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# THE POTENTIAL SOURCES OF POLLUTION AFFECTING THE WATER QUALITY OF LAKE IZNIK

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***Abstract-****This study aimed to examine Lake Iznik, one of the most significant water resources of the South Marmara Region, and the anthropogenic pollution types affecting the drainage basin and their possible effects. Lake Iznik, a water resource that is quite significant because of its geographical position, is polluted not only with the point and non-point sources of pollution around it, but also with the pollutants spread via highways which are linear pollutants. The fertilization and disinfection of agricultural lands are considered to be one of the most significant factors changing the trophic level of the lake. Biological diversity of the lake is examined in many studies, while the studies on water quality are limited. The decrease in the type and amount of the productions of the lake indicates to the increasing destruction of the ecological balance as a result of the water pollution.*

***Keywords:*** *Lake Iznik, water pollution, point and non-point sources, pollution loads*

## 1. INTRODUCTION

Lakes are private wetlands which are of great importance in the lives of the people and offer many advantages regarding the economy of the region and the country. They constitute a significant and different place in other ecosystems in terms of the preservation of the natural balance and biological diversity [1]. However, lakes are considered to be the potential agriculture-residential-industrial areas in the development plans for years because of their high values [2]. Wetlands are polluted by the domestic, industrial and agricultural pollutants, and thus their biological diversities are destroyed. As a result of the intense water drawal from such wetlands and ground waters feeding these wetlands, such reserve areas become gradually smaller. Considering that the total wetlands in Turkey are 2.5 million hectare, it could be deduced that more than half of the wetlands of Turkey are destroyed in the last 40 years [3]. In this study, possible anthropogenic pollution loads in Lake Iznik were calculated.

## 2. MATERIAL AND METHODOLOGY

Lake Iznik, one of the 76 wetlands of international importance in Turkey, is a natural protected (NP) wetland according to the criteria of The Convention on Wetlands of International Importance (The Ramsar Convention) [4]. Lake Iznik, the biggest lake of the Marmara Region and the fifth biggest natural lake of Turkey, is a tectonic freshwater lake (Figure 1) [5]. The lake's height above the sea level is approximately 85 m, its surface area is 313 $km^2$, and its water volume is 12.2 billion $m^3$; it is an elliptical lake [6]. The maximum depth of the lake is 80m, and five streams and different ground waters feed the lake [7]. The highest points in the mountainside surrounding Lake Iznik are the Karakaya Summit (1260 m) on the northeast of the Samanlı Mountains localizing the depression from the north, and the Gürle Mountain (1282 m) localizing the depression from the southwest [8]. The Lake Iznik Basin is one of the depressed areas on the Anatolian Peninsula in the Marmara Region, and Lake

Iznik has developed on the Iznik Basin. The main morphological units of the Lake Iznik Basin consist of the alluvial plains, plateau and mountainous areas [9].

Lake Iznik is a significant water resource not only with its water capacity but also in terms of agriculture, industry, water productions and recreational activities for the region [10]. The ecosystem of Lake Iznik is declared to be a natural protected area in 1990 and conforms to the international criteria with its characteristics [11]. With the lake's 12.2m$^3$ water volume and its 80 m$^3$ annual water yield, Lake Iznik waters approximately a 12.000-hectare agricultural area; and intensive cultivation is conducted by the suppliers in the area [10, 12, and 13]. The agricultural area of approximately 9000 hectares which is watered from the lake is considered to be expanded by 6.945 hectares with the sites builded. Water is drawn from the lake by the farmers in order to water the agricultural areas near the lake.

Using intensive agricultural methods in the basin and on the plains, various products, especially olives, are cultivated; and grains and fodder crops are cultivated using dry farming techniques on the plateau areas surrounding these plains [12]. Although the proportion of the agricultural areas in the Lake Iznik Basin seems to be small, these areas are intensely used by most of the population to make a living. Moreover, Lake Iznik is a significant bird watching area in Turkey; and there are eight host and five stationary bird species, 13 in total, in this area [14]. Fishery is mostly seen on the shallow coasts of the lake. Six of the bird species in this area has an economic value. The most important products of the lake are crayfish and catfish. *Astacus leptodactylus*, fresh water lobster also known as the crayfish, has an economic value. Lake Iznik (557 tone/year) and Lake Egirdir (237 tone/year) are among the significant production areas in terms of crayfish [15]. Fishery of argentine is intensely seen in Lake Iznik. Moreover, the lake is richer than many other lakes in terms of diversity of the fish species. *Rutilus frisii*, Nordmann, known as Zander; *Rutilus rubilio*, Bonaparte, known as Bitterling; *Chaldalburnus chalcoides*, Linnaeus, known as Becket; and *Coregonus* sp., Linnaeus, known as Koregon are the species that are consumed [16].

However, as a result of the disruption of the water quality, the fish population decreased and the fishery in the area nearly came to an end. The advantages that the lake offer, its geographical position and the active sectors in the area result in a rapid industrialization around the lake and in an increase in the population as a consequence [17, 18]. Along with this rapid population growth in this water basin, industrialization and agriculture are significant factors for the disruption of the water quality.

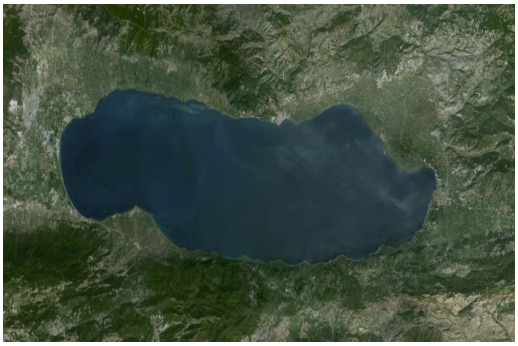

**Figure1.** Satellite Photograph of Lake Iznik

## 2. NON-POINT SOURCES OF POLLUTION

### 3.1. Pollution Resulting From Traffic Activities

In our country, nearly the whole highway transportation network meets the water conservation areas. Highway routes pass near the water conservation areas such as the lakes and the dams. As a result, water resources and basins are at a great danger. The same situation applies to Lake Iznik, the subject matter of the present study [19]. Istanbul-Bursa highway passes through Orhangazi on the west coasts of the Lake Iznik. This road is quite a busy highway, and at every hour of the day, heavy traffic is observed. Exhaust fumes of the cars, hydrocarbons, nitrogen oxides, leads and carbon monoxides produced by the systems in and around the lake pollute the air through the year in every season and especially in winter [URL 1]. Exhaust fume consists of approximately 0.1% NO, 1% CO, 0.3% $H_2$, 10% $H_2O$, 0-1% $O_2$, 77.6-78.6% $N_2$, and this composition changes dramatically depending on the loads the vehicle carries. When the tires are worn out, particulate matters are created. Moreover, the dispersion of these ground level emissions is quite hard. Acidification which may occur as a result of these emissions is significant as it affects the land the water resources. These emissions result in changes in the characteristics of the land and the water resources when they are acidified because of the factors such as humidity and the temperature [20]. As the pollution loads and their diffusion resulting from traffic depend completely on the meteorological factors, obtaining consistent results is quite hard. Pollution loads resulting from traffic are not calculated within this study.

### 3.2.Pollution resulting from agricultural activities

There are fifty six residential areas in the Lake Iznik Basin. The population in these areas lives on olive and fruit growing. Thus, the use of fertilizers and agricultural pesticides are quite common in the basin. Fertilizers and agricultural pesticides reach to Lake Iznik along with the waters and flows resulting from the rain. The pollution of the water resources resulting from agricultural activities can be examined under three headings: erosion, use of artificial and natural fertilizers, and consumption of pesticides/herbicides. Nutrients (including fertilizers) and agricultural pesticides and herbicides are carried to the rivers and lakes through the flows resulting from the rain. Nitrogen, phosphate and potassium in the fertilizers result in significant changes in the natural waters. On the other hand, unconscious and extreme use of the artificial fertilizers makes the lands interfile and result in water pollution and similar negative effects within the natural cycle [21].

Pollutants having toxic, teratogenic and methanogenic effects on the flora and fauna even in very low concentrations in the receiving environment are used extremely in the basins.

Fighting the parasites and insects in agricultural areas, agricultural pesticides, herbicides and fungicides are used [22]. Agricultural pesticides are composed of compositions of arsenic, mercury, borate and fluoride, and of sulphur, nitrogen and phosphorus. In case that the high concentrations of copper-ion enter the water resources; the enzyme activity of the living organisms is affected and the normal functioning of their organs is disrupted. Moreover, compositions of mercury are toxic for all the living organisms [23]. Pesticides in the land are moved over time depending on the type of the pesticide, its solubility, its durability and on the climate conditions, and they reach the surface or ground waters. As a result of the movement of these pesticides in the air used for agricultural protection, water resources are polluted.

The increase in the compositions of nitrogen and phosphorus in natural waters results in significant changes. Agricultural activities are quite common in the basin; thus, the water resources there are polluted by the fertilizers. Compositions of phosphorus are found in fertilizers and many detergents. Concentration of phosphorus in most of the natural surface waters varies between 0.005-0.02 mg/L $PO_4$-P. High concentrations of phosphorus result in another problem in the water masses in which the algal growth is naturally restricted to phosphorus. In these situations, additional compositions of phosphorus result in the stimulation of the algal bloom and the acceleration of the eutrophication process [24, 27]. Another pollutant is the fertilizers with nitrogen, which are one of the common agricultural pollutants in the area; and these fertilizers, as in the case with phosphorus, are moved to the water sources along with the surface waters as a result of the meteorological factors such as rain and snow. The primary source of nitrogen is the air. Production of the fertilizers and burning of fossil fuels result in biological reactive nitrogen to enter into the ecosystems. These changes in the nitrogen cycle have negative effects on the natural ecosystems and the human health. The use of industrial areas result in the high concentrations of nitrite and nitrate; the residential areas cause the total nitrogen load to increase; and the highways cause the concentrations of nitrogen to increase [28, 29]. The maximum concentrations of the compositions of nitrogen and phosphorus in the receiving water environments and in the drinking water are reported by many countries and the authorities; and they are given in Table 1.

Export coefficients for nitrogen and phosphorus are given in different ranges in various sources, and these values are given in Table 2 and Table 3. In order to calculate the nutrient loads of non-point sources (N-P) using the Export Coefficient Model (ECM), topographic and land use maps of the basin are used.

**Table 1.** The highest allowed concentrations of the N-P compositions [25]

| Parameter mg/L | Drinking water | | | | | Fishery and the aquatic life | | |
|---|---|---|---|---|---|---|---|---|
| | WHO | EU | Canada | USA | Russia | EU | Canada | Russia |
| $NH_3$-N | | | | | 2.0 | 0.005-0.025 | 1.37-2.2 | 0.05 |
| $NH_4$-N | | 0.5 | | | 2.0 | 0.04-1.0 | | 0.5 |
| Nitrate (N) | | | 10.0 | 10.0 | | | | |
| $NO_3$-N | 50 | 50 | | | 45 | | | 40 |
| Nitrite (N) | | | 1.0 | 1.0 | | | | |
| $NO_2$-N | 3.0 | 0.1 | | | 3.0 | 0.01-0.03 | 0.06 | 0.08 |
| Phosphorus | | 5.0 | | | | | | |

**Table2.** Total nitrogen export coefficients (kg N/ha/year)

| Source | Urban areas | Rural areas | Industrial areas | Forest areas | Pasture areas | Vehicle emissions |
|---|---|---|---|---|---|---|
| [30] | 6 | 6 | - | 3.2 | - | - |
| [31] | 3 | 10 | - | 2 | - | - |
| [32] | 6 | 6.4 | 8 | 2.8 | 8.65 | - |

**Table 3.** Total phosphorus export coefficients (kg P/ha/year)

| Source | Urban areas | Rural areas | Industrial areas | Forest areas | Pasture areas |
|---|---|---|---|---|---|
| [31] | 0.5 | 0.3 | - | 0.05 | - |
| [32] | 1.4 | 1.2 | 2.3 | 0.26 | 1.5 |
| [33] | 0.5 | 0.25 | - | 0.1 | - |
| [34] | 0.95 | 0.45 | - | 0.11 | - |

More nutrient export coefficient is needed, and thus the agricultural coefficients are updated for the semi-naturalvegetation and forest areas, and for the urban areas where sewage or septic tank systems are used [35].

$$L_{\text{Distributed source}} = E*A \qquad (1)$$

L: Annual total loads according to the land use
E: Export coefficient
A: Acreage according to the type of land use

The use of export coefficient (EC) for the calculation of phosphorus and nitrogen loads depends on some certain information such as the climatic regimes and the specific types of land use. Possible concentrations of nitrogen and phosphorus resulting from the fertilizers used in the agricultural areas around Lake Iznik and affecting the lake are calculated and given in a graph (Fig. 2).

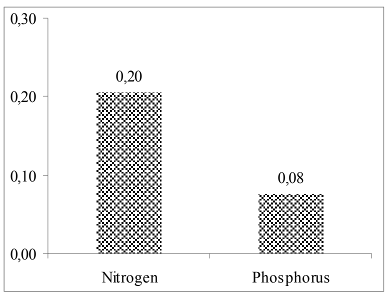


**Fig. 2.** Possible N-P concentrations calculated at the end of the fertilization (kg/day)

## 4. POINT SOURCES OF POLLUTION

### 4.1 Pollution resulting from industrial activities

Lake Iznik is polluted by the waste water of the Orhangazi Industrial Area, the tankages of Iznik and Osmangazi, Marmara Birlik Olive Processing Plants in Iznik, and by Ispak industrial plants in Orhangazi [8]. Moreover, the lake is under threat because of the small olive oil plants around it [3]. According to the reports, some industrial plants increasing the water pollution in the area and the amount of the waste water discharged by them are given in a table (Table 4). However, some institutions in the table are also known to discharge more water than stated.

Processing types of the industries are determined and the amount of water used per product is calculated. Pollutant amounts in waste water per unit for each process (kg/m$^3$ or mg/l) are examined in the literature and the possible pollution loads are determined by multiplying the amounts of waste water in the industry [36].

**Table 4.** Industrial plants discharging waste water in the Lake Iznik drainage basin [18]

| Plant | Sector | Amount of the waste water(m$^3$/day) |
|---|---|---|
| Swedish M.Kibrit & Çakmak A.Ş. Orhangazi | Forest Products | 50-200 |
| Asilçelik San.Tic.A.Ş.- Orhangazi | Iron Steel Industry | 200-1000 |
| Ormo Yün İplik San.- Orhangazi | Textile Ind. | 200-1000 |
| Namsal Gıda San.- Orhangazi | Food Ind. | 200-1000 |
| Polifleks Otomativ San.- Orhangazi | Automotive Ind. | 200-1000 |
| Karbogaz-$CO_2$ ve Kurubuz San.- Orhangazi | Chemical Ind. | 50-200 |
| Döktaş Döküm San.- Orhangazi | Casting Ind. | 200-1000 |
| Cargill Tarım San.- Orhangazi | Corn Processing | 200-1000 |
| Mezbaha - Orhangazi | Animal Slaughter | >200 |
| Marmara Birlik Zeytin -İznik | Olive Processing | 200-1000 |

$$L_{PS} = C.Q \qquad (2)$$

$L_{PI}$: Annual total loads according to the type of the process in the industries
C: Pollutant concentration of a certain process (kg/m$^3$)
Q: Daily – hourly flow rate of the process (m$^3$/d)

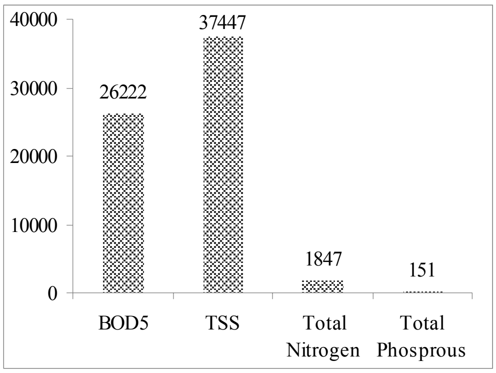


**Fig. 3.** Possible pollution loads calculated at the end of the industrial activities (kg/day)

### 4.2. Pollution resulting from the population

It is a well-known fact that the pollution in Lake Iznik increases parallel to the population growth. The common use of the septic tanks in Orhangazi and Iznik around Lake Iznik causes the pollution of the lake to increase. Although the population outside Iznik and Orhangazi is not dense, pollutant loads of domestic waste water affecting the lake are calculated. A certain amount of the used water (70-90% in general) is thought to return to the sewages. The flow rate of the waste water discharged into the sewages might be calculated as follows:

$$Q_{Calc} = \frac{MaxQ_{Domes}}{n_1} + \frac{Q_{Leak}}{n_2} \qquad (3)$$

Here;

Max ($Q_{Domes}$): 1.5 x $Q_{Ave}$ (lt/sec)

$Q_{leakage}$: the flow rate of the ground water returning the sewage
$n_1$: coefficient equal to certain population values

$n_{24}$: coefficient of the waste water returning to the channel (24 especially in areas with

$$L_{PS} = N*q \qquad (4)$$

channel).
Leakage flow rate except for the domestic use is not calculated in this study. Average daily consumption values can be seen at Table 5 for various countries.

**Table 5.** The flow rate of the daily consumption water determined for certain countries (except for the leakage flow rate) [37].

| Country | Flow rate of the daily water consumption (l/person-day) |
|---|---|
| Germany | 150 |
| Belgium | 80 |
| Denmark | 150 |
| France | 95 |
| Switzerland | 275 |
| Norway | 150 |
| Italy | 230 |

Certain institutions in Turkey determine the flow rate of the waste water and the loads per unit for some conventional pollutants. Values that are determined in the General Specification of the Waste Water Discharge Process of the Provincial Bank are given in Table 6 below; and they are considered to constitute the base for activated sludge, trickling filter and stabilization basin design.

**Table 6.** Pollutant loads determined in the general specification of the Provincial Bank [38].

| Parameter | (g/person.day) |
|---|---|
| $BOD_5$ | 50—60 |
| TSS | 70—90 |
| N | 10—12 |
| P | 3–4 |

The flow rate produced according to the population is calculated with an equation ($Q_{calculation}$) as the average population living in the basin is known; then the domestic waste water loads as the point sources are calculated by multiplying this rate by the values in Table 6 (Equation 2). Possible load amounts returning to the lake according to the population are calculated and given in a graph (Fig. 4).

and the drainage basin disrupts the

L: Pollution load according to the population (domestic waste water load kg/day)
N: Population in the basin (person)
q: Pollution per unit daily produced per person (g/person-day)

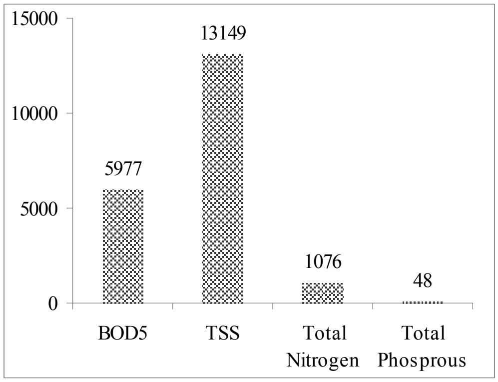


**Fig. 4.** Possible domestic pollution loads (kg/day)

## 4. CONCLUSION

Lake Iznik is a surface water resource used for drinking and domestic water and is an ecosystem used for recreative purposes. The lake has an economical and touristic value for the region and the population in the area dramatically increases. The population growth results in industrialization, land use and water consumption. Especially the overuse of the pesticides in agricultural activities in the drainage basin has a negative effect on the ecosystem of the lake. The return of nitrogen and phosphorus to the lake in great amounts requires a re-evaluation of the trophic level of the lake; and this indicates that the lake acquires an eutrophic characteristic. Moreover, industries using the water of the lake in processing goods discharge their waste water to the lake without sufficient purification. Phosphorus in the industrial pollution is determined to be 3 times more than that in the domestic waste water; and nitrogen in the industrial pollution is determined to be 1.5 times more than that in the domestic waste water. However, nitrogen and phosphorus used in agricultural activities do not pollute the lake like other sources because of various factors such as adsorption, dilution and degradation. The sustainable water quality of Lake Iznik

[9] Akbulak C., *İznik Gölü Havzasında Arazi*

preservation-use balance against the lake. The decrease in the number of fresh water resources or their pollution indicates that the necessary measures should be taken in order to preserve these sources. It is obvious that the shelter belts are insufficient in the preservation of the lake and that the activities and residences in the drainage basin should be organized within the frame of a certain planning. Basin management is a planning approach that requires to be integrated to the water quality management; and the sustainable water quality management is maintained using this approach in many countries. As a consequence, Sustainable Water Quality plannings integrated with the Basin Management should immediately be realized in Lake Iznik.

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