The Mucilage Problem: Causes, Consequences and Solutions

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Introduction

The Marmara Sea has been facing a marine mucilage (sea snot) problem since November 2020. Mucilage is a harmless substance secreted by almost all plants, including phytoplankton. However, as the phytoplankton population grows, the amount of mucilage secreted increases. As a result, this substance can cover the surface of the sea and below, block the sun's rays, increasing the ambient temperature, and reducing the amount of oxygen in the sea, causing mass death of sea creatures. In addition, mucilage can attract bacteria and viruses, trap plankton and crumbled particles suspended in the sea and spread diseases to the environment (Savun-Hekimoğlu and Gazioğlu, 2021). The phytoplankton population, which grows mainly as a result of the arrival of nitrogen and phosphorus loads from urban and industrial wastewater and agricultural areas with precipitation and runoff, can explode when environmental conditions such as a decrease in biodiversity and an increase in sea temperature come together.

The level of mucilage in the Marmara Sea unprecedently increased with the warming of the weather in 2021 and became visible to everyone, prompting the authorities in June. In the first stage, the visible part of the problem was solved by a sea cleaning campaign to collect the mucilage on the surface, but in fact, this made the mucilage problem more invisible. Because, unless the main causes of the increase in mucilage (urban, industrial and agricultural pollution, loss of biodiversity, increased sea temperature due to climate change, etc.) were taken under control, it would not be possible to solve this problem with temporary methods. As a matter of fact, with the Marmara Sea Action Plan made during the same period, the things to be done in the Marmara Sea in the medium and long term were also determined.

However, it should not be forgotten that the ecosystem in the Marmara Sea Marmara has been deteriorating under various pollution loads that have been going on for decades. The pollution-induced increase in mucilage is not an issue that can be easily eliminated with a single action plan. Realizing the action plan is a true effort in its own right, and there are certain uncertainties and deficiencies in some of the 22 items of the action plan, in terms of targets, deadlines and scope. The lack of important issues that were not addressed in the action plan is also striking. The most important issue is how these action items will be implemented and how much budget is required for implementation. To discuss these issues and spare this action plan from simply being a series of well-intentioned wishes, the problem of mucilage should be explained to the public, along with its causes, consequences and solution proposals. The participation of not only policy makers and technical experts, but also all segments of the society in the solution of the mucilage problem is of great importance for the action plan to be successfully implemented.

For these reasons, a group of experts from different academic disciplines came together to evaluate the problem of mucilage, which will trigger further disasters if not resolved, with its causes and consequences. Our evaluation of the current action plan and its deficiencies and our recommendations for a general solution are presented at the end of the report. We kindly present this study to the Turkish and international public by turning it into an information note with a simple, understandable but inclusive narrative. We hope that the study will provide guidance for the solution of the mucilage problem in the Marmara Sea, which threatens other seas as well.

1. Drawing the boundaries of the mucilage problem in the Marmara Sea

Surrounded by seven cities (İstanbul, Tekirdağ, Çanakkale, Balıkesir, Bursa, Yalova, Kocaeli), five of which are metropolitan cities, the Marmara Sea is home to around 25 million people. As Turkey's second smallest region in terms of surface area and collecting only 4 percent of its total runoff, the Marmara Region hosts about 30 percent of the country's population and has a

share of nearly half of the national income. In other words, the Marmara Region is by far the densest region of Turkey in terms of population and economic activities despite its limited natural resources such as land and water.

The Marmara Sea is located in the middle of all this dense urbanization and industry. Industrial wastewater from Tekirdağ, Kocaeli, Yalova and Bursa and pollutants from agricultural activities in the Thrace Peninsula, Balıkesir, Bursa and Yalova end up in the Marmara Sea. Since millions of cubic meters of wastewater, both directly generated by the dense population and as a result of all industrial and agricultural activities is discharged to the sea in legal and illegal ways, without adequate treatment or without any treatment at all, the Marmara Sea has become unable to handle such pollution.

The developments that took place in Istanbul, especially in the last two centuries, have been effective for the Marmara Sea to reach this point. Starting from the 19th century, Istanbul and its surroundings became the centre of Ottoman industrialization attempts (Kırlı, 2018) and at the beginning of the 20th century, 55 percent of the industrial facilities in the Ottoman lands were concentrated in this region (Köksal and Ahunbay, 2016). Industrialization coupled with migration, rapid population growth and unplanned urbanization increased Istanbul's population to over one million for the first time in 1945[1]. Industrialization movement continued until the 1980s and increased the population of the city to over 4.7 million. Both industrial facilities and urban areas with poor infrastructure were using the Marmara Sea as a waste pond. Although action plans, basin regulations and laws were introduced to save the Marmara Sea in the 1980s, the situation did not change much. The decentralization of industrial facilities in Istanbul by moving them out of the city only changed the location of the problem to neighbouring cities such as Kocaeli and Tekirdağ.

In the 2000s, Istanbul was rapidly advancing towards becoming a world metropolis with an economy model that brought sectors such as trade, tourism, construction and investment to the fore, attracting more immigrants and investors to the city with giant infrastructure projects (e.g. Marmaray, Büyük Melen Water Transport System, Yavuz Sultan Selim Bridge, Istanbul Airport, Canal Istanbul project still in the planning stage, etc.), and eventually turning into a vast city with a population of close to 16 million, covered with concrete and asphalt, whose water basins have been handed over to construction, and green areas and wetlands lost. Over the last two centuries, Istanbul has continued to grow in different sectors and to discharge an increasing amount and variety of pollution loads into the Marmara Sea. Various problems such as red-tide, green-tide, increase in jellyfish population and dramatic fluctuations in fish production have been observed since 1989, when Istanbul's wastewater started to be discharged into the Marmara Sea by deep discharge method[2]. After the mucilage disaster that occurred for the first time in 2007 (Aktan and Topaloğlu, 2011), the same problem was experienced in 2021, this time on a larger scale, as necessary actions were not taken.

Marine mucilage is a problem that concerns not only the people living in the Marmara Region, but all of Turkey. The fact that the heart of the country's population and economy beats in the Marmara Region is not the only reason for this. Another important reason is that the Marmara Sea connects the Aegean Sea, which is the extension of the Mediterranean Sea, and the Black Sea. Because of the similarity of climatic and geographical conditions and mismanagement, both seas can face a similar mucilage problem at any time. In fact, if the mucilage problem is not resolved in time, it may turn into a threat to neighbouring countries bordering the Mediterranean, Aegean and Black Seas.

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[1] Istanbul population by census year, annual population growth rate between censuses and mid-year population estimate http://www.ibb.gov.tr/tr-tr/bilgihizmetleri/istatistikler/documents/demografi/t211.pdf

[2] https://www.birgun.net/haber/doktuklerimizi-deniz-geri-verdi-346152

The 1982 United Nations Convention on the Law of the Sea stipulates that the protection and preservation of the marine environment is a general duty of governments (Turkish Bar Association, 2015). Protection of the Mediterranean and the Black Sea is regulated by international agreements to which Turkey is a party, i.e., the Convention for Protection of the Mediterranean Sea against Pollution (the Barcelona Convention) and the Convention on the Protection of the Black Sea against Pollution (the Bucharest Convention) (Kalelioğlu and Özkan, 2000). Although the provisions of these two separate international conventions are precedent for the Marmara Sea as it connects these two seas, the Marmara Sea is practically exempted from many protection activities. However, it is geographically impossible to see the Marmara Sea apart from the two seas it unites, and international conventions have the force of law according to Article 90 of the Constitution of the Republic of Turkey. Therefore, Turkey has to fulfil its international legal obligations regarding the Marmara Sea, despite the fact that it is an internal sea. Moreover, many laws and regulations, including the Environment Law and the Coastal Law under Turkey's domestic law also contain these protective provisions (Turkish Bar Association, 2015).

In summary, the problem of marine mucilage is not limited to the Marmara Sea in terms of geographical borders, but also concerns all of Turkey and the neighbouring countries that have coasts to the seas it unites. Administrative areas related to the mucilage problem are not limited to domestic and industrial wastewater and agricultural pollution loads. Effects such as decrease in biodiversity in the Marmara Sea and global warming, causing an increase in sea temperatures should also be considered as part of the overall mucilage problem. From a temporal point of view, this is also not only a problem of the present, but also a process from the past extending into the future. As a matter of fact, without comprehensive and permanent solutions, it will lead to greater disasters in the future. If lessons are not learned from this disaster this time, the next environmental disaster may trigger national and even regional problems, bringing the Marmara Sea and its surrounding region on the brink of ecological, economic and social collapse.

2. Causes of mucilage

The increase in marine mucilage in the Marmara Sea is primarily caused by land-based point and nonpoint sources of pollution (urban and industrial wastewater discharges, and polluted water from agricultural activities carried by precipitation and overirrigation). Other important reasons are the loss of biodiversity due to over-fishing and pollution in the Marmara Sea, and global warming-induced increase in the sea temperatures. These three reasons overlap and intensify each other at many points. Marine mucilage emerges because of these three main factors, and at the same time, it exacerbates the negative effects of these factors on the marine ecosystem. For example, increased mucilage could further pollute the sea, accelerate biodiversity loss, and increase sea temperature. Therefore, it should not be noted that mucilage is both a result and a problem, and it has become a vicious circle.

2.1. Urban, industrial and agricultural pollution

Being home to approximately 25 million people, the Marmara Region contains the cities with the highest population density in our country. While there are big cities such as Kocaeli and Bursa, the population in the basin is concentrated in Istanbul, where nearly 16 million people live. There are 5 different basins in the Marmara Region, including the entire Meriç-Ergene and Marmara basins, two of Turkey's 25 hydrological basins, and certain parts of the Susurluk, Northern Aegean and Sakarya basins (Figure 1). Of these, the Marmara and Susurluk basins end in the Marmara Sea. The cities of Balıkesir, Bursa, Çanakkale, Istanbul, Kocaeli, Tekirdağ and Yalova also discharge their wastewater into the Marmara Sea.

Figure 1. Water basins and cities in the Marmara Region

Figure 2 shows the distribution of wastewater discharge to the Marmara Sea by cities. Istanbul alone is responsible for 76.53 percent of this discharge, followed by Kocaeli with 8.33 percent, Bursa with 7.21 percent, Tekirdağ with 2.54 percent, Yalova with 1.88 percent and Çanakkale with 1.38 percent (Turkish Academy of Sciences, 2021).

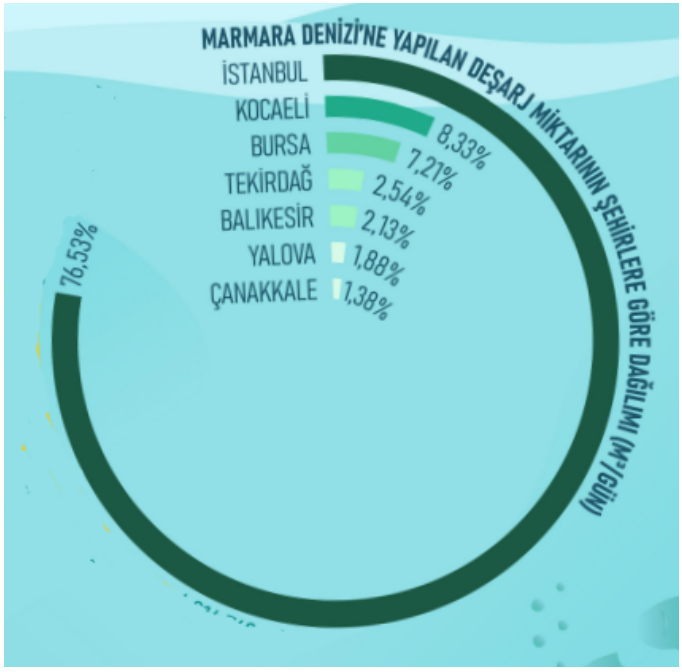


Figure 2. The distribution of wastewater discharge to the Marmara Sea by cities (Source: Turkish Academy of Sciences, 2021)

How wastewater is discharged into the Marmara Sea is as important as the amount of discharge. For many years, a significant part of the municipal and industrial wastes coming from the cities located in the basin are discharged to the sea without undergoing an adequate treatment. To be more precise, as seen in Figure 3, 53 percent of the wastewater in the Marmara Region is subjected to physical treatment (pre-treatment) [3], 5 percent to biological treatment[4] and 42 percent to advanced treatment[5] (Turkish Academy of Sciences, 2021)[6]. In other words, more than half of the municipal and industrial wastewater is discharged to the sea after only pre-treatment. For this reason, there is an increase in the amount of polluting nutrient salts such as nitrogen and phosphorus, which are transported to the Marmara Sea with wastewater. Only the municipal nitrogen load discharged from Istanbul to the Marmara Sea is 48.772 kg/day, and the phosphorus load is 6.649 kg/day (Öztürk et al., 2021). This corresponds to more than 60 percent of the loads that other cities in the basin will bring. Istanbul, therefore, stands out as a hot spot in terms of municipal nitrogen and phosphorus discharges.

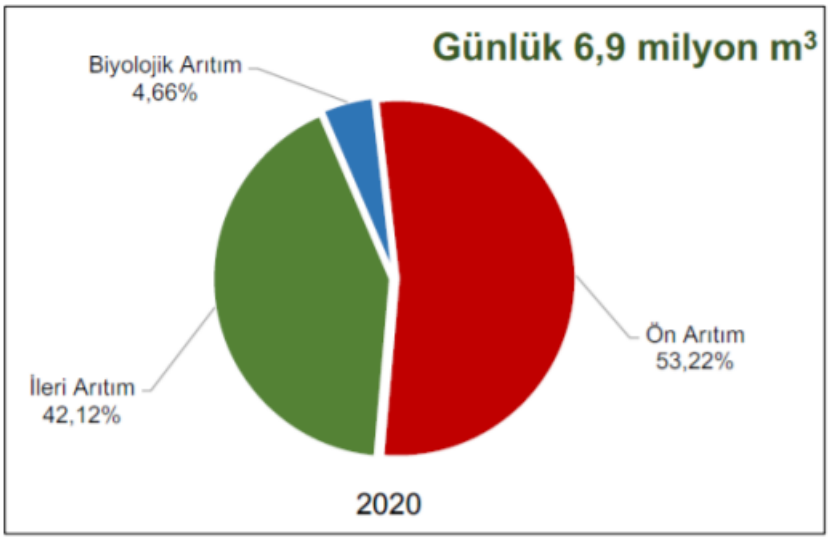


Figure 3. Ratios of wastewater discharged to the Marmara Sea based on treatment method (Source: Turkish Academy of Sciences 2021)

The Marmara Region, one of the most developed regions in Turkey in terms of industrial production, accommodates most of the plants operating in a wide variety of sectors, from food to metal products. According to 2018 records of the Industry Registry Information System, Istanbul hosts 22 percent of the industrial enterprises in our country and has the highest concentration of industrial enterprises not only in the Marmara Basin but also in Turkey. There are 45 Organized Industrial Zones (OIZs) that discharge wastewater directly or indirectly into the Marmara Sea, 9 industrial zones with legal entity, 6 of which are active, and 6 free zones (Abolished Ministry of Environment and Urbanization, 2021).

[3] Pre-treatment or physical treatment is the stage in which the undissolved pollutants in the wastewater are separated from the wastewater by sedimentation or flotation. Grids, screens, grit traps, balancing, sedimentation and flotation ponds are the most commonly used physical treatment units.

[4] Biological treatment is the process of removing organic-based solids, which are dissolved in wastewater and cannot be removed at the desired level by physical or chemical methods from wastewater with the help of microorganisms.

[5] Advanced treatment is the treatment process used to remove pollutants (nitrogen, phosphorus, heavy metals, toxic organic substances, etc.) that cannot be sufficiently purified or treated with physical or biological treatment methods.

[6] Minister of Environment and Urbanization, Murat Kurum, announced the Action Plan for Protecting the Marmara Sea, which consists of 22 actions. https://marmarahepimizin.csb.gov.tr/eylem-plani-i-102110

In our country, the protection of the underground and surface water resources is governed by the Water Pollution Control Regulation. The regulation categorizes wastewater based on sectors and determines discharge criteria for each sector. It is possible to meet these standards through treatment plants designed specifically for different categories of wastewater. The fact that some of the wastewater originating from the industrial plants located in the basin is discharged to the Marmara Sea through deep sea discharge without being adequately treated has significantly deteriorated the water quality.

More than half of the nitrogen and phosphorus load coming to the Marmara Sea is land-based. Nitrogen and phosphorus pollution originates from the point sources, as well as nonpoint sources such as agriculture and animal husbandry. Among the nonpoint sources of pollution, the highest nitrogen and phosphorus load is caused by the use of fertilizers (approximately 57% nitrogen; 64% phosphorus) (Abolished Ministry of Environment and Urbanization, 2015). The contribution of animal husbandry (approximately 22 percent nitrogen and 28 percent phosphorus) and land use (approximately 14 percent nitrogen, and 5 percent phosphorus) to the nitrogen and phosphorus load is quite high (Abolished Ministry of Environment and Urbanization, 2015).

A significant part of the waste discharged into the Marmara Sea comes from the Susurluk Basin and Kocaeli. The Simav River, which is heavily polluted by both industrial and agricultural wastes, carries a large waste load to the Sea Marmara all year long. Although there has been a significant decrease in the waste load from Kocaeli to the Marmara Sea in recent years, some streams, especially Dilderesi, keep on polluting the sea.

Monitoring studies to determine the quality of water resources in Turkey have been going on for many years. Since 2011, these studies have been carried out under the "Integrated Marine Pollution Monitoring Programme (DEN-İZ)", with an integrated and ecosystem-oriented approach. Data is reported in three-year periods and the last set of data includes the 2017-2019 monitoring program outputs. According to the latest data, the ecological quality of a large part of the Marmara Sea in 2019 is of medium and low ("poor/weak") quality (Abolished Ministry of Environment and Urbanization, 2020). Ecological quality in parts of the Bosphorus shores, Küçükçekmece, Tuzla, Bandırma Bay and İzmit Bay is classified as “poor/weak”. Susurluk Region, which was determined as a “risk area” in the previous periods, maintains this status, because of lack of improvement in water quality.

Although many wastewater treatment plants (WWTPs) have been built in recent years to control the waste load discharged into the sea, a significant amount of wastewater continues to be discharged into the Marmara Sea and the Bosphorus. Figure 4 shows the revision needs concerning the WWTPs in the Marmara Basin. As far as flow rate is concerned, the wastewater from the facilities that need to be rebuilt is 28.9 percent, while the rate of wastewater from the facilities that need maintenance, repair and revision in terms of pollution parameters such as nitrogen (N), phosphorus (P) and Chemical Oxygen demand (COD) and capacity increase is 47.1 percent in total (Abolished Ministry of Environment and Urbanization, 2021). Wastewater coming from WWTPs that do not need revision, in other words, plants that treat wastewater properly with sufficient capacity, reaches only 24 percent of the total (Abolished Ministry of Environment and Urbanization, 2021). This is indeed a worrying situation for the Marmara Sea.

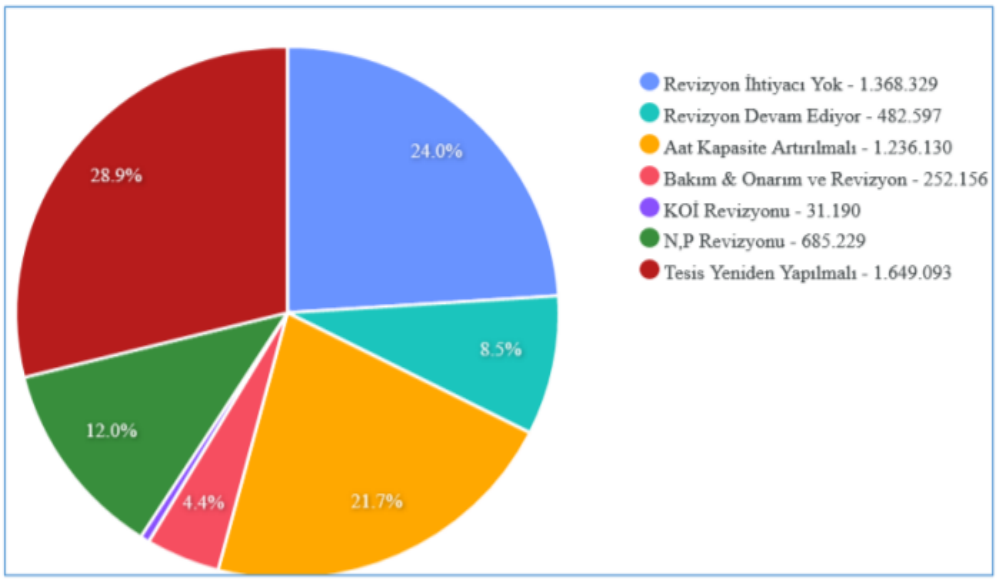


Figure 4. Wastewater discharges of WWTPs based on their revision status (flow based m3/day) (Source: Abolished Ministry of Environment and Urbanisation 2021).

Decades long wastewater-based pollution puts the Marmara Sea, whose surface area is only 11350 km2 and water volume is 3377 km3, under great environmental pressure (Artüz and Artüz, 2010). As a result of these pressures, environmental disasters, especially marine mucilage, are no longer a possibility but a matter of time.

Apart from these, point pollutants such as wastewater leaking from landfills and thermal discharges, and polluted waters coming from residential areas within the first 5 to 10 minutes of precipitation also pollute the Marmara Sea. Especially in metropolises such as Istanbul, where majority of the surfaces are covered with water-impermeable concrete and asphalt and green areas are less common, the waters coming with heavy rainfall can contain a significant amount of pollution. However, they have a smaller share compared to the pollution load from urban and industrial wastewater that is regularly discharged into the sea and from agricultural lands by precipitation and over-irrigation. Pollution from maritime traffic is also low compared to terrestrial sources.

2.2. Loss of biodiversity in the Marmara Sea

The Marmara Sea is unique in the sense that it hosts two of the 13 important straits and canal systems in the world and has rich biological diversity and productivity due to its morphological and geographical structure. In addition to being the habitat of protected species such as sea mammals, the Marmara Sea is also a migration route for fish with high economic value such as bluefish and bonito. The Marmara Sea serves as an ecological bridge between the world's biological reserve areas such as the Mediterranean (Boucher and Bilard, 2020) and the Black Sea (Bat et al., 2011), with high occurrence of endemic species. Therefore, the Marmara Sea meets six of the seven criteria determined by the Ecologically or Biologically Significant Marine Areas (EBSA)[7] at the “high” category level.

The biological diversity of the Marmara Sea has been affected by the Black Sea and the Mediterranean, which differ from each other in terms of physical, chemical and biological characteristics. The Marmara Sea has a double-layered system. The difference in water density between the bottom layer and the top layer affects the bottom dissolved oxygen exchange. The oxygen-rich waters from the Mediterranean, which enter the Marmara Sea from

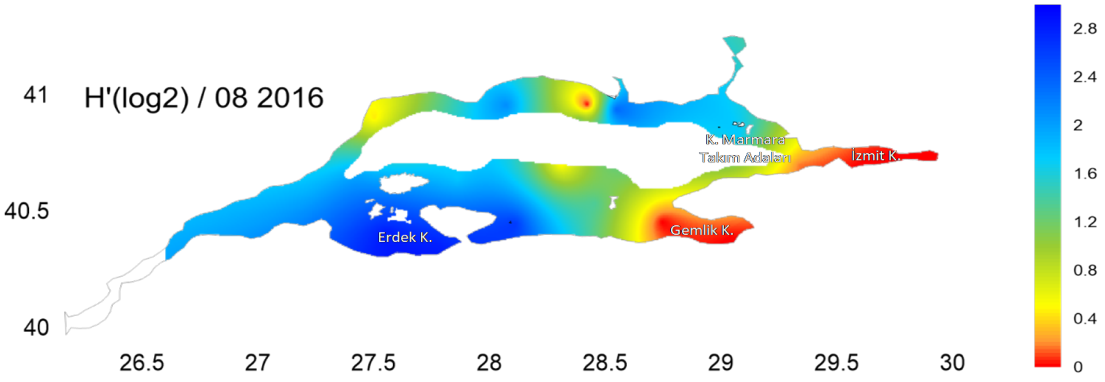
[7] EBSA-Ecologically or Biologically Significant Marine Areas

the Çanakkale Strait, generally follows along the southern coastline and heads towards the north. Therefore, the lower layer water on the southern coast of the Marmara Sea is richer in oxygen. This is an important parameter that directly affects biodiversity.

According to Polat's research (1995), the Marmara Sea reached its pollution limits in terms of organic matter in the early 1990s. According to current research, the Marmara Sea contains much more nitrogen and phosphorus than the seas of Europe (Ediger et al., 2016). The layer with the highest production is the upper layer and the pycnocline (the layer with sudden changes in salinity and density). The substrate is permanently low in oxygen, i.e. hypoxic; although it varies temporally and spatially, the approximate oxygen saturation is between 20 and 30 percent (Polat-Beken, 2018). In terms of seawater chemistry, 37 percent of the phosphate load enters from the Black Sea, and 40 percent from the Marmara and Susurluk basins (Polat-Beken, 2018). 42 percent of the nitrogen compounds reach the sea from the Black Sea and 50 percent from the Marmara basins (Polat-Beken, 2018).

While the Marmara Sea was mainly polluted by the Black Sea in the 1970s, it is now being polluted by its own basin. In the last 30 years, the oxygen level has been decreasing rapidly inversely with the increase in nutrients in the bottom layers of the Marmara Sea. This also affects the demersal (seafloor dependent) and pelagic (water body) ecosystems (Ediger et al., 2016). When the variation of low oxygen according to depth is examined, it is seen that the oxygen level has decreased from 3mg/L to below 1mg/L in 20 years in the Çınarcık (East) trench. This decline also affects the southern shelf, where biodiversity is high (Figure 5). Dissolved oxygen is especially effective in the distribution of macrozoobenthic species[8], which are important components of the ecosystem. Biodiversity is high in areas where oxygen is high, and low in northern Marmara Sea where it is low. The abundance of the few species that can survive in low oxygen conditions is high in these areas.

As can be seen in Figure 5, the species diversity (Shannon Wiener index (H′)) is high in regions such as Erdek Bay where current and bottom oxygen are high and is quite low in areas such as Izmit Bay and Gemlik Bay where the current is low, human pressure is intense and the bottom oxygen is hypoxic (low oxygen level) or not existing (azotic conditions). On the other hand, in the Istanbul region, where human pressure is quite high, it is relatively high due to the high current system keeping oxygen at the bottom. Coral reefs, which are trying to hold on to life, especially around the Northern Marmara Archipelago, are the best examples of this.



[8] Macrozoobenthic species are all invertebrate organisms associated with the seafloor (living on or in the sediment, feeding on and breeding in that environment) that can be captured by a sieve with a 1 mm mesh size.

Figure 5. Distribution of the Macrozoobenthic Species Diversity in the Marmara Sea (Yüksek, 2016)

Another factor behind biodiversity loss in the Marmara Sea is over-fishing and incorrect fishing. Rumour has it that in the 17th century, “the Bosphorus was full of fish” and it was even possible to fish in the Bosphorus and the Golden Horn by dipping baskets in the water (Özdağ, 2013; Ulman et al., 2020). However, due to ill policies on fisheries, rich fish resources in the Marmara Sea have been largely destroyed. It has been determined that 19 species are extinct, and 22 species are commercially extinct in the Marmara Sea. 56 percent of commercial fish species are in danger of extinction (Ulman et al., 2020).

Of the 16 fish and 1 shrimp stocks analysed for the Marmara Sea, only sardines and horse mackerel remained within the maximum catchable limits, while the others remained under the pressure of overfishing (Demir et al., 2020). When the fish distributions are examined over a ten-year period, it is seen that overfishing and wrong fishing techniques have brought the fish populations to the point of extinction, especially in the southern Marmara shelf, and caused great damage to the habitat and macro-benthic species diversity.

While mackerel was the dominant species in the Marmara Sea in the 1950s, the most commonly seen species were anchovy, sardine, and sprat in the last 30 years. Known as small pelagic fish, these species feed on plankton. If a high proportion of juvenile fish is taken out of the environment, the ecosystem replaces it with another species that was previously in balance. These species are generally jelly-like creatures like jellyfish. Jelly-like creatures emerge especially when the ecosystem balance is disturbed. The population and distribution of this group of creatures are increasing rapidly in all seas of the world, generally associated with temperature increases due to climate change. If there are no predators or small pelagic fish to compete in the environment, the number of jelly-like creatures increases rapidly and causes the balance in the food web of the marine ecosystem to deteriorate rapidly (Yüksek and Sur 2010; Yüksek, 2021; Yılmaz, 2015). These sudden changes in the food web are the most important factors triggering the increase in mucilage (Yüksek and Sur, 2010; Yüksek, 2021).

2.3. Climate change and increase in sea temperature

The global climate system is changing rapidly due to increased atmospheric accumulations of anthropogenic greenhouse gases resulting from various human activities such as fossil fuel burning, land use and changes in land use, deforestation, energy, transportation, housing, waste management and industrial processes. Climate change is one of the greatest threats to human health and well-being as well as to water supply, food production and food security, with increasing and exacerbating heat waves, droughts, floods, and increasingly volatile and unpredictable extreme weather and climate events and disasters. (Türkeş, 2014; Erlat and Türkeş, 2017; Türkeş, 2018; Türkeş, 2020a; Türkeş, 2020b; Türkeş, 2021; Türkeş and Erlat, 2018; Chen et al., 2021; IPCC, 2021; Erlat et al., 2021).

In the summer of 2021, Turkey subsequently or simultaneously experienced severe weather and climate events and disasters, such as heat waves, droughts, wildfires, strong and heavy rains, floods and landslides associated with the observed consequences of the direct and/or indirect effects of climate change, with visible differences of severity in different regions. Almost all countries in the Mediterranean Basin, including Turkey, experienced high tropical temperatures and heat waves over a 2-month period from the end of June to the end of August in the summer of 2021. During successive periods of extreme heat waves, temperatures in large parts of Turkey, especially in the west, south, southeast, and east (except for the north and northeast of Eastern Anatolia), were 4-8°C higher than normal temperatures. New records were set for the highest temperatures at some measuring stations.

Spatial and temporal changes observed in the mean surface air temperatures and sea surface temperatures (SST) in the Western Black Sea, Marmara and Northern Aegean regions in 2020-2021 should be analysed, to better understand the severe and prevalent mucilage problem in the Marmara Sea and the Dardanelles. For this purpose, regional maps created from ready-to-use grid reanalysis data of the Mediterranean and Black Sea basins and the wider surrounding region (the region between 30 and 50 degrees north in latitude and 10 degrees west and 45 degrees east in longitude) should be consulted (Kalnay et al., 1996; https://psl.noaa.gov/cgi-bin/data/composites/printpage.pl)

According to the areal distributions of seasonal and quarterly composite (combined) SST anomalies starting in September 2020 (Figures 6(1) and 6(2)), the largest positive SSTs in the study area, i.e. significantly warmer-than-normal sea surface temperatures, appeared in the period of September 2020 - March 2021, which includes the months when the mucilage event started (November 2020) and when it was most severe. Composite SST anomalies in the 2020 autumn season and the period between October-December in 2020 (Figure 6(1)a and b) were 2-3 °C in the Western Black Sea Basin (Danube) and the Marmara Sea, and 1.5-2.5°C in the Northern Aegean. SST anomalies in the Western Black Sea, Marmara Sea, and Northern Aegean Sea occurred at 1.8-2.7°C in the period of November 2020- January 2021 (Figure 6(1)c). In the winter of 2021 (December 2020 - February 21) (Figure 6(1)d) and in the 3-month period of January-March 2021 (Figure 6(1)e) SST anomalies were between 1.5-2 °C in the Western Black Sea, the Marmara Sea and Aegean Sea. In subsequent seasonal and +1 quarterly consecutive periods (Figure 6(1)f - Figure 6(2)g, i, k, l, m) SST anomalies weakened and generally remained between 0.75-1.25°C, with the exception of a warmer period in April-June 2021 with 2021 (Figure 6(2)h).

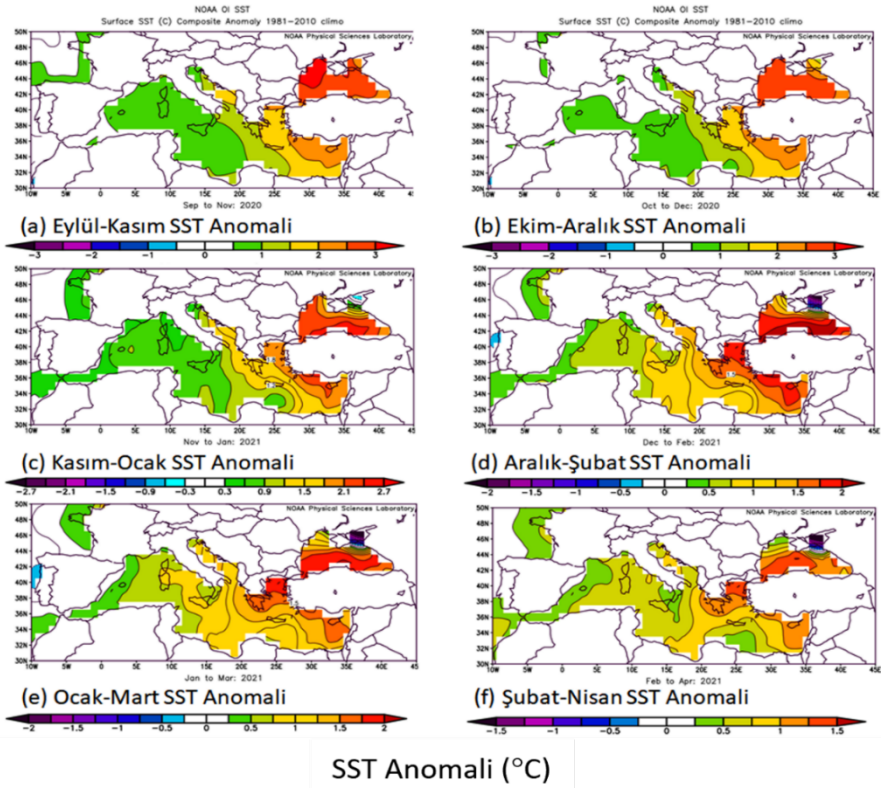


Figure 6(1): Geographical distribution patterns of 3-month composite SST anomalies (C) for the period September 2020-April 2021, seasonal with respect to their normal status (1981-2010) and shifted by one month starting from September 2020

In addition, the magnitude and spatial distribution of seasonal and 3-month combined surface air temperature anomalies, starting from September 2020, with one month shift, were very compatible with the warming trends in the SSTs. Accordingly, in the Western Black Sea, Marmara and North Aegean marine regions, positive surface air temperature anomalies occurred at 2°C in September-November 2020, 2-2.5°C in October-December, 2-2.5°C in 2020 November-2021 January, 2.5-3.5°C in winter 2021 and 1.5-2.5°C in the January-March period. In the following periods, the anomalies in the surface air temperatures weakened and generally changed between 0.5°C and 1.5°C, except for the significant positive anomalies of 1.5-2°C in the 3-month period of July-September 2021.

The results of the analysis show that, in the Dardanelles and Istanbul Straits, the relatively cold upper current from the Black Sea and the relatively warm undercurrent from the Aegean Sea became similar in terms of temperature values in the 2020 September-2021 March period (especially in the 2020 September-2021 January period). In other words, both the relatively warm currents originating from the Aegean Sea and the relatively cold currents originating from the Black Sea are much warmer than normal during the mucilage period, therefore it can be concluded that not only the surface air temperatures and SSTs of the Marmara Sea, but also possibly the bottom waters during this period were warmer.

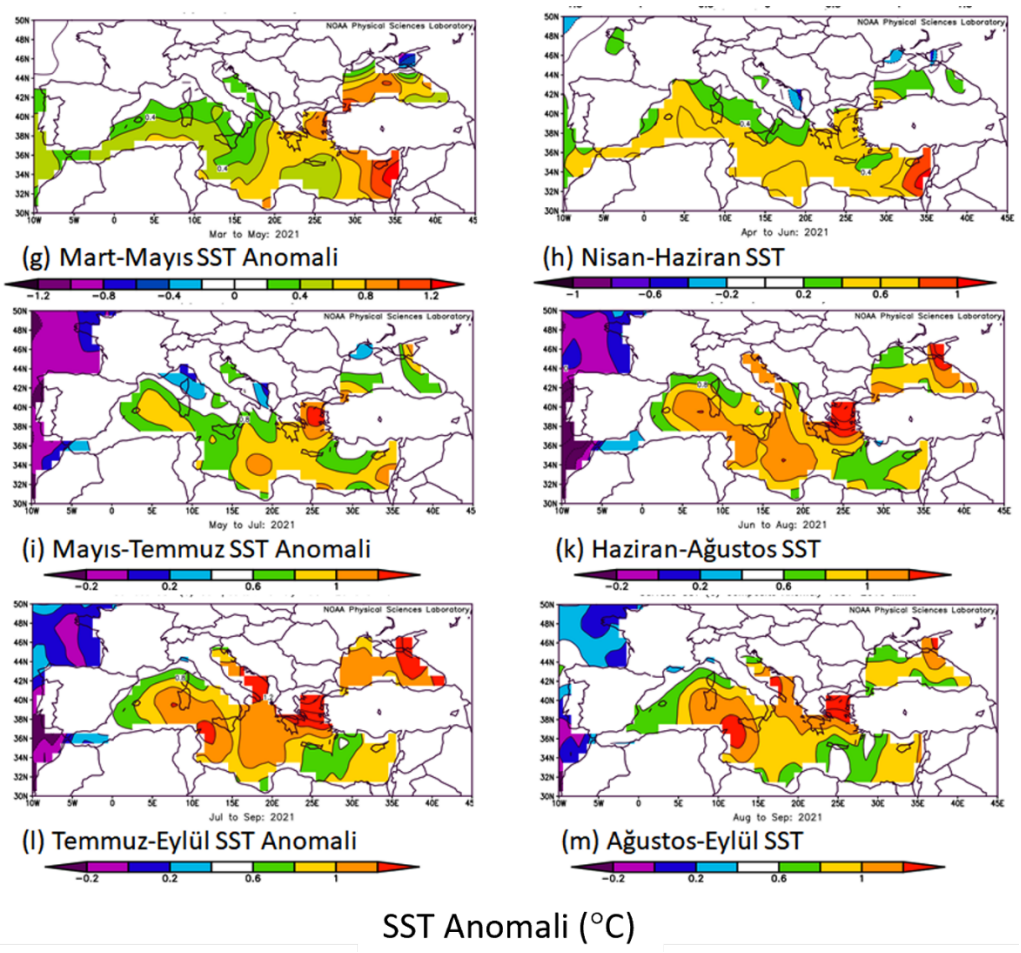


Figure 6(2): Geographical distribution patterns of 3-month composite SST anomalies (C) for the period March 2021-September 2021, seasonal with respect to their normal status (1981-2010) and shifted by one month starting from September 2020.

The conclusion is that long-term "marine heat waves" triggered by these changes and combined with other factors (pollution, biodiversity loss, changes in life and nutrient cycles, oxygen depletion, etc.) play an important role in the rapid emergence of the mucilage problem in a wider area.

3. Mucilage, public health, and socio-economic impacts

As stated in the founding constitution of the World Health Organization (1948) health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity[1]. This definition was approved and accepted by the Grand National Assembly of Turkey (GNAT) and turned into Turkey's legal definition of health. Also, according to Article 25 of the Universal Declaration of Human Rights (UDHR), adopted in 1948, the right to health is within the scope of the right to life, which is a fundamental right[9]. Article 12 of the "Covenant on Economic, Social and Cultural Rights", which is the continuation and explanation of the UDHR also defines the right to health as a right in itself[10]. According to the regulations made in 2004 in Article 90 of the 1982 Constitution, international agreements and conventions approved by the Grand National Assembly of Turkey have the force of domestic law, and it cannot be claimed that these texts are contrary to our Constitution[11]. Health is an absolute condition and right that is necessary for people to lead a socially and economically productive life[12]. In addition, Article 17 of our Constitution mentions the right to live and Article 56 mentions the right to live in a healthy environment[13]. When all these are evaluated together, a healthy environment comes first among the conditions that ensure good health.

Many of the shores of the Marmara Sea are biologically polluted and may pose a risk to human health. Biological pollution means the presence of microorganisms in seawater at such a level and type that is detrimental to human health and the health of other living things. For example, when mucilage accumulates in large quantities, it can turn into a suitable habitat for harmful pathogens and harm humans and other creatures that come into direct contact with the sea. Ingestion of microbiologically contaminated seawater or ingestion of contaminated sea creatures by humans can cause gastrointestinal problems such as nausea, vomiting, fever, and diarrhea. Moreover, the toxins secreted by these microorganisms have various neurological effects on humans; they can cause partial paralysis and numbness. These effects may occur shortly after consuming these foods.

The effects of chemical pollution in the Marmara Sea can manifest themselves in many ways. Heavy metals that accumulate in the tissues of sea creatures and fish may lead to different and serious symptoms in the human body. Metals accumulating in the body, especially in vital organs such as the kidney and heart, can prevent these organs from performing their functions. These can accumulate in the bones, causing severe pain and fractures due to a reduction in bone density. In addition, some of these toxic substances can cross the blood-brain barrier and leave damage to the brain and nervous system, sometimes manifested by irreversible neurological symptoms. Some of these substances (mercury, cadmium, arsenic, etc.) are considered certain cancer-causing substances in humans, according to the International Cancer Agency (IARC), affiliated with the World Health Organization.

Since the pollution in the Marmara Sea is of different levels and contents, it can also cause allergic reactions in the human body. The main signs of allergic reactions on the skin are

[9]https://www.ohchr.org/en/udhr/documents/udhr_translations/eng.pdf
[10]https://www.avrupa.info.tr/tr/avrupa-birligi-temel-haklar-bildirgesi-708
[11]https://www.resmigazete.gov.tr/eskiler/2004/05/20040522.htm#1
[12]Oxford Textbook of PublicHealth, Chapter 7.3
[13]https://www.mevzuat.gov.tr/MevzuatMetin/1.5.2709.pdf

redness, rash, burning, and stinging. Also, even if the infectious agents in the sea do not cause a problem when they come into contact with intact skin, they can cause significant skin infections when they come into contact with tissues such as the eyes and mouth, abrasions, injured/bruised skin and mucous membranes. These infections can occur in any part of the skin with impaired tissue integrity, as well as in the eyes, nose, and female or male reproductive organs.

Moreover, the direct health effects of pollution in the Marmara Sea are expected to increase further with mucilage. Mucilage increases the pollution in the sea even more by creating a barrier between the sea surface and the air, preventing the oxygenation of the sea and the penetration of the sun's rays into the depths of the sea, and causing the sea to warm up, as it increases the ratio of the suspended solids in the sea. Although the content and extent of the pollution in the Marmara Sea are not known exactly, considering the pollution type, load and content of the wastes discharged into the sea, there may be negative effects on public health that cannot be foreseen in the long run.

In addition to all these direct effects, biological and chemical pollution and lack of oxygen cause the extinction of sea creatures, a decrease in their numbers, their migration to other seas and/or the deterioration of the quality of the sea. This situation drastically affects the fisheries as well. In addition to mass fish deaths, mucilage clogs the filters of fishing boats making them inoperable, and blocks the meshes of the fishing nets, making them unable to catch fish. Some fishers eventually stopped fishing in the Marmara Sea and moved their businesses to other seas. The tourism industry has also suffered from mucilage. Hotels, holiday resorts, restaurants, summer houses, and beach facilities in the coastal region are gradually losing their tourism capacity and appeal. Water sports such as diving, swimming, wind and kite surfing, sailing, rowing, as well as boat tours and gastronomic activities are also adversely affected by mucilage. All these economic effects, job and income losses, and increasing anxiety about the future show that the social and spiritual dimensions in the definition of health have not been realized. These social and economic impacts will inevitably increase as the pollution and mucilage problems in the Marmara Sea grow.

Therefore, it is important to discuss the economic costs of the mucilage problem in the Marmara Sea. Such costs have negative effects on different segments of the society, especially vulnerable groups, and exacerbate other existing problems such as fair income distribution. Moreover, all this can become a risk to life itself in the medium and long term.

Considering the similar disasters experienced in the past years, the economic loss caused by the *Mnemiopsis leidyi*, which caused the collapse of the Black Sea ecosystem in 1989, was calculated as 100 million dollars (Kideys, 2002). Although the extent of the economic damage done by the same species in the Marmara Sea in 1994 is not known, mucilage that collapsed to the bottom caused great damage to the seabed ecosystem, the collapse of the hake population and shrimp fisheries, and it took about four years for the ecosystem to recover (Yüksek, 2016; Yüksek, 2021).

Marine mucilage was first seen in the Marmara Sea in October 2007 spanning a large area. It not only caused visual pollution but also survived on the upper layer for months, blocking the meshes of fishing nets and affecting fisheries, causing problems in many commercial and amateur marine vessels and financial losses for industrial facilities taking water from the sea (High, 2021). The socio-economic studies focusing only on fisheries in this period revealed that the decrease in fishing income was 27459 Euros/year on average, and the loss of fishing income was 61.41 percent (Keleş et al., 2020). Considering that the mucilage disaster in 2021 lasted longer and was more intense than in 2007, it is understood that great economic losses in fisheries have occurred.

However, analysis of the mucilage problem needs to go beyond available concrete data. According to Hardin (1968), the basis of environmental problems is the lack of a clear definition of the right to use the commons. The commons, including the seas, are the places where polluters freely release their wastes without any costs, as they are open to everyone's use free of charge. Economic literature defines the cost of waste caused by pollutants to be incurred by society and other living things as “external costs” (Pigou, 1920). The external costs of mucilage can take various forms. Some of the external costs are: The losses in the income of those who make a living from tourism and fishing, the shortcomings in the exports of fisheries products, the loss of marine life, and possible cases of food poisoning that may be encountered in people who consume seafood, the reduction in the participation of these people to the workforce when they fall ill and the increase in health expenditures to solve the problem. In Turkey, the problem of “opportunity cost” also arises because the state budget has limited resources that can be spent more efficiently elsewhere.

The external costs listed above are short-term costs. If effective measures are not taken against the mucilage problem, more significant external costs may arise in the medium and/or long term. Some of these costs are: Decrease in the nutritional quality of marine life; poor nutritional quality of people who feed on these creatures; forced migration of fisheries communities, disappearance and possible extinction of the traditional fisheries culture; the endangerment of the marine species due to intense and continuous pollution, the onset of biodiversity collapse threatening the lives of other living things.

To combat the mucilage problem, private and public sector wastewater treatment plants (WWTPs) should be renewed, the existing regulations should be reviewed, and sanctions should be aggravated. Legal and practical arrangements for the use of commons are the responsibility of governments, and these arrangements are public services that must be performed to increase economic welfare. It is estimated that up to 1 billion dollars is required to equip the WWTPs with advanced biological treatment systems[14]. This is a big cost, but when the external costs of inaction are considered, the cost of taking action seems to be much lower. When the mucilage problem is eliminated, all the above-mentioned costs can be expressed as benefits with economic value. In other words, each measure makes a positive contribution to the economy. Therefore, making a detailed cost-benefit analysis of the mucilage problem is very important while taking precautions.

The biggest threat caused by all environmental problems, including marine mucilage, is that life becomes unsustainable for some living things in the short term and for all living things in the long term. All the 17 interrelated sustainable development goals (SDGs), identified by the United Nations to be met by 2030, especially Goal 14 on "life in water", already are and will be adversely affected by the mucilage problem. Effectively combating mucilage also contributes to the realization of these goals. If we consider environmental problems as risks; countries that define the risks correctly, take the necessary precautions against the risks, and even prevent the risks before they occur will be economically strong.

4. Emerging threats

It is expected that the issue of marine mucilage and other problems that currently affect the Marmara Sea will grow and turn into crises in the coming years. The reasons for this are not only increasing pollution loads, growing biodiversity loss and exacerbating climate change. In addition to these factors, there are also large-scale projects such as the Ergene Deep Sea Discharge system, which started to discharge the wastewater from the Ergene Basin into the Marmara Sea, despite being outside the Marmara Basin, and the Canal Istanbul project, which is still in the planning stage. When these projects are fully implemented, mucilage and similar

[14] https://www.aa.com.tr/tr/politika/tbmm-musilaj-sorununu-arastirma-komisyonu-toplandi-/2323329

environmental disasters can add other layers, making them even bigger and causing vast ecological destruction.

4.1. Out-of-basin pollution: Ergene Deep Sea Discharge system

There are over 2,000 industrial facilities within the borders of Ergene Basin, which is in the northwest of the Marmara Basin, of which 70 percent operate in the textile industry, 15 percent in the food industry, and 10 percent in the metal industry. These facilities intensively use water during processes such as textile dye printing and metal surface coating and discharge almost all this water as wastewater to the receiving environment. The flow rate of the wastewaters is 0.648 m3/sec at the State Hydraulic Works' (DSI) Güneşyaka observation point of the Ergene River, located around the Tekirdağ Province, Saray district and 28,656 m3/sec at the DSI Yenicegörece point around the Meriç district of Edirne Province, which is the location before it meets the Meriç River (Marmara Municipalities Union, 2018). The water used in these industrial facilities after being drawn from underground sources is given to the receiving environment, Ergene River. So much so that the Ergene River no longer flows with its own charm but is rather used as a wastewater line. Therefore, the Ergene River, which is exposed to a wastewater discharge above its own capacity, cannot handle this load any longer.

To solve this problem, the Ergene Basin Protection Action Plan was developed, and Organized Industrial Zones (OIZ) were established in 2012. According to this plan, wastewater from the individual facilities in the OIZ would be discharged after being treated in the OIZ's joint wastewater treatment plant instead of being treated in individual wastewater treatment plants. The plan also arranges for the discharge of this wastewater, which is treated at a rate of 90-95 percent, into the Marmara Sea, which has a larger carrying capacity than the Ergene River. According to this plan, the Ergene River will clean itself over time by working as a piston-flow reactor as a result of the disposal of the bottom sedimentary sludge.

The total landline of the Ergene Deep Sea Discharge system is 82 km long, and the total sea line is 4.5 km long (Figure 7). In this system, treated wastewater is discharged into the Marmara Sea at a depth of 47.5 m and 4.5 km from the shore. In the current dilution calculations made for the discharge to the substrate, the initial dilution is predicted to be 55 times. In the Marmara Sea, it is not possible for the current from the Mediterranean and the current from the Black Sea to mix, since there are significant differences in temperature, salinity, density, and dissolved oxygen parameters between the two currents. Therefore, the discharge into the bottom current will remain suspended between 20-21 meters and will not rise to the surface and reach the shore.

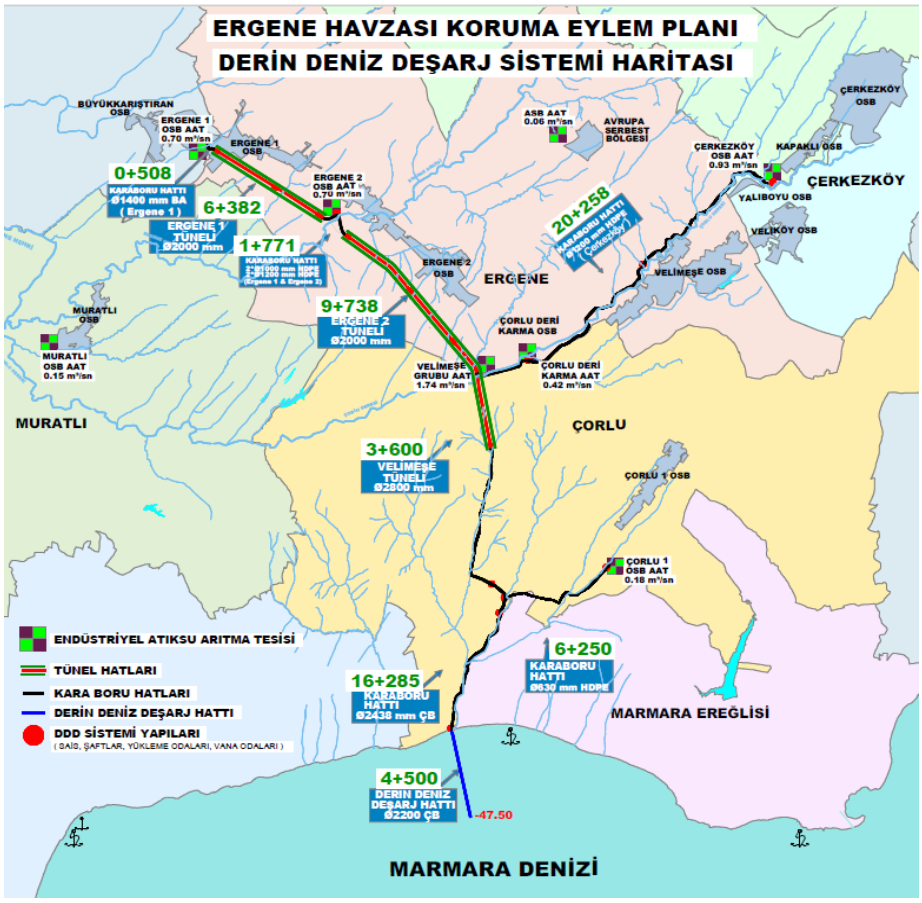


Figure 7. Ergene Deep Sea Discharge System Map (Source: Deep Sea Discharge Project Introduction File[15])

Treated wastewater started to be discharged from the Ergene Deep Sea Discharge System to the Marmara Sea for the first time on 13 November 2020. The first OIZ to supply wastewater to the Deep-Sea Discharge System is the Çorlu Leather Mixed OIZ Wastewater Treatment Plant, with a flow rate of 10,000 m3/day. With the inclusion of other OIZs in the Ergene Basin into the system, this amount is expected to increase to 583,500 m3/day, within 2 years. The full capacity of the Deep-Sea Discharge system is 643,500 m3/day[16]. Therefore, only 1,7 percent of the treated wastewater is currently discharged into the Marmara Sea.

Currently, the Ergene Deep Sea Discharge System has an insignificant effect on the increase of the mucilage problem in the Marmara Sea. However, this system will carry increased levels of pollution load to the Marmara Basin in the future. In addition, it should be accepted that the Ergene Deep Sea Discharge System will not be a sustainable solution as it is an inter-basin wastewater transport project. As a requirement of sustainable water management, ground and surface waters in the Meriç-Ergene Basin should be used cyclically within the basin, instead of being transferred to the Marmara Basin.

[15] Tekirdağ Ergene Deep Sea Discharge Project Introduction File (EIA Report) https://eced-duyuru.csb.gov.tr/eced-prod/duyurular.xhtml

[16] Ergene Deep Sea Discharge Project Introduction File (EIA Report) https://eced-duyuru.csb.gov.tr/eced-prod/duyurular.xhtml

4.2. Potential impacts of the Canal Istanbul project

The Canal Istanbul project, which is still in the planning stage, is also an important threat to the future of the mucilage problem in the Marmara Sea. Canal Istanbul is a seawater canal project that will be built on the European Side of Istanbul and will connect the Black Sea and the Mediterranean, with a length of 45 kilometers, a width of 275 meters, and a depth of approximately 20.75 meters. As seen in Figure 8, the canal will descend from the Black Sea in the north to the Marmara Sea in the south, passing through the east of Terkos Lake, incorporating Sazlıdere freshwater reservoir and Küçükçekme Lake on its way. In order to understand how the mucilage problem and other pollution loads in the Marmara Sea will be affected by this project, which is said to become the second strait in Istanbul, it is necessary to first look at the structure of the Bosphorus.

Figure 8. Canal Istanbul project route (Source: Ministry of Transport and Infrastructure, 2020)

The Marmara Sea connects the Mediterranean and the Black Sea, two very different seas in terms of various parameters such as salinity, oxygen content, nutrient content, temperature, and altitude. When the Mediterranean and Black Sea waters, which are different in many respects, meet in the Marmara Sea and the Straits System, they do not mix with each other and turn into a current instead. The Bosphorus is a natural water passageway. On the upper layer, the water from the Black Sea, which is 55 cm higher on average than the Marmara Sea flows into the Marmara Sea, and then to the Aegean Sea, while the dense and salty Mediterranean water in the lower layer flows into the Black Sea. (Alpar et al., 2000).

The water from the Mediterranean lacking in oxygen, remains under the salty and richly oxygenated Black Sea water, forming the upper 25 meters of the Marmara Sea, and this environment is far from supporting fish life (Saydam, 2018). The Black Sea water, which enters the Bosphorus from the Black Sea through an opening of 50-60 meters, is compressed to 15 meters in front of Salacak and flushes into the Marmara Sea like water coming out of the end of a squeezed hose. On the other hand, the lower layer water from the Marmara Sea continues its journey, which starts at 30-40 meters deep in front of Ahırkapı, towards the Black Sea with reduced salinity, through mixing with water from the upper layer (Figure 9). The reason for this is water from the Mediterranean, which enters the Bosphorus from the Marmara Sea . Although this dense and salty water is stuck at a 5–10-meter layer at the very bottom of the Black Sea exit of the Bosphorus, it still manages to reach the Black Sea (Beşiktepe et al., 1994; Özsoy et al., 2001).

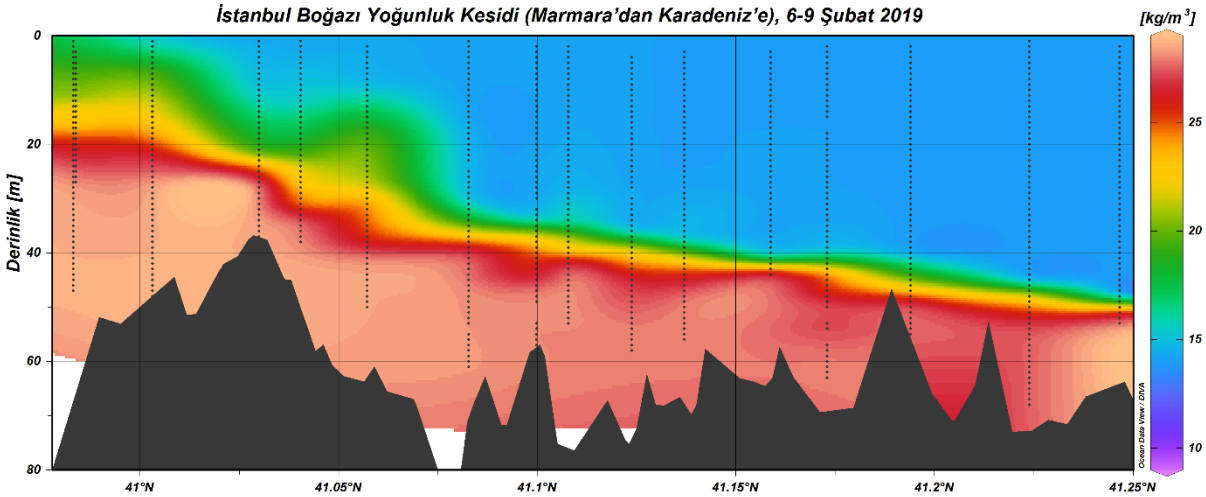


Figure 9. Salinity cross-section along the Bosphorus (Source: METU Erdemli Marine Sciences Institute 2019)

This bottom current is used to transport Istanbul's urban wastewater to the deep waters of the Black Sea. Istanbul produces 3.8 million m3 of wastewater per day (Istanbul Water and Sewerage Administration, 2020). The aim is to clean the Marmara Sea by transporting the wastewater from Istanbul which is given to the bottom water in the Marmara Sea through the deep discharge method, to the Black Sea via the bottom current and thus clean the Marmara Sea. As it is known, water enters the Bosphorus from the Black Sea through an opening of 50-60 meters and exits from an opening of 15 meters with an increased speed, known as the "jet stream", to ensure the continuity of the water flow (Beşiktepe, 2010; Ozsoy, 2016). In this case, the dense Mediterranean water, which does not mix in any way under normal conditions, mixes with the upper water due to this jet exit. When Mediterranean water, which is very rich in organic matter and nutrient salts, mixes with the upper layer, it creates an enabling environment for nutrient formation, with the help of sunlight.

However, the organic load formed on the surface passes into the lower layer over time as it moves towards the Çanakkale Strait, undergoes bacterial degradation with the help of oxygen in deep waters, and moves towards the Bosphorus due to the undercurrent. Atmospheric oxygen is abundant in the Black Sea water in the first 25 meters. However, oxygen cannot pass into the lower water due to stratification. The only source of oxygen for the bottom water is the water from the Mediterranean coming from the Çanakkale Strait, but oxygen disappears as soon as it enters the Marmara Sea (Saydam, 2020). Therefore, the Marmara Sea does not have the oxygen to support fish life at a depth of 25-30 meters.

If realized, the Canal Istanbul project will create a second jet stream due to the natural flow that will occur from the Black Sea to the Marmara Sea and will carry an additional burden that the Marmara Sea cannot handle in terms of oxygen. The Marmara Sea, which cannot even tolerate the current pollution loads, will encounter an additional water load of 22 km3 per year due to Canal Istanbul (Saydam, 2020). Moreover, this additional water will carry the pollution loads coming from the Black Sea. In addition, the last point where the wastewater of the additional population that will live in the new settlement areas planned to be established around Canal Istanbul will also be the Marmara Sea.

In addition to all these, this waterway, which plans to use the Sazlıdere and Küçükçekmece lakes as a natural transit route, will inevitably bring the organic load accumulated on the ground of these freshwater basins for decades to the Marmara Sea. This situation will make a huge impact on the bottom water and seafloor of the Marmara Sea, which are already fighting a battle for survival. All these additional wastes given to the Marmara Sea will serve a nutrient-

dense feast for bacteria, fungi and phytoplankton in the sea, potentially leading to greater mucilage problems.

5. What has been done to solve the mucilage problem?

The mucilage problem in the Marmara Sea started in November 2020 and turned into a disaster in 2021 with the warming of the weather. In June of the same year, immediate actions were taken to solve the problem, and a series of actions were planned to eliminate the causes that created the issue in the medium and long term, some of which have been implemented until today.

First, an online workshop on "Mucilage in the Marmara Sea and Possible Solutions" was held on June 4, 2021, in cooperation with the Union of Marmara Municipalities (MBB) and the then Ministry of Environment and Urbanization. On June 5, the workshop outputs were evaluated in consultation with the water and sewerage general managers and environmental protection and control departments of the cities around the Marmara Sea. On June 6, the final meeting, as a result of which the Marmara Sea Protection Action Plan was formed, was held with the participation of the mayors of Balıkesir, Bursa, Kocaeli, Istanbul and Tekirdağ as well as Yalova and Çanakkale, MBB committee members, governors, members of the Parliamentary Environment Commission, representatives of the then Ministry of Environment and Urbanization, representatives of the Ministry of Agriculture and Forestry, water and sewer general directors of the public administrations, heads of environmental protection and control departments, representatives of TÜBİTAK MAM and academics working on the Marmara Sea. The action plan, which consists of 22 items, was signed with the senior executives of all the provinces that have a coast on the Marmara Sea and presented to the public on 6 June.

Within the scope of the Circular 2021/12 of 07/06/2021 on the implementation of the action plan, a mucilage removal campaign was launched on 8 June 2021 with the cooperation of the then Ministry of Environment and Urbanization, all provinces that have a coast to the Marmara Sea and the Marmara Union of Municipalities. The campaign was carried out on 8 June-7 July 2021, with the involvement of 1550 people, 46 boats and a large number of land cleaning equipment. A total of 11 thousand m3 of mucilage was collected from the Marmara Sea. 6,640 m3 of this was collected from Istanbul. Having the largest share in mucilage formation, the province of İstanbul joined the campaign with 13 mobile cleaning teams consisting of 70 people, 7 sea surface cleaning boats and 11 vacuum trucks under the responsibility of the Istanbul Metropolitan Municipality’s Environment Protection and Control Department, Marine Services Branch. All areas with mucilage accumulation were cleaned.

The Marmara Sea Action Plan Science and Technical Board, consisting of 21 scientists from 11 different universities was established together with TÜBİTAK under the auspices of MBB, in accordance with the 1st article of the Marmara Sea Protection Action Plan, The Board developed scientific recommendations for the activities of the Marmara Sea Action Plan Coordination Board in order to find solutions to the mucilage problem with a holistic approach.

Within the scope of the 2nd article of the action plan, "Preparation of the Marmara Sea Integrated Strategy Plan", 7 provinces bordering the Marmara Sea completed their own strategic plans and submitted them to the abolished Ministry of Environment and Urbanization. Within the framework of the Action Plan, "Marmara Sea Integrated Strategic Plan" for the period 2021-2024 was prepared by the Ministry to determine and implement policies and strategies to achieve good environmental status in the Marmara Sea Basin and announced on the official website on November 24, 2021.

The integrated strategic plan includes the establishment of a governance structure for the protection of the Marmara Sea Basin; designation of the basin as a "protected area" and

ensuring its adaptation to climate change; detection, reduction, control and prevention of pollutants in the basin (reduction, control and prevention of point source pollutants, prevention of pollution and effective management of non-point pollution sources); effective management of pollution from maritime activities; expanding zero waste management system in the basin; implementing circular economy principles and ensuring resource management; supporting R&D studies for the protection of the basin; strengthening participation, training, information and awareness; developing a risk management system for the protection of the basin; strengthening environmental audit capacity; developing a monitoring, evaluation and reporting system[17].

In addition to these, within the scope of Article 3 of the Marmara Sea Protection Action Plan, "Initiating efforts to designate the entire Marmara Sea as a protected area", the Marmara Sea and Islands were determined and declared as a Special Environmental Protection Area with the Presidential Decree No. 4758 dated November 4, 2021.

Also, in accordance with the Ministry's Delegation of Authority Circular No. 2011/9, ship-borne marine pollution inspections are carried out from the sea with 3 inspection boats, from the air with 3 UAVs, on land with mobile vehicles within the maritime borders of Istanbul, while the coast and sea surface are continuously monitored with 83 cameras placed on the coasts. Administrative sanctions are imposed on marine vessels found to cause marine pollution in accordance with the Environment Law No. 2872. 13 licensed waste reception vessels collect liquid domestic waste and petroleum derivative wastes from ships and send them to Haydarpaşa Waste Acceptance Facility for disposal and petroleum derivative wastes for recycling. The shipyards are frequently inspected and the scraping activities in the shipyard pools are controlled to ensure that necessary precautions are taken. Administrative sanctions are imposed on shipyards that cause pollution by operating without taking the necessary precautions in accordance with the Environment Law No. 2872.

In addition, within the scope of the "Zero Waste Blue Movement", which is a continuation of the Zero Waste Project, the Circular on the Preparation and Implementation of the Provincial Action Plan for Marine Litter was published. The Marine Litter Provincial Action Plan, the preparatory work of which was completed by the Marine Litter Management Commission established in accordance with the Circular, was decided at the Local Environmental Board Meeting held on 03/12/2019 under the auspices of the Governorship of Istanbul. Within the scope of the action plan, activity reports for the collection of marine litter are submitted to the Provincial Directorate of Environment and Urbanization on a quarterly basis.

Controlling wastewater discharges to the Marmara Sea is also one of the important steps. Within the scope of converting all existing wastewater facilities in the region into advanced biological treatment plants, which is Article 5 of the Marmara Sea Protection Action Plan, Istanbul Water and Sewerage Administration (ISKI) has started to implement 22 projects such as new facility construction, facility revision, capacity increase and collector construction.

Finally, the Grand National Assembly of Turkey's (GNAT) Mucilage Investigation Committee submitted a 570-page report to the Speaker of the Parliament in April 2022, after 4 months of work. On April 27, 2022, the mucilage report was accepted by the General Assembly of the Grand National Assembly of Turkey. The proposed law envisages the obligation to establish Advanced Biological Wastewater Treatment Plants for the provinces such as Istanbul, Kocaeli, Yalova, Bursa in the Marmara Basin and the provincial municipalities bordering these provinces.

[17] Marmara Denizi Bütünleşik Strateji Planı 2021-20214
https://webdosya.csb.gov.tr/db/cygm/icerikler/marmara-den-z--butunles-k-stratej-k-plani-20211124094432.pdf

6. Evaluation and solution proposals

Unless the factors such as point and diffuse pollution, loss of biodiversity, and rising sea temperature that create the problem of mucilage in the Marmara Sea are not taken under control, it is inevitable that this problem will grow. The costs of unresolved problems to nature and society will grow, and these costs may deepen existing socio-economic inequalities and cause irreparable crises. Therefore, realistic risk management needs to be developed and put into practice without waiting for the emergence of further crises. This is because the solutions offered after the crisis has started are often superficial and tend to miss the roots of the problem. Therefore, there is a need for a roadmap that will include risks and measures from the very beginning.

This roadmap is the Marmara Sea Protection Action Plan. The 22 items in the action plan should be carefully examined as they determine the direction of the fight against mucilage. When these items are analysed according to action areas and topics, it becomes clearer how much they touch the causes and consequences of the increase in mucilage. Identifying the untouched points will play a vital role in the applicability and success of the action plan and ultimately in saving the Marmara Sea. Therefore, in the last part of this study, evaluations of the current action plan and various suggestions are presented to make this action plan more effective, inclusive and fair.

As a result of the examination of 22 articles of the Marmara Sea Protection Action Plan, the following results emerge. The first 4 articles of the action plan were realized, and the Coordination Board and the Scientific and Technical Board were established; the Integrated Strategy Plan for the Marmara Sea was prepared and shared with the public; the Marmara Sea and the Islands were declared as a Special Environmental Protection Area and studies were carried out for the physical cleaning of mucilage.

Articles 5, 6, 7, 8 and 9 of the action plan are related to the wastewater treatment plants (WWTPs) in the region discharging to the sea as onshore point sources of pollution, including updating and implementing their discharge standards; converting all of them to advanced biological treatment plants; using treated water on-site in a circular manner; accelerating the transition of OIZs to advanced treatment; and realizing public-private partnerships (PPPs) to facilitate the construction and operation of WWTPs. While the work on items 5, 6, 7 and 8 is still ongoing, the most serious challenge is the budget required for these actions. The PPP model has been proposed due to the high technology and energy costs of WWTPs from initial installation to operation. However, even though state budget resources are limited in Turkey, it is important to keep in mind that unconditional inclusion of high budget projects within the scope of PPP does not always bring positive results for the whole society and nature. It should be remembered that the treasury-guaranteed projects realized within the scope of PPPs impose large costs on the public, and investment decisions should be made by calculating the additional burdens that treasury-guaranteed WWTPs may bring.

Article 10 of the action plan includes regulations on ships as marine point sources of pollution and Article 11 includes regulations on shipyards. Article 12 deals with the monitoring and inspection of WWTPs discharging into the Marmara Sea and increasing the number of existing monitoring points in the Marmara Sea. Regarding this article, in the current practice, monitoring of all terrestrial inputs discharged to the sea is carried out seasonally. For the realization of this action item, all terrestrial inputs discharged to the Marmara Sea should be monitored monthly by the relevant municipalities in terms of physical, chemical and biological variables. In areas with a strong dynamic structure such as the Marmara Sea, monitoring must be carried out at least monthly and the operational infrastructure must be in place to take emergency measures when necessary. There is an article in the action plan not only on wastewater but

also on solid wastes. Article 13 mentions the preparation of action plans covering waste management and marine litter on the coasts of the Marmara Sea.

Article 14 of the action plan is related to agricultural activities as diffuse sources of pollution and aims to reduce nutrients such as nitrogen and phosphorus, which are transported to the sea by both precipitation and over-irrigation, through good or organic agricultural practices and efficient irrigation techniques (pressurized and drip irrigation). However, efficient water use should not be limited to the agricultural sector. It should not be forgotten that water savings achieved through methods such as gray water reuse and rain harvesting in industry and settlements both reduce the pressure of use on primary water resources and protect them better and reduce the loads on WWTPs. Because less water use means less wastewater discharge to the Marmara Sea. At the beginning of 2021, with the Regulation on the Amendment of the Planned Areas Zoning Regulation, the use of rain cisterns in new settlements over 2000 m2 has already become a legal obligation. Istanbul Metropolitan Municipality, on the other hand, has made this threshold compulsory for new settlements larger than 1000 m2 and is working to make gray water systems compulsory. These current efforts to save domestic water use should be linked to this action plan with an additional article.

Articles 15, 16 and 17 of the action plan support the creation of artificial wetlands and buffer zones in stream beds to prevent the watersheds that end in the Marmara Sea from carrying pollution into the sea; reducing wastewater from the olive and cheese farming sectors; and reducing the use of chemicals for hygiene purposes and replacing them with organic cleaning products. Complementing point 15, an action to increase both the quantity and quality of green spaces in urban and rural areas would be useful to reduce polluted water from residential areas to the sea through rainfall. In other words, the reorganization of both urban and rural areas to increase green space through nature-based methods to restore and protect the hydrological cycle should be included as an addendum to Article 15.

Articles 18, 19 and 20 of the action plan are related to the fisheries sector. In these three articles, action areas are defined to clean ghost nets, which are the enemy of biodiversity, within 1 year; to switch to ecosystem-based fisheries; and to provide economic support to fishers affected by the mucilage disaster. These items, which concern the marine ecosystem and biodiversity, are complementary to each other. However, actions such as preventing coastal erosion; protecting sandy beaches by reducing coastal embankments; protecting important habitats, spawning grounds, strait systems and gulf areas from all kinds of professional fishing activities should be added to Articles 18 and 19 to expand their scope. The first step in reducing the fishing pressure that weakens biodiversity is to determine the pressures, biological processes and catchable status of the stocks in the Marmara Sea and to draw up an appropriate management plan for "sustainable fishing". First of all, the status of small pelagic fish stocks that eat plankton in the Marmara Sea should be determined and the catchable stock criteria (catch size, fishing area, catch amount, fishing technique, etc.) should be identified. Although purse seine fishing, which is the most important fishing method that negatively affects the pelagic system, should be stopped immediately, since this will not be very feasible, it is necessary to increase the inspections for on this kind of fishing and to ensure that the sanctions and penalties are deterrent. In addition, important regulations in fisheries management (narrowing the fishing season, setting quotas, keeping regular catch records in Marmara, etc.) should be revisited. Articles 18 and 19 should be reorganized to include all these issues.

In addition to item 20, research should be planned and supported to cover how fisheries are not the only sector affected by the mucilage disaster, but how many other sectors such as maritime trade, amateur maritime and tourism are affected and their economic losses. It would also be useful to include an article for this purpose in the action plan.

Article 21 of the action plan calls for efforts to raise citizens' awareness of all forms of marine pollution, including mucilage. The effectiveness and sustainability of this action item requires, first and foremost, effective public participation. The Marmara Sea is an indispensable asset for humans, other living creatures, and future generations at every stage of both vital and economic activities. Therefore, it is essential that the public participates in the decisions taken at every stage from planning to implementation in the use and protection of the Marmara Sea. The way to save the Marmara Sea is not only through creating new technological solutions but also through a political and social transformation that will improve our relationship with nature. Therefore, this article should emphasize comprehensive and real participation that is more advanced than the level of informing citizens.

The last article of the action plan deals with the issue of reducing the inflow of cooling water and hot water from thermal facilities, which have a share in the heating of the coastal waters of the Marmara Sea. This thermal pollution, which harms the marine ecosystem and biodiversity, is important and every step to be taken in this regard is necessary. However, these factors alone are not decisive in increasing the temperature of the Marmara Sea. In the action plan, the issue of global warming, which plays the main role in the warming of the sea, and the actions that can be taken regarding climate change mitigation and adaptation are not mentioned. The last article should be expanded in this direction. In addition, taking into account that global warming will increase in the coming years, precautions and special measures should be taken for all other actions according to models, forecasts, and scenarios.

Another missing element in the action plan is basin-based management. This management model, which is accepted in the world and in Turkey, means that each basin manages its own water within its own boundaries. The Marmara Sea is an inland sea where the waters of two of Turkey's 25 basins, the Marmara Basin and the Susurluk Basin, end. It is extremely inconvenient to discharge industrial wastewater from the neighbouring Meriç-Ergene Basin into the Marmara Sea, which is facing a mucilage problem because it has difficulty in carrying even the intense wastewater load of these two basins. Although the Ergene Deep Sea Discharge project, which is currently being used at a very low capacity, does not have a significant contribution to today's mucilage problem, its negative effects on the sea will increase as the rate of use of the system increases. The way to save the Ergene River from heavy pollution should not be to sacrifice the Marmara Sea. The Ergene River can be cleaned with nature-based solutions that will not overflow the geographical boundaries of the Meriç-Ergene Basin. Therefore, an article should be added to the current action plan to prevent the entry of pollution loads from outside the basin into the Marmara Sea.

In addition, it should be emphasized in an article in the action plan that reductionist methods such as the release of mucilage-degrading or decomposing bacteria into the Marmara Sea should be avoided. Such experiments with a huge and complex ecosystem such as the Marmara Sea may have unpredictable and negative consequences. It should be clearly emphasized from the very beginning that such methods, which have the risk of further increasing the loss of biodiversity, which is one of the important causes of the mucilage problem, should not be preferred.

There is no article in the action plan to cancel the Canal Istanbul project. Canal Istanbul, if built, will not only change the soil and topography but will also change the structure of the Marmara Sea and the Black Sea and may cause unforeseen disasters. This project will trigger more migration to Istanbul, which has already exceeded its ecological thresholds and will increase urban water use and thus wastewater production, resulting in a further increase in wastewater discharged into the Marmara Sea. Moreover, the nutrient and pollution load that has accumulated over decades at the bottom of the water sources that will join the canal (Sazlıdere reservoir and Küçükçekmece Lake) will descend into the sea with the canal's operation. Due to the fact that it will trigger such major negative changes, the action plan should include an article on the immediate cancellation of the Canal Istanbul project.

Another factor that is not mentioned in the action plan is the ever-increasing population in the cities bordering the Marmara Sea due to migration. In order to prevent and/or reduce vulnerability to mucilage and other environmental disasters in the Marmara Sea and the Marmara Region, steps must be taken to control the swelling population. For this, the causes of migration should be identified, and population planning should be made and put into practice. Although population movements are not the direct subject of this action plan, any action plan without addressing the population dimension will be inadequate.

There is no provision in the action plan to identify and calculate the public health and socio-economic dimensions of mucilage. Problems whose effects on society are not measured realistically grow without solutions because they cannot be controlled. Therefore, such an article should be included in the action plan.

There is also a conspicuous absence of an article in the action plan stating that the problem of mucilage in the Marmara Sea is not only a domestic issue in Turkey but also an international issue as it connects two international seas. In order to protect the Marmara Sea, dialogues, experience sharing and cooperation should be established with the countries bordering the Baltic, Adriatic, Tyrrhenian, and Alboran seas, which have had mucilage problems in the past. Such collaborations to be established within the framework of the mucilage problem can be a guide and catalyst in overcoming the factors that block and complicate the process of saving the Marmara Sea. Therefore, this issue should be included in the action plan as a separate item.

Finally, a comprehensive and realistic budget study should be carried out urgently for the realization of the action items in the Marmara Sea Protection Action Plan and the measures and precautions proposed within the scope of this information note. Actions without a clear budget are destined to remain on paper. The cost of such comprehensive actions is undoubtedly high. However, in light of the discussions presented in this briefing note, the cost of inaction on the mucilage problem to nature, society, and future generations will be much higher. Although budgetary resources are limited, as more resources will be needed to tackle worsening problems in the medium and/or long term, immediate implementation of these actions will lead to the more rational use of resources and contribute to sustainability. One of the most important tasks of policymakers is to ensure both security (internal and external security) and healthy environmental conditions for their citizens. Moreover, in this era of risks, countries that protect human health with a healthy environment, ensure food security, rationally use living resources and preserve biodiversity will become stronger and more resilient in the face of current and potential crises.

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