spain, Sweden. *North America*: Arkansas, Québec. *Asia*: Russia (Far East).
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Species: *Mallomonas teilingii* Conrad 1927 (Figure 3n)
Synonym: *Mallomonas litomesa* var. *major* Teiling 1912
Mallomonas tridentata Nygaard 1949
Description: Cells broadly spindle-shaped, 15 µm long, 7 µm wide. Bristle as long as body length. Chloroplast two.
Ecology: This is freshwater species. The water quality indicator is sensitive.

Distribution: *Europe*: Netherlands, Britain, Germany, Netherlands, Romania, Sweden. *South America*: Brazil.
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Species: *Mallomonas tonsurata* Teiling 1912 (Figure 3o)
Synonym: *Mallomonas heterotricha* Nygaard 1949
Description: Cells ovoid, 12 µm long, 7 µm wide, bristles forming an apical tuft, a group of short curved bristles surrounded by some longer straight ones.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Baltic Sea, Britain, France, Germany, Greece, Latvia, Netherlands, Romania, Scandinavia, Slovakia, Spain, Sweden. *North America*: Arkansas, Florida, Laurentian Great Lakes, Québec. *South America*: Argentina, Brazil. *Asia*: China, Japan, Russia, Taiwan, India, Myanmar (Burma), Vietnam. *Australia and New Zealand*: Australia, New South Wales, New Zealand, Northern Territory, Tasmania, Victoria.
Occurrence: It has been detected in freshwater habitats (lakes) in the Yeşilırmak basin.

Order: Chloramoebales
Family: Chloramoebaceae
Genus: *Phacomonas*

Species: *Phacomonas pelagica* Lohmann 1903 (Figure 3p)
Synonym: --
Description: Protoplast lens-shaped, broadside almost circular, narrow side elliptical, 10 µm long, 6 µm wide. Chloroplast two.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Britain
Occurrence: It has been detected in freshwater habitats (lakes) in the Fırat-Dicle basin.

Class: Xantophyceae
Order: Mischococcales
Family: Centritractaceae
Genus: *Centritractus*

Species: *Centritractus africanus* F. E. Fritsch & M. F. Rich 1930 (Figure 3r)
Synonym: *Centritractus lemmermanni* Skvortsov & Noda 1969

Description: Cells solitary, long, cylindrical, slightly curved, with a spine at each apex, 20 µm long, 4 µm wide. Cell membrane tough. Spines slightly curved, 22 µm long.
Ecology: This is freshwater species. The water quality indicator is tolerant.
Distribution: *Europe*: Bulgaria, Germany, Netherlands, Romania, Spain, Ukraine. *America*: Brazil, Cuba. *Africa*: D. R. of Congo. *Asia*: India. *Australia and New Zealand*: New Zealand.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Asi basins.

Genus: *Pseudotetraëdron*

Species: *Pseudotetraëdron neglectum* Pascher 1912 (Figure 3s)
Synonym: --
Description: Cells narrowly oblong, 12 µm long, with four spines. Spine length 13 µm.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: *Europe*: Czech Republic, Netherlands. *Asia*: Russia (Far East).
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Family: Botryochloridaceae
Genus: *Ducellieria*

Species: *Ducellieria chodatii* var. *armata* (Skuja) Teiling 1957 (Figure 3t)
Synonym: --
Description: Cells conical, 10 µm in diameter, connected at the hexagonal base by bridges 7 µm long and 1.5 µm thick. Horn-liked 10-12 µm long extension protruded from the top of the outer cells. Coenobia 65 µm in size.
Ecology: This is freshwater species. The water quality indicator is sensitive.
Distribution: --
Occurrence: It has been detected in freshwater habitats (lakes) in the Sakarya basin.

Discussion and Conclusion

A total of 30 taxa were determined as new records for Turkish freshwater algae in the division of Ochrophyta. These taxa were dispersed into genus *Bicosoeca, Bitrichia, Chromulina* (4)*, Ochromonas, Chrysococcus, Dinobryon* (2)*, Kephyrion* (2)*, Kephyriopsis, Pseudokephyrion* (7), *Chrysosphaerella, Mallomonas* (5), *Phacomonas, Centritractus, Pseudotetraëdron, Ducellieria*. Previously 2 taxa in *Bicosoeca,* 12 taxa in *Dinobryon,* 1 taxon in *Pseudokephyrion*, 4 taxa in *Mallomonas*, and 1 taxon in *Centritractus* genus were recorded in Turkey (Taşkın et al., 2019; Maraşlıoğlu & Gönülol, 2020). However, 10 genus (*Bitrichia, Chromulina, Ochromonas, Chrysococcus, Kephyrion, Kephyriopsis, Chrysosphaerella, Phacomonas, Pseudotetraëdron, Ducellieria*) and taxa in these 10 genus were found as a new record for the first time for algal flora of Turkey.

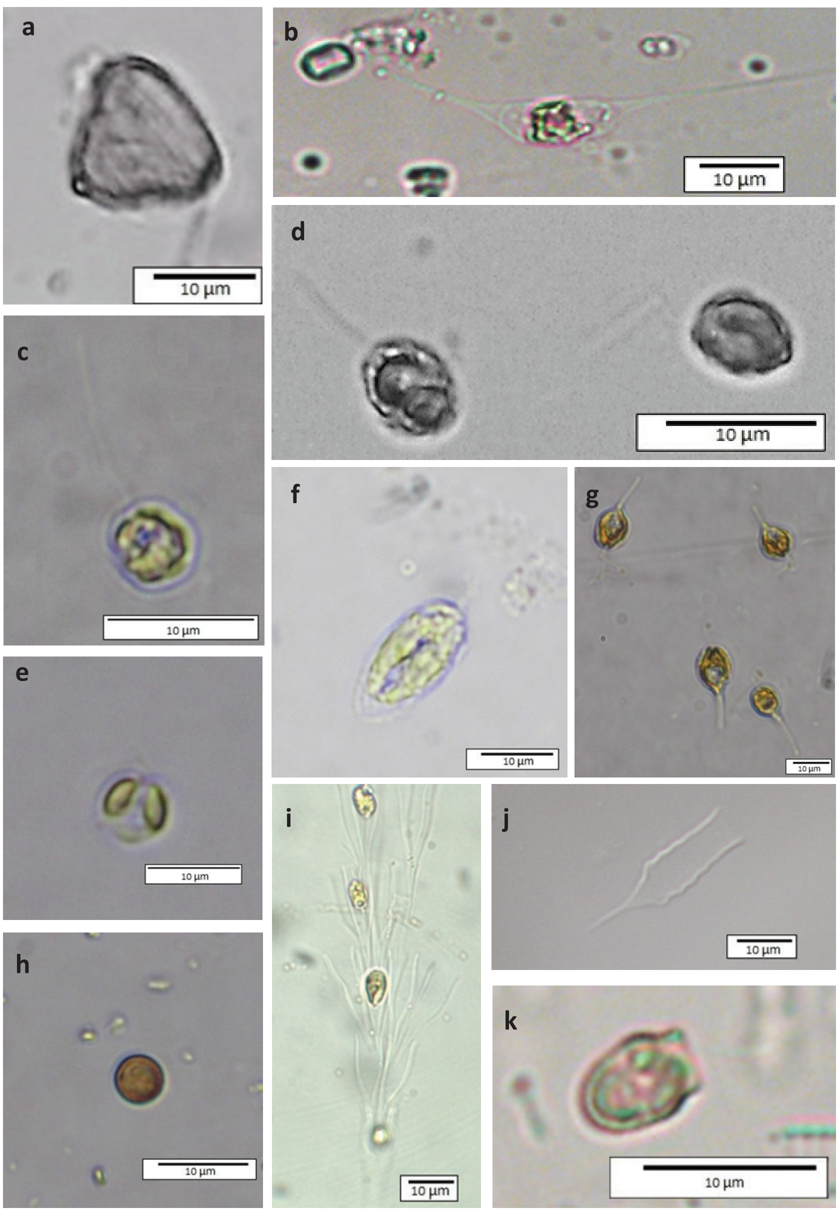
Only *Bicosoeca* is in Bikosea class, the others are in Chrysophyceae and Xantophyceae classes. The members of the Chrysophyceae class have been determined mostly in freshwaters but few species were found in the snow, soil, and marine habitats (Harper et al., 2012). A large majority of Xanthophyceae members were found in freshwater and soil, while some of them have distributed in brackish and marine habitats (Maistro et al., 2016). The members of freshwater Ochrophyta are characterized in oligotrophic lakes and ponds. Their ecological status is generally sensitive, but *Bicosoeca planctonica* and *Bitrichia chodatti* are tolerant.

Although these 30 taxa are mostly distributed in Europe, some species have been found in Australia and New Zealand, Asia, Africa, North and South America. Only *Pseudokephyrion pseudospirale* has been determined in Antarctic and Antarctic islands (Guiry & Guiry, 2020). These new records in Ochrophyta were found in Batı Akdeniz, Büyük Menderes, Küçük Menderes, Susurluk, Sakarya, Yeşilırmak, Doğu Karadeniz, Akarçay, Meriç Ergene, Çoruh, Fırat-Dicle, and Asi Basins from Turkey.

In conclusion, 30 new records were added to the freshwater algal flora of Turkey with this study. It was observed that these taxa were distributed in different regions of the world. The number of new records for the algal flora of Turkey is expected to increase in the future.

Figure 2

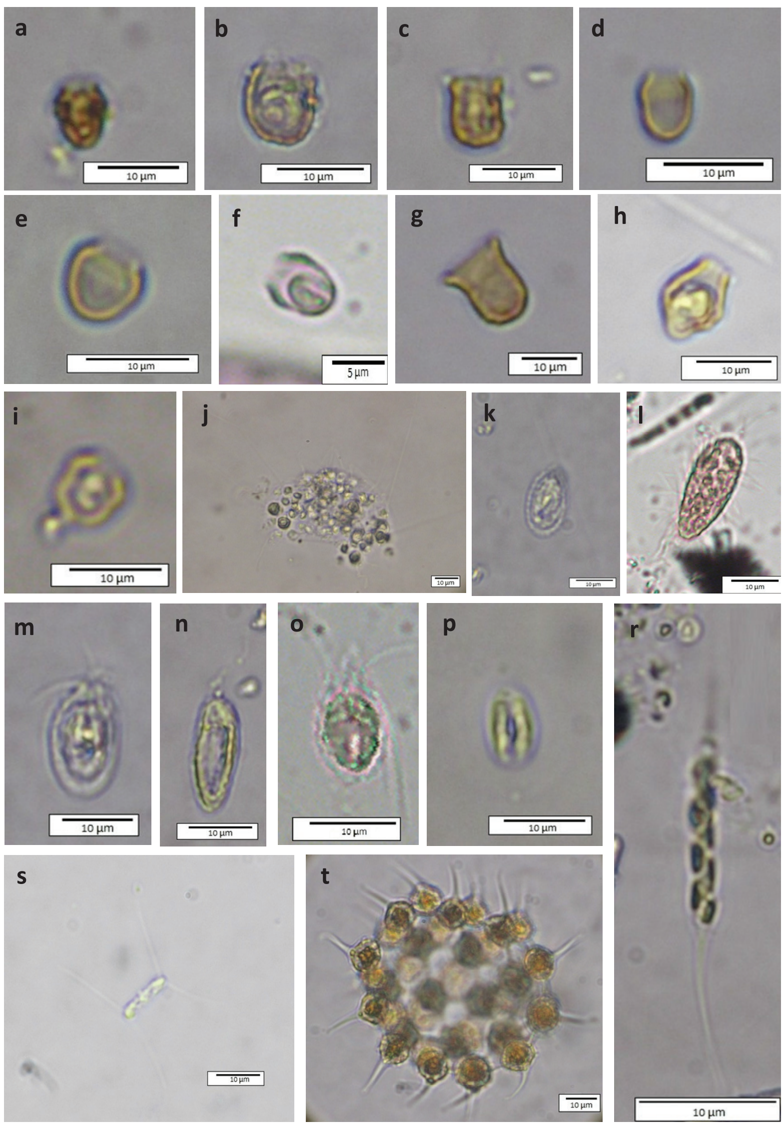
Eleven New Records of Ochrophyta Taxa



Note. a. *Bicosoeca planctonica*, b. *Bitrichia chodatti*, c. *Chromulina annulata*, d. *Chromulina ovalis*, e. *Chromulina sphaeridia*, f. *Chromulina wislouchiana*, g. *Ochromonas granulosa*, h. *Chrysococcus minutus*, i. *Dinobryon cylindricum* var. *alpinum,* j. *Dinobryon korshikovii,* k. *Kephyrion littorale.*

Figure 3

Nineteen New Records of Ochrophyta Taxa



Note. a. *Kephyrion rubri-claustri,* b. *Kephyriopsis ovum,* c. *Pseudokephyrion cinctum,* d. *Pseudokephyrion entzii,* e. *Pseudokephyrion minutissimum,* f. *Pseudokephyrion ovum,* g. *Pseudokephyrion pilidium,* h. *Pseudokephyrion pseudospirale,* i. *Pseudokephyrion ruttneri,* j. *Chrysosphaerella longispina,* k. *Mallomonas anglica,* l. *Mallomonas caudata,* m. *Mallomonas majorensis,* n. *Mallomonas teilingii,* o. *Mallomonas tonsurata,* p. *Phacomonas pelagica,* r. *Centritractus africanus,* s. *Pseudotetraëdron neglectum,* t. *Ducellieria chodatii var. armata.*

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Türkiye'deki 25 Nehir Havzasından Türkiye Tatlı Su Alg Florası İçin Yeni Kayıtlar, Bölüm IV: Ochrophyta

Avrupa Birliği Su Çerçeve Direktifine (WFD) göre biyolojik kalite bileşenlerinden biri olarak kabul edilen fitoplankton üzerine Türkiye'de yapılan taksonomik ve ekolojik çalışmaların sayısı her geçen gün artmaktadır. Avrupa Birliği müktesebatına uyum çalışmaları çerçevesinde Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü (SYGM) ve Devlet Su İşleri (DSİ) Genel Müdürlüğünce biyolojik kalite bileşenlerinin de dikkate alındığı çok sayıda proje gerçekleştirilmiştir. Birçok nehir havzasında yapılan su kalitesi izleme çalışmaları, göl yönetim planı çalışmalarının bazıları, biyolojik kalite bileşenleri kullanılarak su kalitesini belirlemek için geliştirilen indeks geliştirme projeleri tamamlanmıştır. "Türkiye'de Referans İzleme Ağının Kurulması" Projesinin bir parçası olan bu çalışma da Su Yönetimi Genel Müdürlüğü tarafından desteklenen çalışmalardan biridir. Proje kapsamında 25 nehir havzasında bulunan 275 gölde çalışmalar yürütülmüş ve toplam 1363 fitoplankton taksonu tespit edilmiştir. Bu taksonlardan 56 tanesi Ochrophyta divizyosuna aittir.

Bugüne kadar dünya genelinde bu alanda yapılan çalışmalarda 4325 Ochrophyta taksonu tanımlanmıştır. Planktonik Ochrophyta türleri genellikle tek hücreli ya da koloniyal formda olan kamçılı alglerdir ve daha çok tatlı su ekosistemlerinde dağılım gösterirler.

Türkiye dört farklı iklim tipine ve farklılık gösteren topografyaya sahip olması nedeniyle göllerinin morfometrik ve hidrolojik özellikleri de farklılıklar göstermektedir; bu özellikler alg biyoçeşitliliğini de desteklemektedir. Son yıllarda Türkiye alg florası için çok sayıda yeni kayıt bildirilmiştir, böylece tespit edilen toplam alg sayısında kayda değer artış görülmüştür. Bu çalışmanın amacı Türkiye alg florasına yeni kayıtlar tespit ederek katkıda bulunmaktır.

Türkiye'nin 25 nehir havzasında 200 kadar doğal göl, 806 kadar baraj gölü ve 1000 kadar gölet bulunmaktadır. 25 nehir havzasında gerçekleştirilen bu çalışmada baraj gölleri de dahil olmak üzere 275 göl örneklenmiştir. Çalışılan göller 26º19´ - 43º54´D ve 35º56´ - 42º00´K koordinatları arasında bulunmakta olup 22 göl tipolojisinde gruplanmıştır . Ayrıca çalışma yapılan göller deniz seviyesi (Gala Gölü) ile 2757 m (Çamlu Gölü) arasında farklı yüksekliklerde dağılım göstermektedir.

Yılda üç defa (ilkbahar, yaz ve sonbahar) olmak üzere 2017 ve 2019 tarihleri arasında her bir gölde yüzey alanları büyüklüğüne göre bir, iki ya da üç farklı istasyondan fitoplankton örnekleri alınmıştır. Göl yüzey alanı 50 hektardan küçük göller için bir, 50 ve 500 hektar arası olan göller için iki, 500 hektardan büyük göller için üç örnekleme istasyonu seçilmiştir. İstasyonlardan biri ise mutlaka gölün en derin noktasında belirlenmiştir. Öfotik bölgenin (Secchi diski derinliği × 2.5) üç farklı derinliğinden (yüzey, orta ve dip) su örnekleyicisi ile alınan su örnekleri karıştırılarak alt su numunesi alınmıştır. Ayrıca örnekleme sırasında 50 µm göz açıklığına sahip plankton kepçesi de kullanılmıştır. Alg taksonları farklı laboratuvarlardaki ışık ve ters mikroskopları kullanılarak teşhis edilmiştir. Mikroskoplara bağlı dijital kameralarla da fotoğrafları çekilmiştir. Türkiye'deki güncel literatürlerdeki takson kayıt listesi ile çalışmada tespit edilen taksonlar karşılaştırılmış ve yeni kayıt olup olmadığı tespit edilmiştir. Aynı zamanda takson isimlerinin güncelliği kontrol edilip, türlerin dünyadaki dağılımı da belirlenmiştir.

Bu çalışmada Türkiye tatlı su algleri için yeni kayıt olarak 30 Ochrophyta taksonu tanımlanmıştır. Ochrophyta divizyosunda bulunan taksonlar *Bicosoeca, Bitrichia, Chromulina* (4), *Ochromonas, Chrysococcus, Dinobryon* (2), *Kephyrion* (2), *Kephyriopsis, Pseudokephyrion* (7), *Chrysosphaerella, Mallomonas* (5), *Phacomonas, Centritractus, Pseudotetraëdron* ve *Ducellieria* cinsleri içinde dağılım göstermiştir. Daha önce Türkiye'de yapılan çalışmalarda *Bicosoeca* cinsine ait 2, *Dinobryon* cinsine ait 12, *Pseudokephyrion* cinsine ait 1, *Mallomonas* cinsine ait 4, *Centritractus* cinsine ait 1 takson rapor edilmiştir. Bununla birlikte bu çalışma ile birlikte ilk defa 10 cinse (*Bitrichia, Chromulina, Ochromonas, Chrysococcus, Kephyrion, Kephyriopsis, Chrysosphaerella, Phacomonas, Pseudotetraëdron, Ducellieria*) ait taksonlar Türkiye alg florası için yeni kayıt olarak belirlenmiş bulunmaktadır.

Sadece *Bicosoeca* cinsi Bikosea sınıfı içinde bulunmaktadır. Diğer taksonlar Chrysophyceae ve Xantophyceae sınıfları içinde dağılım göstermektedir. Chrysophyceae sınıfı üyeleri daha çok tatlı su ortamlarında tespit edilselerde çok az türün kar florasında, toprak florasında ya da denizel habitatlarda dağılım gösterdiği bilinmektedir. Xanthophyceae sınıfı üyelerinin büyük bir çoğunluğu tatlı su ve karasal habitatlarda dağılım gösterirken bazılarının acı su ve denizel habitatlarda da bulunduğu görülmektedir. Ochrophyta divizyosuna ait alglerin genellikle oligotrofik göl ve göletleri tercih ettikleri bildirilmiştir. Ekolojik durumları genellikle hassas olan bu grubun üyelerinden *Bicosoeca planctonica* ve *Bitrichia chodatti* taksonları toleranslı olarak belirlenmiştir.

Her ne kadar tespit edilen bu 30 takson çoğunlukla Avrupa'da dağılım gösterse de, bazı türler Avustralya, Yeni Zelanda, Asya, Afrika, Kuzey ve Güney Amerika gibi dünyanın farklı bölgelerinde dağılım göstermektedir. Sadece *Pseudokephyrion pseudospirale* türü a Kuzey Kutup ve Güney Kutup bölgelerinde bulunan adalarda tespit edilmiştir. Türkiye'de bu taksonların ise Batı Akdeniz, Büyük Menderes, Küçük Menderes, Susurluk, Sakarya, Yeşilırmak, Doğu Karadeniz, Akarçay, Meriç Ergene, Çoruh, Fırat-Dicle ve Asi havzalarında dağılım gösterdiği bilinmektedir.

Sonuç olarak, bu çalışma ile birlikte 30 yeni kayıt, Türkiye tatlı su alg florasına eklenmiştir. Ayrıca 10 cinse ait takson da yapılan bu çalışmayla ilk defa kayıt altına alınmıştır. Bu taksonların dünyanın farklı bölgelerinde de dağılım gösterdikleri tespit edilmiştir. İlerleyen yıllarda yapılacak çalışmalarla Türkiye alg florası için yeni kayıt sayısının artması beklenmektedir.

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Research Article

New Records for the Turkish Freshwater Algal Flora in Twenty Five River Basins of Turkey, Part V: Cryptophyta

Türkiye'deki 25 Nehir Havzasından Türkiye Tatlı Su Alg Florası için Yeni Kayıtlar, BölümV: Cryptophyta

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Abstract

There is an increasing number of taxonomic and ecologic studies on phytoplankton, one of the biological quality elements according to the EU Water Framework Directive, in Turkey day by day. This study was carried on from 2017 to 2019 in 275 lakes lies in 25 river basins of Turkey with the aim of examining the taxonomy and biological diversity of the Cryptophyta group. It was the fourth part of the Project, entitled "Establishment of Reference Monitoring Network in Turkey", financially and technically supported by the Ministry of Agriculture and Forestry, Directorate General for Water Management. In each lake, phytoplankton was sampled with water samplers from three depths (surface, middle, and bottom) of the euphotic zone, and then the water samples taken from these three depths were mixed for obtaining subsamples. The algal taxa was identified by using different light and inverted microscopes in many laboratories. A total of 24 Cryptophyta taxa were identified in the study. 9 of the identified Cryptophya taxa were presented as new records for the freshwater algal flora of Turkey.

Keywords: *Cryptophyta, freshwater algae, new record, Turkey*

Öz

AB Su Çerçeve Direktifi'ne göre biyolojik kalite unsurlarından biri olan fitoplankton konusunda Türkiye'de her geçen gün artan sayıda taksonomik ve ekolojik çalışma bulunmaktadır. Bu çalışma, Cryptophyta grubunun taksonomisini ve biyolojik çeşitliliğini incelemek amacıyla, Türkiye'nin 25 nehir havzasında yer alan 275 gölde 2017-2019 yılları arasında gerçekleştirilmiştir. Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü tarafından mali ve teknik olarak desteklenen "Türkiye'de Referans İzleme Ağının Kurulması" başlıklı projenin dördüncü bölümüdür. Her gölde fitoplankton, öfotik bölgenin üç derinliğinden (yüzey, orta ve alt) su örnekleyiciler ile örneklenmiş ve daha sonra bu üç derinlikten alınan su örnekleri karıştırılmıştır. Alg taksonlarının teşhisi ışık ve ters mikroskoplar kullanılarak gerçekleştirilmiştir. Çalışmada toplam 24 Cryptophyta taksonu tanımlanmıştır. Tespit edilen Cryptophya taksonlarından 9 tanesi Türkiye'nin tatlı su alg florası için yeni kayıt olarak sunulmuştur.

Anahtar kelimeler: *Cryptophyta, tatlı su algi, yeni kayıt, Türkiye,*

Introduction

Members of Cryptophya are cosmopolitan species, but they are rarely dominant organisms in the system. The taxonomy of these algae has been receiving considerable attention globally owing to their widespread occurrence in all aquatic habitats (Novarino, 2003). Despite being widespread in freshwater habitats, cryptomonads are a neglected group, with most reports in the literature consisting of lists of taxa with few illustrations of the specimens observed (John et al., 2003). Their ecology has universally received much less attention, and almost everything that is presently known about it is from the temperate region of the world (Bicudo et al., 2009). Recent researches have shown that even in well-sampled geographical regions and habitats, the true diversity of cryptomonads is often unknown (Hoef-Emden, 2007; Lane & Archibald, 2008; Choi et al., 2013; Martyneneko et al., 2020).

Until now, 223 Cryptophyta taxa were listed in previous studies in the world (Guiry & Guiry, 2020). Cryptomonads are unicellular, mainly pigmented, small (~5–50 µm) biflagellate protists found in diverse freshwater, brackish, and marine habitats. They are characterized by a distinct cellular asymmetry and flattened in shape, with an anterior groove or pocket. At the edge of the pocket there are typically two slightly unequal flagella (Hoef-Emden & Archibald, 2016).

Due to the effects of three different types of climate, and noticeable altitude differences, Turkish lakes have different morphometry and hydrology that support distinct algal diversity. In recent years, many new records were given for the algal flora of Turkey (Aysel et al., 1993; Öztürk et al., 1995a, 1995b; Şahin, 2000, 2002, 2007, 2009; Yağcı & Turna, 2002; Atıcı, 2002; Baykal et al., 2009, 2012; Sevindik et al., 2010, 2011, 2015, 2017; Özer et al., 2012; Akar & Şahin, 2014; Yüce & Ertan, 2014; Varol &Fucikova, 2015; Varol & Şen, 2016; Maraşlıoğlu & Soylu, 2018; Yüce & Aktaş, 2020), and the total number of taxa have increased (Taşkın et al., 2019; Maraşlıoğlu & Gönülol, 2020).

In this project, 275 lakes in 25 river basins were studied, and a total of 1363 phytoplankton taxa were detected. The present study aimed to contribute to the algal flora of Turkey by describing 9 species in Cryptophyta as new records for the Turkish freshwater algal flora.

Materials and Methods

Study Area

Turkey has 25 river basins (Figure 1), and inland water bodies in these basins consist of 200 natural lakes, 806 reservoirs, and 1000 small reservoirs (Foreign Relation Office of DSİ, 2014). Foreign Relation Office of DSİ data show that the volume of annual average precipitation is estimated to be 501 billion m^3 water, of which about 55% is lost to evapotranspiration, 31% flows into water bodies (158 billion m^3) and 14% feeds aquifers (69 billion m^3). The Dicle-Fırat Basin is Turkey's largest single volume of available exploitable freshwater resources, representing 28.5% (Foreign Relation Office of DSİ, 2014).

A total of 275 lakes, including reservoirs, were sampled during the study in 25 river basins. The number of studied lakes in the river basins is given in Table 1. These lakes are grouped in 22 lake typologies based on altitude, lake depth, lake size and lakebed material (DGWM, 2015a). They are located between the longitudes of

26º 19´ and 43º 54´E and the latitudes of 35º 56´ and 42 º 00´N. The altitudes of the sampled lakes vary between sea level (Lake Gala) and 2757 m (Lake Çamlu).

Figure 1

River Basins of Turkey

Sampling and Identification

Phytoplankton samples were collected from three depths (surface, middle, and bottom) of the euphotic depth with a water sampler in spring, summer, and fall of the each year between 2017 and 2019 at the sampling stations in each lake. Subsamples were used from the mixed water of the three depths. Plankton net with a pore diameter of 50 µm was also used for sampling. Phytoplankton determinations were carried out on subsamples preserved in acetic Lugol's solution that was sedimented in the counting chambers. Algal cells were counted on inverted microscopes following Huber-Pestalozzi (1968) and John et al. (2003). Determination of new taxa for Turkish freshwater algal flora were checked with the checklist of Aysel (2005), Taşkın et al. (2019), and the database of Turkish algae (Maraşlıoğlu & Gönülol, 2020). The currently accepted nomenclature and distribution of taxa have been given according to Guiry & Guiry (2020).

Table 1

Number of Studied Lakes in 25 River Basins

River Basins	Lakes
Burdur	6
Akarçay	10
Sakarya	23
Batı Karadeniz	14
Doğu Karadeniz	7
Yeşilırmak	14
Kızılırmak	23
Meriç-Ergene	5
Marmara	9
Antalya	9
Batı Akdeniz	13
Büyük Menderes	13
Gediz	6
Kuzey Ege	5
Küçük Menderes	6
Konya	18
Susurluk	9
Aras	3
Çoruh	8
Fırat-Dicle	17
Van	7
Asi	8
Ceyhan	18
Doğu Akdeniz	12
Seyhan	12
TOTAL	275

Results

A total of 24 Cryptophyta taxa were determined in a study conducted from 2017 to 2019 in 25 river basins of Turkey. 9 Cryptophyta taxa presented as new records for the freshwater algal flora of Turkey are described below.

Phylum: Cryptophyta
Class: Cryptophyceae
Order: Cryptomonadales
Family: Hemiselmidaceae
Genus: Chroomonas

Species: *Chroomonas breviciliata* Nygaard (Figure 2a)
Synonyms: -
Description: Cells 15-17 µm long, 4-6 µm wide, pearshaped, rounded front, pointed back and slightly pulled out to the side. 2 pyrenoid and very short flagella are present.
Ecology: This is a freshwater species.
Distribution: *Europe*: Netherlands, Romania.
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Family: Cryptochrysidaceae
Genus: Cryptochrysis

Species: *Cryptochrysis minor* Nygaard (Figure 2b)
Synonyms: -
Description: Cells 11 µm long and 6 µm wide, two slightly unequal flagella. Cells ellipsoidal, small, free-swimming, both ends equally and regularly rounded, anterior end convex which is asymmetrically bilobed; pyrenoid present in the dorsal position.
Ecology: This is a freshwater species.
Distribution: *Europe*: Germany; *South America*: Brazil; *South-west Asia*: Bangladesh.
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Family: Cryptomonadaceae
Genus: Cryptomonas

Species: *Cryptomonas anomala* F.E.Fritsch (Figure 2c)
Synonyms: -
Description: Cells 9-11µm wide, 21-24µm long, flagella equal, much shorter than the cell, 2 chloroplasts laterally placed with a circular pyrenoid, central or slightly displaced towards cell anterior.
Ecology: This is a freshwater species.
Distribution: *Europe*: Britain.

Occurrence: It has been detected in freshwater habitats (lakes) in Konya and Sakarya basins.

Species: *Cryptomonas phaseolus* Skuja (Figure 2d)
Synonyms: -
Description: Cells 8-13 µm long and 5-8 µm wide. The relatively small cells are ellipsoidal or slightly flattened on the ventral side. The gullet is subapical and extends to the middle of the cell. The flagella are subequal and are shorter than the cell.
Ecology: This is a freshwater species. This species is usually found in eutrophic waters.
Distribution: *Europe*: Austria, Germany, Netherlands, Scandinavia, Slovakia, Spain, Sweden; *North America*: Québec; *South America*: Brazil; *South-west Asia*: Bangladesh; *South-east Asia*: Singapore.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Akarçay basins.

Species: *Cryptomonas reflexa* Skuja (Figure 2e)
Synonyms: -
Description: Cells 27-37 µm long, 12-16 µm wide, relatively bigger, broadly ovate or ellipsoidal, spindleshaped, anterior end curved, posterior end pointed. The species lacks pyrenoids but possesses two lateral chloroplasts.
Ecology: This is a freshwater species.
Distribution: *Europe*: Germany, Netherlands, Poland, Scandinavia, Slovakia, Sweden; *South America*: Brazil, Uruguay.
Occurence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Species: *Cryptomonas tenuis* Pascher (Figure 2f)
Description: The cells are small with nearly parallel sides in lateral view but are usually slightly curved toward the ventral surface. Each contains two narrow chloroplasts and sometimes a light-refractive body is visible at the anterior end. The gullet is short and narrow.
Ecology: This is a freshwater species.
Distribution: *Europe*: Germany; *South America*: Brazil.
Occurrence: It has been detected in freshwater habitats (lakes) in the Batı Akdeniz basin.

Order: Pyrenomonadales
Family: Pyrenomonadaceae
Genus: Pyrenomonas

Species: *Pyrenomonas ovalis* P.Kugrens, B.L.Clay & R.E.Lee (Figure 2g)
Synonyms: *Rhodomonas ovalis* Nygaard
Description: Cells oval to ellipsoid, measuring 14-16 µm long and 6-8 µm wide; often forming colonies embedded in mucilage; and have a single red chloroplast with two lobes. The pyrenoid is attached to both lobes, the chloroplast appears H-shaped due to the formation of a bridge between the two lobes. The nucleomorph is embedded within the pyrenoid.
Ecology: This is a freshwater species.
Distribution: Europe: Germany.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Asi basins.

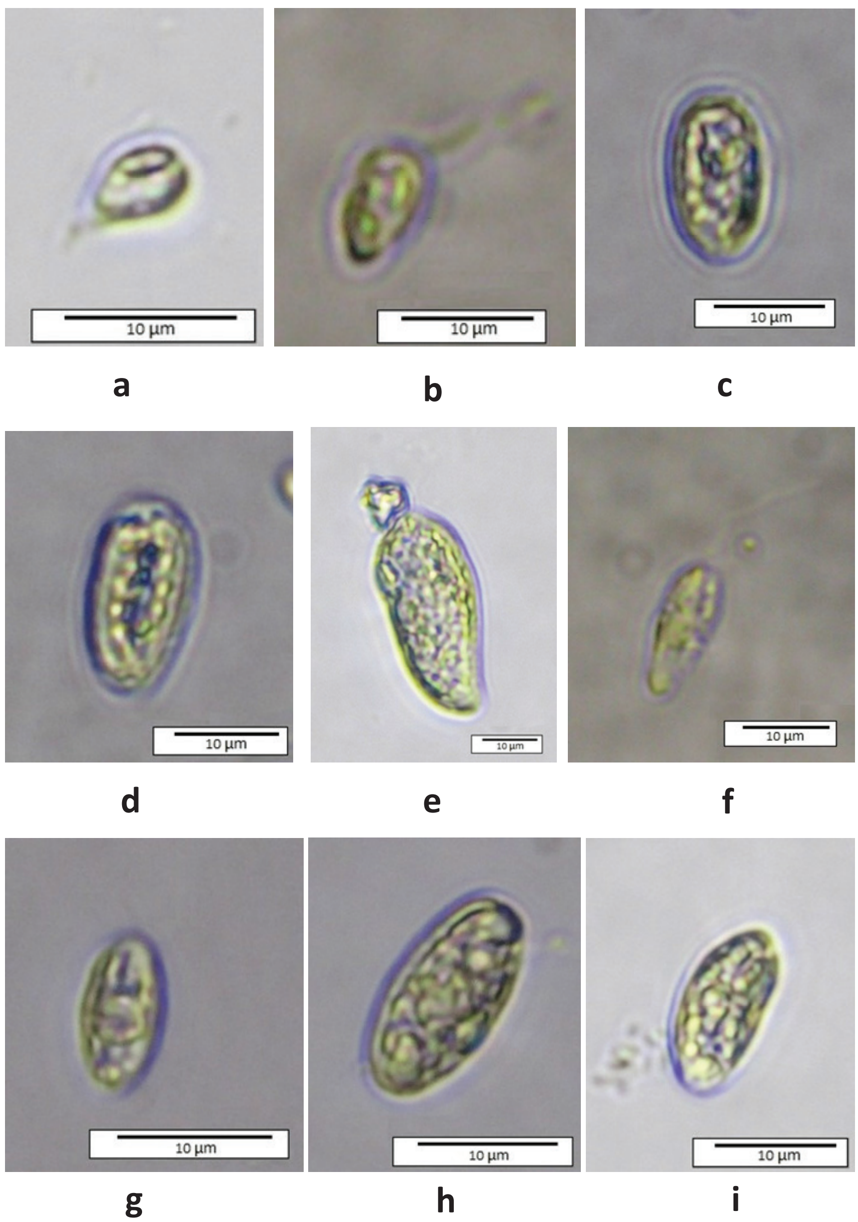
Order*:* Pyrenomonadales
Family*:* Pyrenomonadaceae
Genus: Rhodomonas

Species: *Rhodomonas rubra* Geitler (Figure 2h)
Synonyms: -
Description: Cells elongated oval to long elliptica, 13-20 µm long, 8-10 µm wide. A relatively large pyrenoid positioned centrally or slightly backwards. The chloroplast is clearly H-shaped, and the nucleomorph is located in an invagination of the pyrenoid.
Ecology: This is a freshwater species.
Distribution: *Europe*: Netherlands.
Occurrence: It has been detected in freshwater habitats (lakes) in Batı Akdeniz and Fırat Dicle basins.

Species: *Rhodomonas tenuis* Skuja (Figure 2i)
Synonyms: -
Description: Cells 15-23 µm long, 6-9.5 µm wide, elongated, cylindrical or cylindrical-obovate, cross-section in the area of apex circular or slightly elliptical.
Ecology: This is a marine/freshwater species.
Distribution: *Europe*: Germany, Scandinavia, Sweden; North America: Northwest Territories.
Occurrence: It has been detected in freshwater habitats (lakes) in Sakarya and Asi basins.

Figure 2

Nine New Records of Cryptophyta Taxa



Note. a. *Chroomonas breviciliata*, b. *Cryptochrysis minor*, c. *Cryptomonas anomala*, d. *Cryptomonas phaseolus*, e. *Cryptomonas reflexa*, f. *Cryptomonas tenuis*, g. *Pyrenomonas ovalis*, h. *Rhodomonas rubra*, i. *Rhodomonas tenuis.*

Discussion and Conclusion

A total of 9 taxa were determined as new records for Turkish freshwater algae in the divisions of Cryptophyta. These taxa are dispersed into genus *Chroomonas* (1)*, Cryptochrysis* (1)*, Cryptomonas* (4)*, Pyrenomonas* (1)*, Rhodomonas* (2). Chryptophyta members have been determined in freshwaters but few species are found in the snow, soil, and marine habitats (Harper et al., 2012). Regarding their nutritional requirements, they are considered to be the responsible for the eutrophication, i.e. they can tolerate a wide spectrum of trophic conditions (Reynolds, 1976). Cryptophyceae have a wide environment spectrum, as they are typical of nutrients and organic matterrich waters (Rosen, 1981), but they can also tolerate occasional nutrient, especially N depletion (Haffner & McNeely, 1989). In the periphyton community in oligotrophic conditions, *C. phaseolus* was associated with the greatest ammonium content (Vercellino, 2001). Some freshwater species from Cryptophyta prefers the oxic/anoxic boundary layer (chemocline) near the lake bottom as type-habitat (Gervais 1997). *Cryptomonas phaseolus* was also found to co-exist simultaneously with *Cryptomonas undulata* in short-term changes in the light climate near the chemocline (Gervais 1998). It is clear that different cryptomonads may adapt to a wide variety of environmental conditions from calm, stratified, well-lit and nutrient-enriched summer conditions to cool, mixed and light-limited winter situations despite an apparent homogeneity of morphological, phylogenetic and functional characteristics (Cerino & Zingone, 2006). According to Barone & Naselli-Flores (2003), photoadaptive strategy and formation of resting forms are physiological mechanisms that could explain the Cryptophyta success in shallow systems. Based on Reynolds et al. (2002) functional groups, the genus Cryptomonas belongs to group Y, whose species are well adapted to living in several kinds of habitats, but mainly shallow enriched ones.

In the world 223 Cryptophyta taxa were identified up to now. In this study, we identified 24 species of which 9 species as the first record for Turkey from the genus of *Chroomonas, Cryptochrysis, Cryptomonas, Pyrenomonas* and *Rhodomona*s. Genus *Cryptomonas is* cosmopolitan in freshwater habitats, including temporary ponds, rivers, and lakes. More than 100 species have been assigned to Cryptomonas; including marine and blue-green forms. Recent taxonomic revisions have suggested that Cryptomonas should be restricted to the ovoid, olive-green to brown species found in fresh and slightly brackish waters. The majority of species have been described from European waters, but the genus is known from every continent. *Rhodomonas* is cosmopolitan and common, although rarely abundant, in marine and brackish waters and two freshwater species are known from Europe (Guiry & Guiry, 2020). The identified members are freshwater species in Kızılırmak, Burdur, Seyhan, Batı Akdeniz, Konya, Susurluk, Sakarya, Akarçay, Fırat Dicle, and Asi basins from Turkey.

In conclusion, 9 new records were added to the freshwater algal flora of Turkey with this study. It was observed that these taxa were distributed in different regions in the world. The number of new records for the algal flora of Turkey is expected to increase in the future.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Türkiye'deki 25 Nehir Havzasından Türkiye Tatlı Su Alg Florası İçin Yeni Kayıtlar, Bölüm V: Cryptophyta

Su kaynaklarının dengeli kullanımı ve korunmasını amaçlayan Su Çerçeve Direktifi (SÇD) biyolojik kalite bileşenlerinden birisi olan fitoplanktonu biyolojik izleme çalışmalarında biyolojik kalite unsuru olarak kabul etmektedir. Su Çerçeve Direktifi ile, fiziksel ve kimyasal verilerin su kütlesinin kalitesinin belirlenmesinde yeterli olmayacağı, asıl belirleyici etmenlerden birisi olarak sucul floranın izlenmesi gerektiği belirtilmektedir. Bu konuda yapılan taksonomik ve ekolojik çalışmaların sayısı Türkiye'de her geçen gün artmaktadır. Bu amaçla Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü (SYGM) ve Devlet Su İşleri (DSİ) tarafından gerçekleştirilen çok sayıda proje bulunmaktadır. "Türkiye'de Referans İzleme Ağının Kurulması" projesinin bir parçası olan bu araştırma Su Yönetimi Genel Müdürlüğü tarafından desteklenmiştir. Tamamlanan bu projede 25 nehir havzasında 275 göl çalışılmıştır ve toplam 1363 fitoplankton taksonu tespit edilmiştir. Çalışmada toplam 24 Cryptophyta taksonu tanımlanmıştır. Tespit edilen Cryptophya taksonlarından 9 tanesi Türkiye'nin tatlı su alg florası için yeni kayıt olarak sunulmuştur.

AB Su Çerçeve Direktifi'ne göre biyolojik kalite unsurlarından biri olan fitoplankton konusunda Türkiye'de her geçen gün artan sayıda taksonomik ve ekolojik çalışma bulunmaktadır. Bu çalışma, Cryptophyta grubunun taksonomisini ve biyolojik çeşitliliğini incelemek amacıyla, Türkiye'nin 25 nehir havzasında yer alan 275 gölde 2017-2019 yılları arasında gerçekleştirilmiştir. Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü tarafından mali ve teknik olarak desteklenen "Türkiye'de Referans İzleme Ağının Kurulması" başlıklı projenin dördüncü bölümüdür. Göl yüzey alanı 50 hektardan küçük göller için bir, 50 ve 500 hektar arası olan göller için iki, 500 hektardan büyük göller için üç örnekleme istasyonu seçilmiştir. Her gölde fitoplankton, öfotik bölgenin üç derinliğinden (yüzey, orta ve alt) su örnekleyiciler ile örneklenmiş ve daha sonra bu üç derinlikten alınan su örnekleri karıştırılmıştır. Fitoplanktonun teşhis ve sayımları sayım lamlarında çökeltilmiş asetik Lugol solüsyonunda korunan örnekler üzerinde ışık ve ters mikroskoplar kullanılarak gerçekleştirilmiştir. Alg taksonları, veri tabanlarından sinonim durumları ve sistematik kategorileri kontrol edilerek sınıflandırılmıştır. Tespit edilen taksonlar güncel literatürdeki takson kayıt listesi ile karşılaştırılarak yeni kayıt olarak tanımlanmıştır.

Ehrenberg'in bilinen ilk gözlemleri yapmasının üzerinden yaklaşık iki yüzyıl geçmiştir. Kriptomonadlar, tüm su habitatlarında genellikle çok yüksek populasyon yoğunluklarında bulunan bir gruptur. Şimdiye kadar dünya genelinde yapılan çalışmalarda 21 genusa ait 223 Cryptophyta taksonu tanımlanmıştır. Bu çalışmada, teşhis edilen 24 türden 9 tür yeni kayıt olarak tanımlanmıştır. Cryptophyta divizyosunda bulunan taksonlar Chroomonas (1), Cryptochrysis (1), Cryptomonas (4) Pyrenomonas (1) and Rhodomonas (2) cinsleri içinde dağılım göstermiştir. Daha önce ülkemizde yapılan çalışmalarda Chroomonas cinsine ait 7, Cryptomomas cinsine ait 11, Rhodomonas cinsine ait 2 tür belirlenmiştir. Bu çalışma ile ilk defa Cryptochrysis ve Pyrenomonas cinslerine ait 2 tür Türkiye alg florası olarak yeni kayıt olarak belirlenmiştir.

Kriptomonadlar tek hücreli, pigmentli, küçük (~5–50 μm) biflagellatlı tatlı, acı ve denizel habitatlarda yayılış gösteren organizmalardır. Belirgin bir hücresel asimetri ile karakterize edilirler, bir ön oluk veya cep ile şekil olarak düzleştirilmiştir. Cebin kenarında tipik olarak iki tane eşit

olmayan flagella vardır. Kriptomonadların hem bitki benzeri hem de hayvan benzeri özellikler sergilediği göz önüne alındığında, taksonomileri tartışmalıdır ve bazı türler alglerden ziyade protozoalar olarak kabul edilir. Tüm aquatik habitatlarda yaygın olarak bulunmaları nedeniyle küresel olarak büyük ilgi görmektedir. Bu organizmalar sakin, iyi aydınlanan ve besin açısından zengin yaz koşullarından serin, karışık ve ışıkla sınırlı kış koşullarına kadar çok çeşitli çevresel koşullara uyum sağlayabilir. Bu sınıfın üyeleri daha çok tatlı su ortamlarında tespit edilseler de denizel habitatlarda, karasal yüzeylerde, toprakta, yeraltı suyunda ve karda da yayılış gösterebildiği bilinmektedir. Cryptophyta grubu, besin maddeleri ve organik madde bakımından zengin sular için tipik olduklarından geniş bir çevre spektrumuna sahiptirler. Ancak oligotrofik suları tercih eden türleri de bulunmaktadır. Bazı türleri, uygun koşullar altında aşırı çoğalmalar gösterirler, ancak toksik olup olmadıkları bilinmemektedir. Bazı cryptomonad türleri göl tabanına yakın oksik/ anoksik sınır tabakasını (kemoklin) tercih edebilmektedir. Bu şartlarda *Cryptomonas phaseolus* türünün kemoklin yakınlarında düşük ışık şiddetinde bulunabildiği tespit edilmiştir. Aynı türün amonyumu çok yüksek olduğu oligotrofik sularda da yayılış gösterdiği bilinmektedir. Yapılan araştırmada da yeni kayıt olarak tespit edilen bu türün ekolojik toleransının yüksek olduğu anlaşılmaktadır.

Tespit edilen taksonların büyük çoğunluğunun Avrupa'da dağılım gösterdiği görülmektedir. Bunun yanısıra Asya, Kuzey Amerika, Güney Amerika'da da yayış gösterdikleri tespit edilmiştir. Türkiye'de ise bu taksonlar Kızılırmak, Burdur, Seyhan, Batı Akdeniz, Konya, Susurluk, Sakarya, Akarçay, Fırat Dicle, and Asi havzalarında kayıt edilmiştir.

Cryptophyta grubunun taksonomisini ve biyolojik çeşitliliğini incelemek amacıyla yapılan bu çalışma ile Türkiye tatlı su alg florasına 9 yeni kayıt eklenmiştir. Ayrıca 2 cinse ait tür bu çalışmada ilk defa tayin edilerek Türkiye tatlı su alg florasına sunulmuştur. Bu taksonların dünyanın farklı bölgelerinde de dağılım gösterdikleri tespit edilmiştir. Cryptomonad türleri kavramının gelecekteki gelişimi ve dayandığı taksonomi, gelişen bilim ve teknoloji, ekolojik ve moleküler genetik çalışmalarının sayısının artışıyla ilerleyen yıllarda yapılacak çalışmalarla Türkiye alg florası için yeni kayıtların sayısının artması beklenmektedir.

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Research Article

Minimizing Greenhouse Gas Emissions from a Horizontal Subsurface Flow Constructed Wetland

Bir Yatay Yüzey Altı Akışlı Yapay Sulak Alanın Sera Gazı Emisyonlarının Minimizasyonu

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Abstract

In this study, the level of carbon dioxide, methane and nitrous oxide emissions from a horizontal subsurface flow constructed wetland were monitored and greenhouse gas emissions were estimated by using a newly developed model. The effects of three different plant species on greenhouse gas emissions were investigated. *Cyperus esculentus* (Zone I), *Typha latifolia* (Zone II) and *Phragmites australis* (Zone III) were selected as the experimental species. Greenhouse gas emissions were sampled twelve times totally by using the closed chamber method between January and December. The highest level of emission was measured for nitrous oxide emission, released from Zone I in August (10,8371 kg CO_2e/d). The lowest level of emission was measured for carbon dioxide emission (0,0156 kg CO_2e/d) at Zone III in January. The results revealed that *Cyperus esculentus* has the highest greenhouse gas emission and the highest Global Warming Potential. All greenhouse gas emissions were influenced from different plant species. *Phragmites australis* could be used for minimizing the level of greenhouse gas emissions as it has the lowest level of greenhouse gas emission and Global Warming Potential. Finally, the possible level of greenhouse gas emission is estimated by using Monte Carlo simulation if the wetland is vegetated with only *Phragmites australis*. Approximately 33% of greenhouse gas emissions could be reduced if the wetland is vegetated only *with Phragmites australis*.

Keywords: *Horizontal subsurface flow constructed wetland, greenhouse gas emission, the effects of plants*

Öz

Bu çalışmada, bir yatay yüzey altı akışlı yapay sulak alanda oluşan karbon dioksit , metan ve nitröz oksit emisyonları izlenmiş ve yeni geliştirilen bir model kullanılarak sera gazı emisyonları tahmin edilmiştir. Üç farklı bitki türünün sera gazı (SG) emisyonları üzerindeki etkisi araştırılmıştır. Deneysel türler olarak *Cyperus esculentus* (Bölge I), *Typha latifolia* (Bölge II) ve *Phragmites australis* (Bölge III) seçilmiştir. Gaz örneklemesi, Ocak-Aralık ayları arasında kapalı çember yöntemi ile toplamda on iki kez gerçekleştirilmiştir. En yüksek emisyon, Ağustos ayında Bölge I'den salınan

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N_2O emisyonudur (10,8371 kg CO_2e/d). En düşük emisyon Ocak ayında III. Bölge'deki CO_2 emisyonudur (0,0156 kg CO_2e /d). Sonuçlar, Cyperus esculentus'un en yüksek sera gazı emisyonuna ve en yüksek küresel ısınma postansiyeline sahip olduğunu ortaya koymaktadır. Phragmites australis, en düşük sera gazı emisyonuna ve en düşük küresel ısınma potansiyeline sahip bitki olarak kullanılabilir. Tüm sera gazı emisyonları farklı bitki türlerinden etkilenmiştir. Phragmites australis düşük sera gazı emisyonu yayması ve küresel ısınma potansiyeli nedeniyle sera gazı emisyonunu azaltmak için kullanılabilir. Son olarak, sulak alan sadece Phragmites australis ile bitkilendirilmesi durumu için, olası sera gazı emisyonu Monte Carlo simülasyonu kullanılarak tahmin edilmiştir. Sulak alan sadece Phragmites australisle bitkilendirilmiş olsaydı, sera gazı emisyonlarında yaklaşık % 33 azalma elde edilebileceği görülmüştür.

Anahtar kelimeler: *Yatay yüzey altı akışlı yapay sulak alan, sera gazı emisyonu, bitkilerin etkisi*

Introduction

It is an economical method to use aquatic plants for wastewater treatment, especially where the land is abundant and therefore cheap. In addition, eutrophication could be prevented by installing such systems in the lakes and wetlands (Metcalf & Eddy, 2014). It is possible to collect aquatic plants, used in wastewater treatment, in three groups as submerged aquatic plants, rooted water plants and floating aquatic plants. Especially, wetlands which are regarded as the rooted water plants systems are commonly used for wastewater treatment. There are several constructed wetlands applications in Turkey as wastewater treatment systems.

Natural treatment systems such as constructed wetland could be more applicable, feasible, and also they have many advantages due to low cost and effective pollutant removal mechanisms (Metcalf & Eddy, 2014). Constructed wetlands are regarded as a low cost and sustainable system to treat different types of wastewater. In addition to municipal wastewater, agricultural, industrial and leachate could be treated by constructed wetlands. Vegetation in wetlands disposes pollutants from wastewater by plant uptake and harvesting. Vegetation in wetlands could be influenced by temperature and influent wastewater quality (Martinez-Guerrae et al., 2015). The treatment of wastewater in constructed wetlands is mainly based on microbial degradation of pollution in the wastewater [organic matter is decomposed to gases mostly carbon dioxide (CO_2) and methane (CH_4), nitrogen is transformed to gaseous compounds nitrous oxide (N_2O) and these gases are emitted to the atmosphere.].

The advantage of constructed wetlands as compared to conventional treatment systems is low operation and maintenance costs. In addition to nutrient removal, greenhouse gas emissions are emitted from constructed wetlands. Despite many advantages, constructed wetland releases significant amount of greenhouse gases which are formed under anoxic condition of flooded area. The greenhouse gases from constructed wetlands also have a seasonal and temporal diversity resulting from the microbial processes (Chiemchaisri et al., 2009).

Greenhouse gas emissions from wastewater treatment process have been considered as an important environmental challenge by the authorities in recent years (Kyung et al., 2015; Gülşen & Yapıcıoğlu, 2019). Wastewater treatment plants are released three main greenhouse gases which are CO_2, CH_4 and nitrous oxide N_2O due to treatment process, sludge handling and stabilization process, chemical use, energy consumption and maintenance and repair activities (Rodriguez-Caballero et al., 2014; Kyung et al., 2015). Greenhouse gas emissions can be categorized as on-site emissions and off-site emissions (Paravicini et al., 2016). On-site greenhouse gas emissions are those: 1) released in the sewage collection system, 2) resulted from wastewater treatment processes and 3) where the effluent is discharged. Off-site greenhouse gas emissions are occurred by the electricity consumption, air consumption, transportation, chemical use and disposal and reuse processes (Paravicini et al., 2016).

Constructed wetlands are regarded as one of the wastewater treatment units which significantly emit greenhouse gas emissions (Mander et al., 2014). Especially, CO_2, CH_4 and N_2O emissions are emitted from constructed wetlands (Mander et al., 2014) due to treatment process. There are many factors on greenhouse gas emission reduction in constructed wetlands. The impact of plant species diversity on greenhouse gas emissions has gained much significance (Han et al., 2019). Plants species can vary greatly in the vegetation, consumption, and transport of CO_2, CH_4 and N_2O (Han et al., 2019). These variations are majorly defined by anatomical characteristics of species (Han et al., 2019). Plant species diversity could reduce CO_2, CH_4 and N_2O emissions by enhancing nitrogen uptake and carbon capture. CO_2 could be minimized due to photosynthesis. However, several studies have demonstrated that plant species diversity increases the amount of CH_4 and N_2O emissions due to plant species with aerenchyma (Zhang et al., 2012; Chang et al., 2014), while some studies have reported that CH_4 and N_2O emissions have not been affected by species diversity (Abalos et al., 2014; Zhao et al., 2016).

In this study, it is aimed to reveal the effects of different plant species on greenhouse gas emissions from a horizontal subsurface flow constructed wetland in Turkey. CO_2, CH_4 and N_2O emissions from a horizontal subsurface flow constructed wetland are observed twelve times in total using closed chamber method. Also, global warming potential (GWP) of the plant species are determined using Life Cycle

Assessment (LCA) approach considering all GHG emissions. A new developed model based on Intergovernmental Panel on Climate Change (IPCC) method is used to estimate the GHG emissions. The novelty of this study is that a new GHG emission estimation tool is developed for the constructed wetlands. The constructed wetland is divided into 3 zones. *Cyperus esculentus* (Zone I), *Typha latifolia* (Zone II) and *Phragmites australis* (Zone III) are planted as the vegetation species. The originality of this work is that the effects of *Cyperus esculentus, Typha latifolia and Phragmites australis* on GHG emissions are determined in terms of CO_2, CH_4 and N_2O emission for a horizontal subsurface flow constructed wetland. Apart from the studies in the literature, not only CH_4 and N_2O emissions but also CO_2 emission is considered in this paper for these three species using a new developed GHG estimation tool. The other originality of this study, the GHG originated from *Cyperus esculentus* and *other plants* were estimated for a full-scale horizontal subsurface flow constructed wetland. Also, one of the originalities of this work is that LCA methodology is carried out for the determination of global warming potentials related to plant species based on in situ GHG monitoring results. LCA is a method to categorize the effects corresponded with all the phases of a product, service, or process from cradle to grave. LCA is implemented for a product of a process in general; this methodology could be also applied to the environmental impact assessment of a wastewater treatment process.

In the final stage of the study, possible GHG emission was determined using Monte Carlo simulation if Zones (I-II) were vegetated with the plant species which released the lowest GHG emission. The other originality of this work was that Monte Carlo simulation was applied to simulate the possible GHG emission if all zones were vegetated with the plant species which has the lowest global warming potential.

Method

Description of the Study Area

The constructed wetland was built on nearly 0,2-hectare land in the southeastern of Turkey and by the Tigris River. It is a type of horizontal subsurface flow constructed wetland. Clay material was used to seal wetland chamber. In the artificial wetland reservoirs, sieved-washed stream pebbles and circulating stream material were used as bed fill material. The municipal wastewater originated from a village near the Tigris River was treated in this constructed wetland. The influent wastewater characterization was given in Table 1. Wastewater analyses were performed according to the standard methods (American Public Health Association [APHA], 1998).

Table 1

Influent Characterization of the Municipal Wastewater

Parameter	Value
COD (mg/L)	203,2 – 1401,2
TSS (mg/L)	40 – 200
BOD (mg/L)	80,8 – 800,3
TKN (mg/L)	66-75
pH	6,5-7,5
Flow rate (m^3/d)	400-450

**COD: Chemical Oxygen Demand;*TSS: Total Suspended Soils; *BOD: Biochemical Oxygen Demand; *TKN: Total Kjeldahl Nitrogen*

Figure 1 demonstrated the wastewater treatment flow scheme in the constructed wetland. Influent is fed and flows through the porous media under the surface of the bed planted with emergent vegetation to the outlet, where it is collected before leaving via a water level in horizontal subsurface flow constructed wetland. There are 3 vertical flow filtration beds on the wetland. Equalization tank is used as preliminary treatment before the wetland. The constructed wetland has 60 cm of water depth, about 42 m^2 of cross-sectional area, 70 m of length and 40,6 m of width. The surface area of the constructed wetland is approximately 2.842 m^2. The volume of the constructed wetland is about 1.705 m^3.

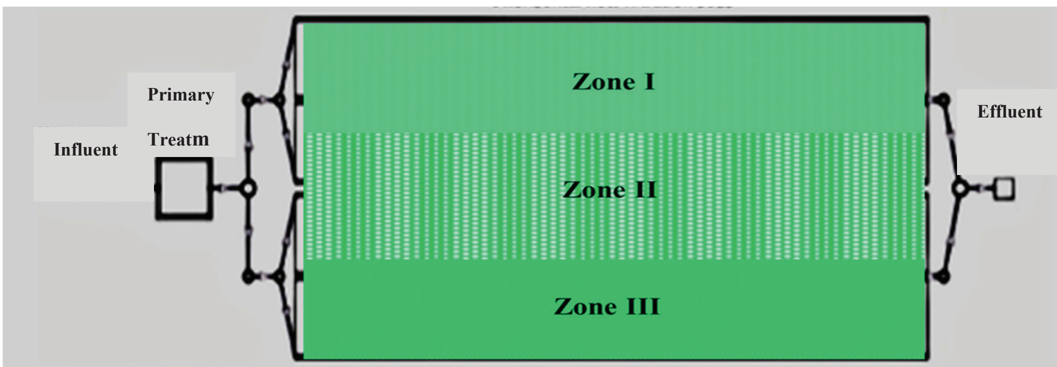
There are 3 zones at the wetland. The zones contain three different vegetation. Planting area is with a depth of 20 cm in bed. Harvesting beds are prepared to be at least 14 m^2 of cross-sectional area.

Plant Species at Horizontal Subsurface Flow Constructed Wetland

Three common plants, *Cyperus esculentus*, *Typha latifolia* and *Phragmites australis* were selected as the experimental species in this study. The reason of selecting these plants was that they are obtained easily in Turkey and can grow well in this system. These species are categorized under the group of rooted and float plants. These plants are also resistant to sunny and arid areas. They can survive at fresh water.

Figure 1

Wastewater Treatment Process Flow Diagram of Constructed Wetland

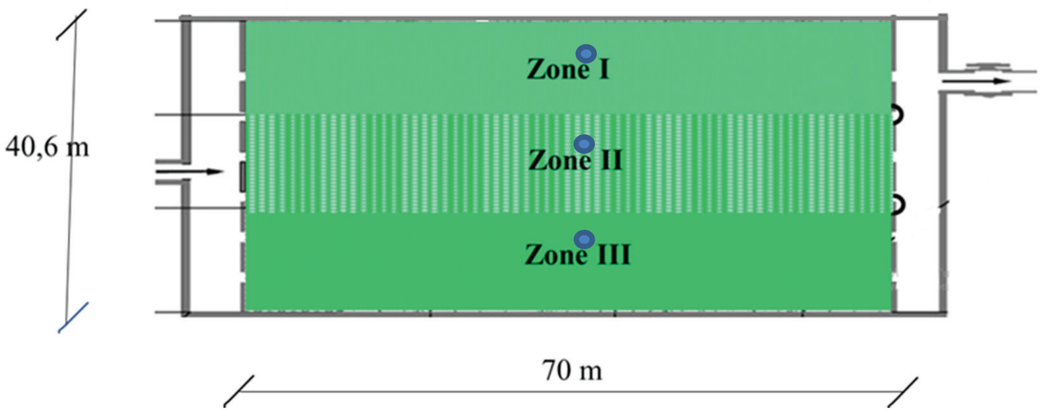


Cyperus esculentus, *Typha latifolia*, and *Phragmites australis* were from Adana, Sakarya and Hatay respectively. These plants were obtained and picked from the nature by the researchers. There is no need for the permission of picking the plants. The wetland was divided into three main regions. Zone I majorly contains *Cyperus esculentus*. *Typha latifolia* is the dominant species at Zone II. Zone III contains mostly *Phragmites australis*. Figure 2 demonstrates the plant zones that contain the plan of the constructed wetland. GHG emission sampling points are the Zone I, Zone II, and Zone III. The surface areas of the zones are equal whose values are about 947.3 m^2. *Cyperus esculentus*, *Typha latifolia* and *Phragmites australis* are under classification of the submerged plant species. All of them are young plants.

These three plant species were planted in spring according to the characteristics of the species before the measurement. All plant species were the same age and one years old. These plant species were harvested in winter. Some plant analyses were applied to determine the dominant plant in the wastewater.

Figure 2

Plant Zones and GHG Monitoring Points of Constructed Wetland in The Plan



Note. GHG Emission Monitoring Point.

Closed Chamber Method and Gas Sampling

Several emission monitoring methods have been developed for WWTPs such as open chamber method, closed chamber method and static chamber method (Masuda et al., 2015). The closed chamber gas measurement method is one of the methods of measurement and determination of greenhouse gases worldwide for wastewater treatment. The closed chamber method was applied to measure the emissions from the constructed wetland. The closed chamber had a cross-sectional area of 0,118 m^2 and the volume of 25 L. It consisted of a portable top and a round Styrofoam base. The gas was pumped into this chamber and collected for 30 min. The gas analyzer was placed in the pump. Drager Polytron fixed 605 multi-gas analyzer was used to determine the GHG concentrations. The optimum gas retention time was assigned as 30 minutes due to observing no increase in the gas concentration in the end of 30 minutes. The gas flux (F) can be considered as the volume of the closed chamber. F was approximately 1,2 m^3/d (it has been figured out using the volume of the closed chamber and the gas retention time). The same closed chamber was used for all zones and 3 plant species. The same gas monitoring method was applied for all zones and plant species. All zones were monitored the same day and respectively. The monitoring points of 3 zones were the top of the zones. The GHG monitoring points were shown in Figure 2. All gas samplings were carried out from the same point.

Gas sampling was performed using the closed emission chamber for each zone. Each zone has been monitored twelve times totally (Zone I-III) between January and December, from the same points. CO_2, CH_4 and N_2O gas concentrations were determined using Drager Polytron fixed 605 multi-gas analyzer.

Estimation of Greenhouse Gas Emission

GHG emissions were determined from F (m^3/d) and gas concentrations in the closed chamber. GHG concentration (mg/m^3) (C_{GHG}) was determined using Drager Polytron fixed multi-gas analyzer. GHG concentration (mg/m^3) was multiplied with F (1,2 m^3/d). GHG emissions were converted to CO_2-equivalent emissions by multiplying GWP of each gas (Intergovernmental Panel on Climate Change [IPCC], 2014). GWP of CO_2, CH_4 and N_2O are 1, 28 and 265 respectively. Equation 1 shows the calculation of GHG emission.

$$GHG\ (kgCO_2e/d) = [(F \times C_{GHG}) / 1000000)] \times GWP \qquad (1)$$

Determination of Global Warming Potential

LCA enables for a better assessment of wastewater treatment technologies in several different approaches. Due to its holistic approach, LCA is regarded as an increasingly crucial decision-making tool in environmental issues (Büyükkamacı & Gökçe, 2017). In this study, the LCA was carried out using GaBi 6.1 Software Thinkstep, Germany. The CML 2001 impact assessment method was used to determine the GWP of the three plant species. The required data for the software was ensured from the GHG monitoring results of the closed chamber and the Eco-invent database, which is integrated into the GaBi 6.1 software. GaBi software run according to a designed flow diagram and defined inputs and outputs. The system boundary defines which inputs and outputs contain. Electricity consumption and chemical use were ignored in this study due to belonging a natural treatment system. The inputs of this study are mainly treated wastewater characterization and wastewater treatment efficiency. The variables were influent and effluent BOD, COD and TKN concentrations. The outputs were N_2O, CH_4 and CO_2 emissions. The main function of this study is to determine the global warming potential of the *Cyperus esculentus, Typha latifolia* and *Phragmites australis* at a horizontal subsurface flow constructed wetland.

Simulation of the GHG Emissions

In the final stage of the study, possible GHG emission was simulated using Monte Carlo simulation if Zones (I, II) were vegetated with the plant species which released the lowest GHG emission. Monte Carlo simulation was used to simulate all GHG emissions related to Zones (I, II) if all zones were vegetated with the plant species which has the lowest global warming potential.

Monte Carlo simulation has been developed based on computational algorithms that contain repeated random sampling to ensure numerical results. This simulation is applied in physical and mathematical problems in general. Monte Carlo simulation is majorly used in optimization, numerical integration, and generating draws from a probability distribution (Kroese et al., 2014). Monte Carlo Simulation is a mathematical technique that produces random variables to determine the risk or uncertainty of a certain system or in order to optimize the variables. @RISK software was used to perform Monte Carlo simulation. Volumetric Reserves 1-Basic @RISK model, 1000 iterations and 1 simulation were performed for this study. Lognormal distribution was selected as the probability distribution. As uncertain inputs were CO_2, CH_4 and N_2O emissions related to each zone, the outputs were the minimum total GHG emission related to *Phragmites australis*. Therefore, the GHG emissions corresponded to Zone (I-III) were simulated to the lowest GHG emission related to *Phragmites australis.* Equation 2 illustrated the calculation of possible minimum GHG emission.

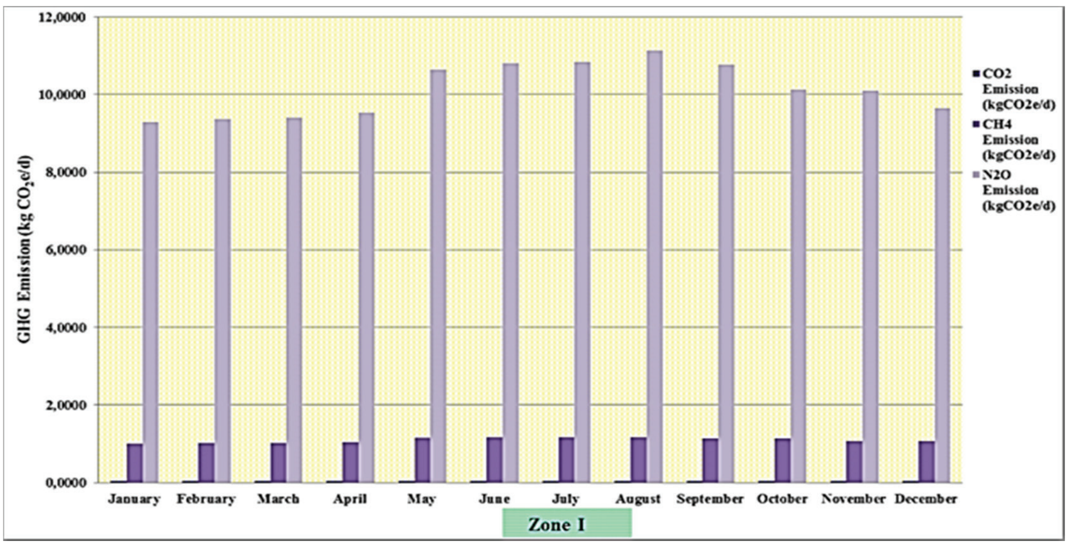
E_{min}= RiskOutput("Lognormal")+RiskLognorm(Z_1;Z_2) (2)
E_{min} = Possible minimum GHG emission
Z_1= Sum of CO_2, CH_4 and N_2O emissions related to Zone (I-III)
Z_2= Total greenhouse gas emission value related to *Phragmites australis*

Results and Discussion

Figure 3 demonstrated the monthly variation of GHG emissions. According to the findings, the highest emission was N_2O emission and the lowest emission was CO_2 emission. The highest GHG emissions were monitored in January in winter and the lowest GHG emissions were monitored in August in summer.

Figure 3

Monthly Variation of GHG Emissions



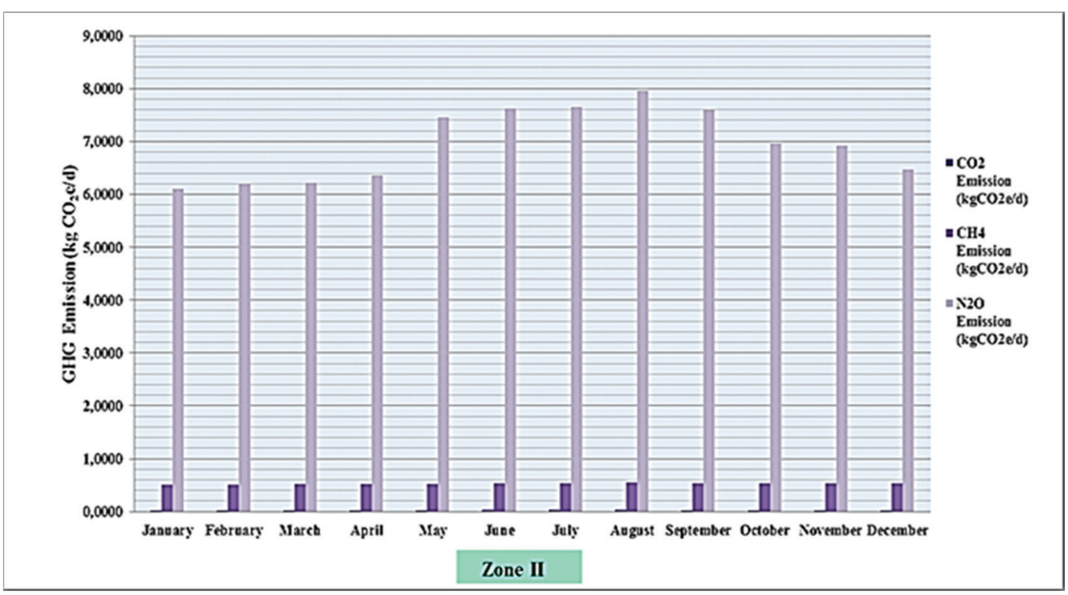
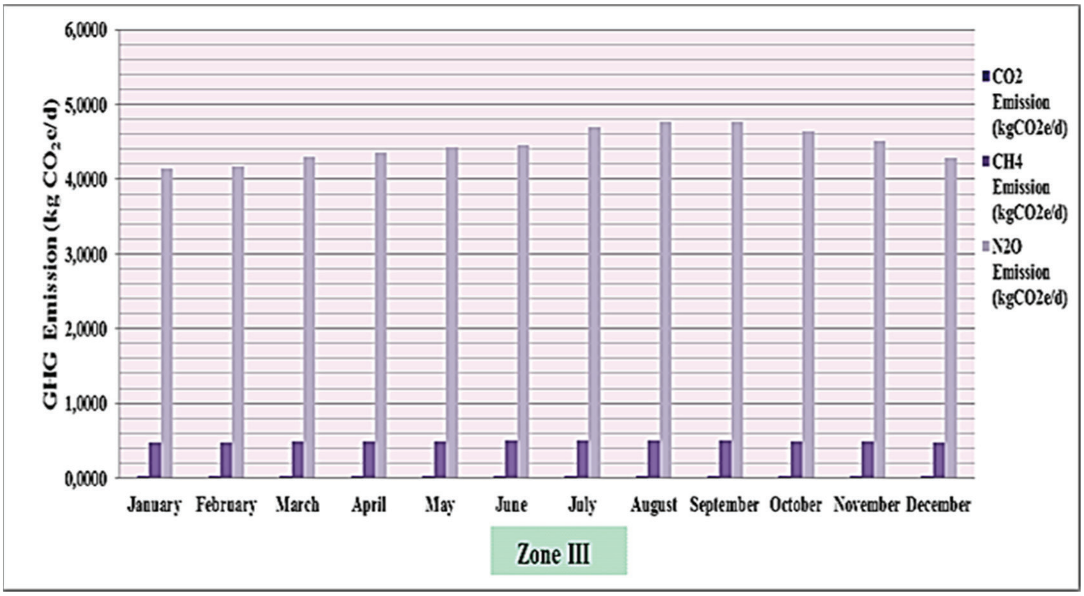


Figure 3

(Continued)



Results of N_2O Emissions Monitoring

Excess nutrients mainly from anthropogenic sources have been demonstrated significantly increase N_2O emissions from wetland soils through denitrification and nitrification processes. The results revealed that N_2O emission was the major GHG emission from each zone of horizontal subsurface flow constructed wetland in Turkey. It could be originated from the high efficiency of nutrient (nitrogen) removal. Table 2 shows the effluent characterization of the municipal wastewater. It could be said that N_2O emissions positive correlated to TKN concentrations in influent. Influent TKN concentration could increase N_2O emission. In August, at the peak concentration of TKN (85 mg/L), the highest N_2O emission was observed.

Table 3 shows the N_2O emission monitoring results. According to the findings, the highest N_2O emission was released from Zone 1 in August with the value of 11,1367 kg CO_2e/d. It could be considered that N_2O emission would have peak value in summer. The lowest N_2O emission whose value is 4,1356 kg CO_2e/d related to Zone 3 was monitored in January. The minimum nutrient removal rate and the low temperature could be effective on this result.

In the literature, similar results have been obtained by the several researchers on this topic. Han et al. (2019) investigated the influence of plant diversity on greenhouse gas emissions for a vertical constructed wetland. They reported similarly that N_2O emissions parallelly correlated to TKN concentrations in effluent. In this study, similar results were monitored. Recent studies have demonstrated that N_2O can be generated due to several chemical and biochemical processes during nitrification and denitrification. Under aerobic conditions, N_2O production resulting from nitrifier denitrification has been described as the major generation mechanism (Aboobakar et al., 2013). Mander et al. (2014) reported that all of the constructed wetland types demonstrated a significant positive correlation between the inflow TKN loading and N_2O emission values. Mander et al. (2008), Teiter and Mander (2005) and Sovik et al. (2006) monitored N_2O emission from the horizontal subsurface flow constructed wetlands treating domestic wastewater in the range of 0,04-3,01 mg m^{-2} h^{-1}. Van der Zaag et al. (2010) found the N_2O emission as 0.396 mg m^{-2} h^{-1} for *Typha latifolia*. Liu et al. (2009) reported N_2O emission as 0.4 mg m^{-2} h^{-1} for *Phragmites australis*. In contrast with this study, Ruckauf et al. (2004) demonstrated in lab-scale study that Phragmites plants significantly enhanced N_2O emission. Xu et al. (2014) investigated the seasonal variation of GHG emissions from a coastal saline wetland in China. They similarly reported that the highest N_2O emission was monitored in summer and the lowest N_2O emission was monitored in winter. Hernández et al. (2018) performed a similar study. They found that N_2O emissions ranged from 3 to 150 mg m^{-2} d^{-1} with the peak of emission during autumn. Nitrous oxide is generated in the result of nitrification at the aerobic zones and resulting from denitrification at the anoxic zones. From this point of view, it could be said that Zone I has the largest aerobic zones and anoxic zones than the other zones. Also, it could be considered that methane oxidizing bacteria can also be a major player in producing N_2O (Metcalf & Eddy, 2014) especially where methane and nitrogen are abundant.

Results of CH_4 Emissions Monitoring

The horizontal subsurface flow constructed wetlands are one of the significant resources of CH_4 emissions. CH_4 emission could be released from anaerobic zones. CH_4 emissions related to Zone I-III were given in Table 4. According to monitoring results, N_2O emissions were higher than CH_4 emission due to nitrogen uptake of the plants at all zones. CH_4 emissions were higher than CO_2 emissions due to carbon capture of the plants. The highest CH_4 emission was released from Zone I in July. Its value was 1,1781 kg CO_2e/d. The lowest emission was occurred in Zone III in January similar with N_2O emission with the value of 0,4704 kg CO_2e/d. The minimum emission was observed in winter. It could be originated from the low temperatures inhibited the activity of anaerobic bacteria and promoted CH_4 oxidation. From this point of view, it could be said that anaerobic zones and microbial growth (algal growth) could be present much more than other zones. Also, oxygen transfer could be poor in Zone I compared with the other zones.

CH_4 emissions from constructed wetlands were investigated by many researchers. Xu et al. (2014) reported CH_4 fluxes averaged from -0.368 to 4.959 mg CH_4 m^{-2} h^{-1}. They observed the highest emission in autumn. In this study, the highest emission was monitored in summer. It could be originated from those high temperatures enhanced the activities of anaerobic methanogens. A study by Han et al. (2019) was reported that CH_4 emissions ranged between 0,254-0,785 μg/m^2 /day for a lab-scale vertical flow constructed wetland. Chen et al. (2013) similarly investigated CH_4 emission from Yellow River delta wetland. Hernández et al. (2018) reported that 0,71-0,75 mg/m^2 h. conducted a similar study. Methane emission in constructed wetland mesocosms ranged from 0 to 2100 mg/m d, with higher emissions observed at surface flow constructed wetland. Similar with this study, the peaks of methane emission were observed in summer (July-August).

In Table 2, influent carbon concentration in terms of BOD and COD could be seen. It can be said that low organic content wastewater generates low CH_4 emissions. When the low carbon concentration was monitored in January, the lowest CH_4 emission was measured (COD=203,2 mg/L, BOD=80,8 mg/L).

Results of CO_2 Emissions Monitoring

Constructed wetlands play a crucial role on global balance of the major greenhouse gases which are CO_2 and CH_4. They play an important role as a buffer for CO_2 by photosynthetic assimilation and carbon sequestration in the wastewater. A net carbon flux is observed as a result from carbon uptake from the atmosphere by photosynthesis and its release because of decomposition of organic materials at constructed wetlands. Both the rates of carbon uptake and decomposition are affected by climate, nutrient concentrations, water saturation and oxygen availability. In aerobic conditions, decomposition emits CO_2 and CH_4 emissions dominate in anaerobic conditions (IPCC, 2006). Also, CO_2 uptake from atmosphere and dissolved CO_2 from wastewater might be achieved due to photosynthesis. In this study, minor amounts of CO_2 were released from this horizontal subsurface flow constructed wetland. Table 5 shows CO_2 emissions from the wetland. The lowest CO_2 emission was monitored in Zone III with the value of 0,0156 kg CO_2e/d in January. The highest CO_2 emission (0,0363 kg CO_2e/d) was monitored in Zone I in August. CO_2 emission could be originated from the respiration of the microbial community in the constructed wetland. The aerobic microorganisms would be more active in summer. In a study by Chen et al. (2013) investigated the greenhouse gas emission from a wetland. Similar with this study, they found that CH_4 emissions were higher than CO_2 emission. They reported that it could be concluded that CO_2 emission was enhanced by personal activities. Xu et al. (2014) similarly observed higher CO_2 emissions during the summer and autumn seasons. In the literature, CO_2 emission was ignored due to low global warming potential by many researchers.

From Table 2, it could be said that the highest CO_2 emission was released in August in the day of the high effluent BOD and COD concentration. In parallel, the lowest CO_2 emission was generated at the monitoring day of the lowest effluent in terms of COD and BOD concentration.

Effect of Different Plant Species on GHG Emissions

In this study, the effect of *Cyperus esculentus, Typha latifolia* and *Phragmites australis* on GHG emission were investigated. It could be said that N_2O, CO_2 and CH_4 emissions were affected by plant diversity. *Phragmites australis* released the lowest CO_2, CH_4 and N_2O emissions. From this point of view, it could be said that *Phragmites australis* is the best for carbon capture, CH_4 adsorption and N_2O uptake. The results also show that communities with *Phragmites australis* could obtain higher nitrogen removal and lower greenhouse gas emissions than other wetland vegetation. *Phragmites australis* has negative effect on GHG emissions.

Cyperus esculentus is the supply of the highest CO_2, CH_4 and N_2O emission. *Cyperus esculentus* released the largest GHG emission in the wetland. *Typha latifolia* follows it in terms of N_2O and CO_2 emission. Figures (4-6) shows the monthly change of GHG emissions on a plant basis.

Table 2

Influent Characterization at Monitoring Day

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
COD (mg/L)	203.2	440	678	785	888	925	1259	1401,2	1000	645	325	295
BOD (mg/L)	80,8	95	289	380	445	525	690	800,3	603	368	154	101
TKN (mg/L)	66	67	69	70	72	75,5	78	85	83	80	79	69

Table 3

N_2O Emission Monitoring Results

	N_2O Emission (kg CO_2e/d)											
Monitoring Point	January	February	March	April	May	June	July	August	September	October	November	December
Zone I (*Cyperus esculentus*)	9,2859	9,3641	9,3991	9,5359	10,6390	10,8079	10,8371	11,1367	10,7802	10,1375	10,1041	9,6462
Zone II (*Typha latifolia*)	6,1059	6,1841	6,2191	6,3559	7,4590	7,6279	7,6571	7,9567	7,6002	6,9575	6,9241	6,4662
Zone III (*Phragmites australis*)	4,1356	4,1658	4,2930	4,3566	4,4202	4,4520	4,7000	4,7700	4,7659	4,6428	4,5156	4,2860

Table 4

CH_4 Emission Monitoring Results

	CH_4 Emission (kg CO_2e/d)											
Monitoring Point	January	February	March	April	May	June	July	August	September	October	November	December
Zone I (*Cyperus esculentus*)	1,0080	1,0234	1,0300	1,0412	1,1612	1,1756	1,1781	1,1767	1,1424	1,1353	1,0757	1,0737
Zone II (*Typha latifolia*)	0,5040	0,5043	0,5201	0,5241	0,5242	0,5305	0,5373	0,5443	0,5338	0,5326	0,5309	0,5299
Zone III (*Phragmites australis*)	0,4704	0,4744	0,4898	0,4939	0,4969	0,5006	0,5037	0,5040	0,5002	0,4963	0,4937	0,4738

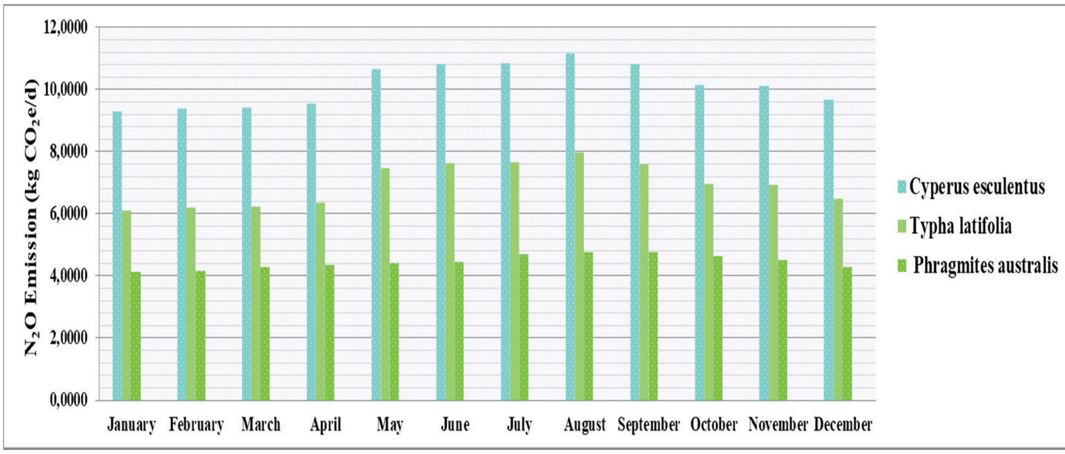
Table 5

CO_2 Emission Monitoring Results

	CO_2 Emission (kg CO_2e/d)											
Monitoring Point	January	February	March	April	May	June	July	August	September	October	November	December
Zone I (*Cyperus esculentus*)	0,0326	0,0335	0,0337	0,0348	0,0349	0,0360	0,0361	0,0363	0,0347	0,0342	0,0345	0,0336
Zone II (*Typha latifolia*)	0,0206	0,0215	0,0217	0,0228	0,0229	0,0240	0,0241	0,0243	0,0227	0,0222	0,0225	0,0216
Zone III (*Phragmites australis*)	0,0156	0,0158	0,0160	0,0161	0,0162	0,0170	0,0171	0,0173	0,0169	0,0168	0,0167	0,0159

Figure 4

Monthly Change of N_2O Emission on a Plant Basis



In this study, global warming potentials of these three plant species were determined using LCA approach. According to the results, *Cyperus esculentus* had the highest global warming potential in the wetland with the value of 3,8 kg CO_2e. *Phragmites australis* had the lowest global warming potential (GWP) in the value of 1,7 kg CO_2e. The global warming potentials of *Typha latifolia* were 2,5. Figure 7 shows the comparison of the global warming potentials. Xu et al. (2014) made the similar study on determination of global warming potential related to *mud flat, S. alterniflora flat, S. glauca flat* and *grass flat*. They used IPCC approach to determine the global warming potentials. They reported that *S. alterniflora* had the maximum global warming potential and *mud flat* had the lowest global warming potential.

Figure 5

Monthly Change of CO_2 Emission on a Plant Basis

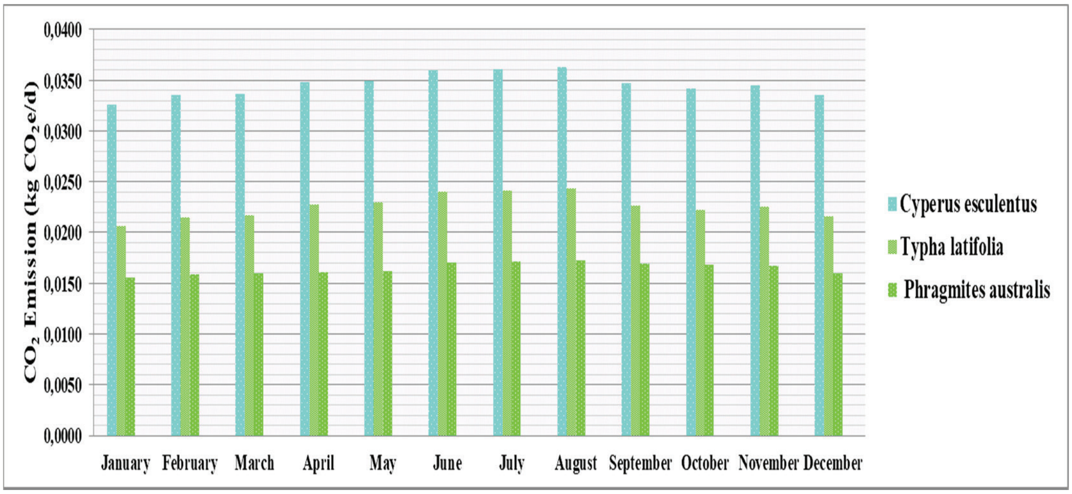
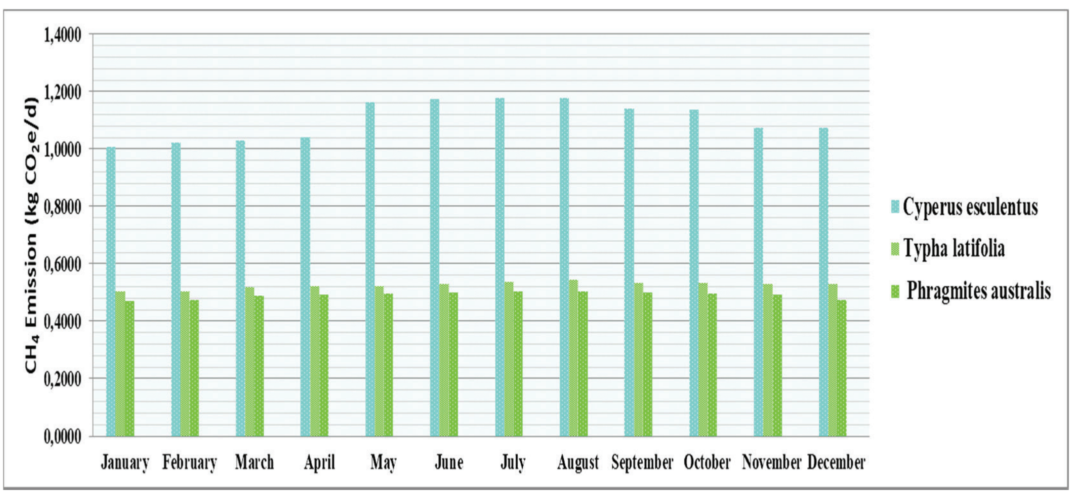


Figure 6

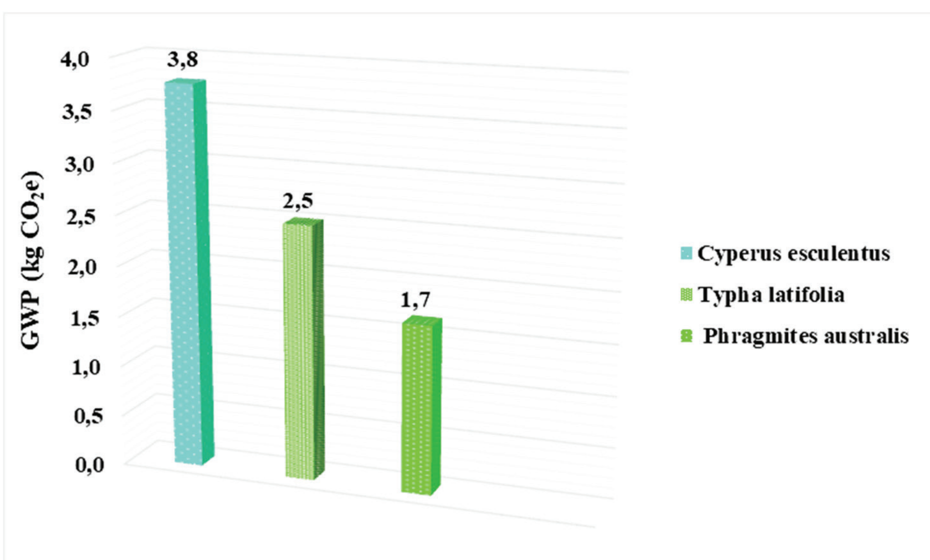
Monthly Change of CH_4 Emission on a Plant Basis



In the literature, similar studies were performed related to other different plant species. Xu et al. (2014) investigated CO_2, CH_4 and N_2O emissions of four different coastal plants which are *mud flat*, *S. alterniflora flat, S. glauca flat* and *grass flat*. They used static chamber method to monitor the GHG emissions. They reported that CH_4 and N_2O emissions were the highest in the *grass flat*, followed by the *S. alterniflora flat*. Higher CO_2 emissions were observed in the *S. alterniflora flat*. This study confirms the result of our study that plant diversity influences GHG emissions. Han et al. (2019) investigated similar influence of plant diversity on greenhouse gas emissions in a vertical constructed wetland. They also reported that the communities with *R. japonicus* presented a decrease in N_2O emissions of 62%. Hernandez et al. (2018) performed a study on greenhouse gas emissions using ornamental plants in a constructed wetland. They reported that plant density had no impact on greenhouse gas emissions in the wetlands planted with *Zhantedeshia aethiopica*. Methane emission was higher in the zones planted with *Zhantedeshia aethiopica* as compared to the zones planted with *Thypha sp* and *Cyperus papyrus*. Chen et al. (2013) investigated the mitigation of GHG emissions in regard to different types of plant species. The plant species, *Phragmites australis,* was similar with this study. The other species were *Beaches bare land, Suaeda salsa, Tamnrix chinesi* and farmland. They reported similar finding with this study that *Phragmites australis* had the lowest CO_2 emission and average CH_4 emission.

Figure 7

Global Warming Potentials of Plant Species



Greenhouse Gas Emission Reduction and Simulation Results

The originality of this work was that Monte Carlo simulation could be applied for the mitigating of GHG emission differently from the other relevant studies in the literature. Table 6 shows the simulation results. The possible GHG emissions were estimated using Monte Carlo simulation if the wetland was vegetated with only *Phragmites australis* at all zones.

Table 6

GHG Minimization Results Using Monte Carlo Simulation

Simulation Point	Total Emission ($kg\ CO_2e/d$)	Possible GHG emission ($kg\ CO_2e/d$)
Zone I	11,2758	5,9280
Zone II	7,5083	5,0337
Zone III	4,9665	4,9665
Constructed wetland	23,74	15,93

The simulation results showed that overall GHG emission minimization was reached up to 33% if *Phragmites australis* were vegetated at all zones in the horizontal subsurface flow constructed wetland.

Conclusion

This study demonstrated that *Cyperus esculentus*, *Typha latifolia* and *Phragmites australis* could have a significant impact on GHG emissions. It could be considered that N_2O, CH_4 and CO_2 emissions were affected by plant diversity. The highest N_2O emission was released in August at horizontal subsurface flow constructed wetland. The lowest CO_2 emission was observed in January in this constructed wetland. According to the results, *Cyperus esculentus* had the highest global warming potential with the value of 3,8 kg CO_2e. *Phragmites australis* had the lowest global warming potential (GWP) with the value of 1,7 kg CO_2e. The simulation results showed that overall GHG emission minimization was reached up to 33% if *Phragmites australis* were vegetated at all zones in the horizontal subsurface flow constructed wetland.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Yatay Yüzey Altı Akışlı Yapay Sulak Alanların Sera Gazı Emisyonlarının Azaltılması

Atıksu arıtma proseslerinden kaynaklanan sera gazı emisyonları, son yıllarda önemli bir çevresel sorun olarak değerlendirilmektedir (Kyung vd., 2015; Gülşen & Yapıcıoğlu 2019). Atıksu arıtma tesisleri uygulanan atıksu arıtma prosesi, çamur işleme ve stabilizasyon prosesleri, kimyasal kullanım, enerji tüketimi ve bakım ve onarım faaliyetlerinden kaynaklı karbondioksit (CO_2), metan (CH_4) ve nitröz oksit (N_2O) olmak üzere üç ana sera gazını salmaktadır. (Rodriguez-Caballero vd., 2014; Kyung vd., 2015). Yapay sulak alanlar, sera gazı emisyonlarını yayan atık su arıtma birimlerinden biri olarak kabul edilmektedir (Mander vd., 2014). Özellikle yapay sulak alanlardan; arıtma prosesi kaynaklı karbondioksit (CO_2), metan (CH_4) ve nitröz oksit (N_2O) emisyonları yayılmaktadır (Mander vd., 2014). Bununla beraber yapay sulak alanlar, son zamanlarda pek çok nedenden dolayı bir sera gazı emisyon azaltma teknolojisi olarak kabul edilmektedir. Yapay sulak alanlarda sera gazı emisyonunu azaltan birçok faktör vardır. Son zamanlarda, yapay sulak alanlardaki bitki türü çeşitliliğinin sera gazı emisyonları üzerinde büyük etkisi olduğu anlaşılmıştır (Han vd., 2019). Bitki türlerinin CO_2, CH_4 ve N_2O'nun üretimi, yayılımı ve taşınmasında büyük farklılıklara neden olduğu görülmüştür (Han vd., 2019). Bu varyasyonlar büyük ölçüde türlerin anatomik özellikleri nedeniyle ortaya çıkmaktadır (Han vd., 2019). Bitki türlerinin çeşitliliği, azot alımını ve karbon tutumunu artırarak CO_2, CH_4 ve N_2O emisyonlarını azaltır. Bitkilerin fotosentez reaksiyonu nedeniyle CO_2, sulak alanda en aza indirilebilir. Bitki türlerinin sera gazı emisyonları üzerindeki etkisi son zamanlarda odaklanılan bir konu haline gelmiştir.

Bu çalışmada, Türkiye'deki bir yatay yüzey altı akışlı yapay sulak alandan salınan sera gazı emisyonları üzerinde farklı bitki türlerinin etkisinin ortaya konması amaçlanmıştır. Yatay yüzey altı akışlı yapay sulak alandan CO_2, CH_4 ve N_2O emisyonları, kapalı çember yöntemi kullanılarak bir yılda toplam on iki kez ölçülmüştür. Ayrıca bitki türlerinin küresel ısınma potansiyelleri (KIP), tüm sera gazı emisyonları dikkate alınarak Yaşam Döngüsü Değerlendirmesi (YDD) yaklaşımı kullanılarak belirlenmiştir. Sera gazı emisyonlarını tahmin etmek için IPCC yöntemine dayalı yeni geliştirilmiş bir model kullanılmıştır. Bu çalışmanın özgünlüğü, yapay sulak alanlar için yeni bir sera gazı emisyon tahmin aracının geliştirilmiş olmasıdır. Bu çalışma, farklı bitki türlerinin etkilerini değerlendirmek için uygulanmıştır. Yatay yüzey altı akışlı yapay sulak alan, sera gazı ölçümü için 3 bölgeye ayrılmıştır. Bitki türü olarak *Cyperus esculentus* (Bölge I), *Typha latifolia* (Bölge II) *ve Phragmites australis* (Bölge III) kullanılmıştır. Bu çalışmanın bir diğer özgünlüğü, *Cyperus esculentus, Typha latifolia* ve *Phragmites australis'in* sera gazı emisyonları üzerindeki etkilerinin, yatay yüzey altı akışlı yapay sulak alan için CO_2, CH_4 ve N_2O emisyonları açısından belirlenmiş olmasıdır. Bu çalışmada literatürdeki ilgili çalışmaların dışında, yeni geliştirilmiş bir sera gazı emisyonu tahmin aracı ile bu üç tür için sadece CH_4 ve N_2O emisyonları değil, aynı zamanda CO_2 emisyonu da ele alınmıştır. Buna ilaveten, bu çalışmanın yeniliklerinden birisi de, sera gazı izleme sonuçlarına dayalı olarak bitki türlerine ilişkin küresel ısınma potansiyellerinin belirlenmesi için YDD metodolojisinin uygulanmasıdır. Çalışmanın son aşamasında, eğer Bölgeler (I-II) en düşük sera gazı emisyonu salan bitki türü ile donatılmış olması durumunda, olası sera gazı emisyonu Monte Carlo simülasyonu kullanılarak tahmin edilmiştir.

Bu çalışmada *Cyperus esculentus, Typha latifolia* ve *Phragmites australis'in* sera gazı emisyonu üzerindeki etkisi araştırılmıştır. N_2O, CO_2 ve CH_4 emisyonlarının bitki çeşitliliğinden etkilendiği söylenebilir. *Phragmites australis* en düşük CO_2, CH_4 ve N_2O emisyonlarını salmaktadır. Bu açıdan bakıldığında, *Phragmites australis*'in karbon yakalama, CH_4 adsorpsiyonu ve N_2O alımı konusunda en efektif bitki olduğu söylenebilir. Sonuçlar ayrıca *Phragmites australis'e* sahip toplulukların diğer sulak alan bitkilerinden daha yüksek azot giderimi ve daha düşük sera gazı emisyonları elde edebileceğini göstermektedir. *Phragmites australis*, sera gazı emisyonları üzerinde azaltıcı bir etkiye sahiptir. *Cyperus esculentus*, en yüksek CO_2, CH_4 ve N_2O emisyonu kaynağı olduğu görülmektedir. *Cyperus esculentus* sulak alandaki en yüksek değerde sera gazı emisyonunu salmıştır. *Typha latifolia* bunu N_2O ve CO_2 emisyonu açısından takip etmektedir. Makalede yer alan şekiller (4-6), bitki bazında sera gazı emisyonlarının aylık değişimini göstermektedir. En yüksek sera gazı emisyonu, Ağustos ayında Bölge I'den salınan N_2O emisyonudur (10,8371 kg CO_2e/d). En düşük emisyon Ocak ayında III. Bölge'deki CO_2 emisyonudur (0,0156 kg CO2e /d). Sonuçlar, *Cyperus esculentus'un* en yüksek sera gazı emisyonuna ve en yüksek küresel ısınma postansiyeline sahip olduğunu ortaya koymaktadır. *Phragmites australis*, en düşük sera gazı emisyonuna ve en düşük küresel ısınma potansiyeline sahip bitki olarak kullanılabilir. Tüm sera gazı emisyonları farklı bitki türlerinden etkilenmiştir. Son olarak, sulak alan sadece *Phragmites australis* ile bitkilendirilmesi durumunda, olası sera gazı emisyonu Monte Carlo simülasyonu kullanılarak tahmin edilmiştir. Sulak alan sadece *Phragmites australisle* bitkilendirilmiş olsaydı, sera gazı emisyonlarında yaklaşık % 33 azalma elde edilebileceği tespit edildi. Bu çalışmada, bu üç bitki türünün küresel ısınma potansiyelleri YDD yaklaşımı kullanılarak belirlenmiştir. Sonuçlara göre *Cyperus esculentus* 3,8 kg CO_2e değeri ile sulak alanda en yüksek küresel ısınma potansiyeline sahiptir. *Phragmites australis*, 1,7 kg CO*2*e değeri ile en düşük küresel ısınma potansiyeline sahip olduğu görülmüştür.

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