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# An overview of the Black Sea pollution in Turkey

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## ABSTRACT

In the last four decades**,** the Black Sea has suffered important changes induced by human activities. 162 million people live in the catchment area of the Black Sea and impose extraordinary demands on its resources. Waste from towns and cities, farms and factories flow into the Black Sea; some come directly from the coast, but most flows relentlessly from the region's major rivers, River Danube, Dnieper and Dniester. Hence, future trends will depend largely on human-related menaces. Depending on place and time ecologists have been principally interested in eutrophication, heavy metals, synthetic chemicals, radionuclides sedimentation, acid-rain and hot water. Airborne pollution also contaminates the sea; while the consequences of a changing climate brought about by greenhouse gases build up in the atmosphere certainly seem to add to the stress already faced by the Black Sea environment**.** A special threat comes from the many big ships or petrol tankers. Unremitting pressure from the effects of the fishing industry and the tourism activities are destroying the natural life that attracts thousands of people to the region every year. It is not surprising that the Black Sea is one of the world's most threatened marine ecosystems. This review is to make a general assessment of the pollution of the Black Sea coast of Turkey.

**KEYWORDS:** Black Sea, pollution, heavy metals, Marine Strategy Framework Directive.

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## 1. Introduction

The environmental problems in the Black Sea resulting from anthropogenic activities are mainly pollution and eutrophication process, accompanied by natural variability and climatic changes, which are evinced by stagy changes in its ecological system and resources. However, anthropogenic activities are with no doubt presently the powerful driver of change in the Black Sea ecosystem at all levels of organization. In the Black Sea coasts, uncontrolled industrial and domestic wastes are either deposited into or stored at a variety of land and water-based disposal sites. The need for economic development apparently either blinded or damaged our view of what constituted a fine life. Ecosystem did perform quite well in treating some substances, which further contributed to our disregard for the hazards caused by wastes. Environmental crisis of the Black Sea is well related to the unique characteristics of the marine environment. The Black Sea is semi closed and the aeration of the deep waters by lateral flows is low. In addition, strong density stratification effectively inhibits vertical mixing.

One of the very depressing tasks scientists will become to face in coming years is the re-evaluation of the framework for the assessment of ecological threats. The aim of this review is to shed light on heavy metals and other pollutants in the Black Sea. Such information would be helpful in the design and implementation of scientific research projects and papers. Another aim is to represent that the wide, multi-disciplinary approach is an effective mean of defining and evaluating likely risks to marine sources and the users of the resources**.**

### Physical properties of the Black Sea

The Black Sea, which is a semi-closed sea, is located between the 40°55' and 46°32' latitudes north and the 27°27' and 41°42' longitudes east. The surface area of the Black Sea is 423,000 $km^2$. The sea's greatest width is 1 200 km. The maximum depth of the Black Sea basin is 2 212 m and its average depth 1 300 m. The total volume of the sea is 547 000 $km^3$, 87% of which is covered with oxygen-poor water (Zaitsev and Mamaev, 1997; Borysova et al., 2005). Its surface area is five times smaller than its catchment basin (Mee, 1992; Unluata et al., 1993). The catchment area of the Black Sea covers entirely or partially 23 countries; six countries are located in its coastal zone and 17 countries are closely linked with the sea via the largest European rivers that flow into the sea. Approximately 162 million people live in the Black Sea Basin, and up to twelve million tourists visit the region annually (Borysova et al., 2005). It's bordered by Turkey, Bulgaria, Romania, Ukraine, Russia and Georgia. It connects the Mediterranean Sea first through the Bosporus Strait, then through the Sea of Marmara and the Dardanelles Strait, then the Aegean Sea. Many rivers flow into the Black Sea including Danube, Dnipro, Don, Dnieper, Kızılırmak, Yeşilırmak and Sakarya. Major rivers of the Black Sea are given in Table 1. Due to the excessive input of freshwater, which causes low salinity in the top waters of the Black Sea, and inflow of saline Mediterranean waters into the deep basin, stable salinity stratification occurred. The Black Sea Basin is under pressure by various pollutants (Figure 1). The dumping of those wastes in the Black Sea provides a significant source of metal and nutrients input.

**Table 1.** Major rivers of the Black Sea (from Zaitsev and Mamaev, 1997).

| Name | Catchment Area km | Length km | Total Runoff $km^3$/year | Sediment Discharge $10^6$ t/year |
|---|---|---|---|---|
| **Danube** | 817 000 | 2 860 | 208 | 51,7 |
| **Dniester** | 71 990 | 1 328 | 10,2 | 2,50 |
| **Dnieper** | 505 810 | 2 285 | 51,2 | 2,12 |
| **Southern Bug** | 68 000 | 857 | 3,0 | 0,53 |
| **Rioni** | 13 300 | 228 | 12,8 | 7,08 |
| **Çoruh** | 22 000 | 500 | 8,69 | 15,13 |
| **Inguri** | 4 060 | 221 | 4,63 | 2,78 |
| **Kodori** | 2 030 | 84 | 4,08 | 1,01 |
| **Bzyb** | 1 410 | - | 3,07 | 0,60 |
| **Yeşilırmak** | 36 100 | 416 | 4,93 | 18,0 |
| **Kızılırmak** | 78 200 | 1151 | 5,02 | 16,0 |
| **Sakarya** | 65 000 | 790 | 6,38 | - |


**Figure 1.** The Black Sea Basin: Under the various pollution affect (data taken from Rouholahnejad et al., 2013 dataset)

This layer incessantly clashes with the limit between the oxygen-opulent and the oxygen-low water. A look at the whole flow regimes shows that there are great-scale cyclonic systems in the West and East basins. These East and West cyclonic current systems cause both the halocline in the central regions and the limit between the oxygen-opulent and the oxygen-low water to rise. This boundary, which is at 70-150 m. in the central parts of the cyclonic vortex system, is at 200-250 m. along its edges. In general, the coastal regions, or continental shelf, are completely lined by oxygen-rich water. Consequently, the leisurely run of oxygen-rich waters off the Mediterranean entering right ahead the straits, is not sufficient to balance

and provide the oxygen needed by the organic matter in the sea Thus, there is all the time an oxygen insufficiency down the halocline. The basin is known to have been characterized by this condition already 7 000 years ago (Sorokin, 1983). Since the Black Sea is a relatively fertile region, the oxygen-poor waters at depths below the photosynthetic layer are biogenic in origin. Due to the fact that sulphate is used as a resource of oxygen in the biological degradation process, the sea bottom is covered with a layer of hydrogen sulphide-having water, making life for many organisms unfeasible at these depths. As a result of the abundant rainfall, low evaporation and the input of fresh inland waters, the water budget in the surface waters of the Black Sea always exhibits a surplus, with the result that these surface waters flow directly into the Sea of Marmara through the Bosphorus. The reverse current system in the Bosphorus, meanwhile, carries the saline waters of the Mediterranean into the deep basin of the Black Sea. Based on salinity data for 1986 and 1987, the annual amount of water entering and exiting through the Bosphorus has been estimated at around 312 and 612 $km^3$ / year, respectively (Özsoy et al., 1988). Owing to anoxia in major parts of deeper waters, pelagic and benthic organisms are mostly absent. The structure of the Black Sea ecosystem differs from its neighbouring Mediterranean Sea by a lower species variety (ratio of the Mediterranean to the Black Sea for species richness is three to one) and the dominant groups are different. But the total biomass and productivity of the Black Sea is pretty higher. The Black Sea is one of the most important European seas; it contributes significantly to the regional economy as a source of fisheries, tourism, oil production and transport. Dominant industries in the littoral countries are shown in Table 2.

**Table 2.** Dominant industries in the littoral countries (from Borysova et al., 2005).

| Country | Dominant Industry |
|---|---|
| Bulgaria | Energy, coal industry, metallurgy, chemical industry |
| Georgia | Energy |
| Romania | Energy, coal industry, metallurgy, chemical industry, machine-building, oil industry, petroleum refining industry |
| Turkey | Energy, chemical industry |
| Russian Federation | Energy, coal industry, metallurgy, chemical industry, machine-building |
| Ukraine | Energy, coal industry, metallurgy, chemical industry, machine-building, oil industry, petroleum refining industry |

## The Turkish Black Sea Cities

The main area of Turkey, known as Anatolia, is in Asia while Turkish Thrace, representing about 3% of the nation's total area, is in Europe. Its capital is Ankara, and Istanbul is the largest city. About 80 million people live in Turkey. One of the most critical developments of the last decades, as critical as the population explosion, is the vast shift of population from the countryside to the cities. The Turkish Black Sea coastal towns and major rivers were shown in Figure 2.


**Figure 2.** The Black Sea coastal towns and major rivers

According to Turkish Statistical Institute (TURKSTAT, 2016) data (available online at: www.tuik.gov.tr) waste generation per capita and municipal wastes in the major cities bordering the Turkish Black Sea coast were as following;

**Sinop**: The population of 2015 is 204 133 persons. In 2014, average amount of waste per capita was 1.41 kg / person day and the amount of municipal waste collected was 57 592 tons / year.

**Artvin:** The population of 2015 was 168 370 persons. In 2014, average waste per capita was 1 kg / person day and the amount of municipal waste collected was 37 501 tons / year.

**Rize:** The population in 2015 was 328 979 persons. In 2014, average amount of waste per person was 0.97 kg / person days and the amount of municipal waste collected was 78 516 tons / year.

**Trabzon:** The population in 2015 was 768 417. In 2014, average amount of waste per capita was 0.67 kg / person day and the amount of municipal waste collected was186 60 tons / year.

**Giresun:** The population in 2015 was 428 686. In 2014, the average amount of municipal waste per capita was 1.12 kg / person-day and the amount of municipal waste collected was 112 929 tons / year.

**Ordu:** The population in 2015 was 728 949. In 2014, the average amount of waste per capita was 0.8 kg / person days and the amount of municipal waste collected was 186 064 tons / year.

**Samsun:** The population in 2015 was 1 279 884. In 2014, the average amount of waste per capita was 0.93 kg / person days and the amount of municipal waste collected was 369 816 tons / year.

**Kastamonu:** The population in 2015 was 372 633. In 2014, the average amount of waste per capita was 1.72 kg / person day and the amount of municipal waste collected was 129 901 tons / year.

**Zonguldak:** Population in 2015 was 595 707. In 2014, the average amount of waste per capita was 1.21 kg / person day and the amount of municipal waste collected was 183 989 tons / year.

**Bartın**: The population in 2015 was 190 708. In 2014, the average amount of waste per capita was 1.3 kg / person day and the amount of municipal waste collected was 41 393 tons / year.

**Düzce**: Population in 2015 was 360 388. In 2014, the average amount of waste per capita was 1.49 kg / person day. And the collected municipal waste amount was 122 298 tons / year in 2014.

**Sakarya**: In 2015 population was 953 181. In 2014, the average amount of waste per person was 1 kg / person day and the amount of municipal waste collected was 339 826 tons / year.

**Kocaeli**: The population in 2015 was 1 780 055. In 2014, The average amount of waste per capita was 0.91 kg / person day and the amount of municipal waste collected was 573 414 tons / year.

**İstanbul**: The population in 2015 was 14 657 434. In 2014, the average amount of waste per person was 1.16 kg / person day and the amount of municipal waste collected was 6 064 688 tons/year.

**Kırklareli**: Population in 2015 was 351 684. In 2014, the average amount of waste per person 1.3 kg / person day and the amount of municipal waste collected is 129 801 tons / year.

**Tekirdağ:** Population in 2015 was 937 910. In 2014, the average amount of waste per person was 1.2 kg / person day and the amount of municipal waste collected was 396 813 tons / year. Population and waste generation patterns along the Turkish Black Sea coast are given in Figure 3.

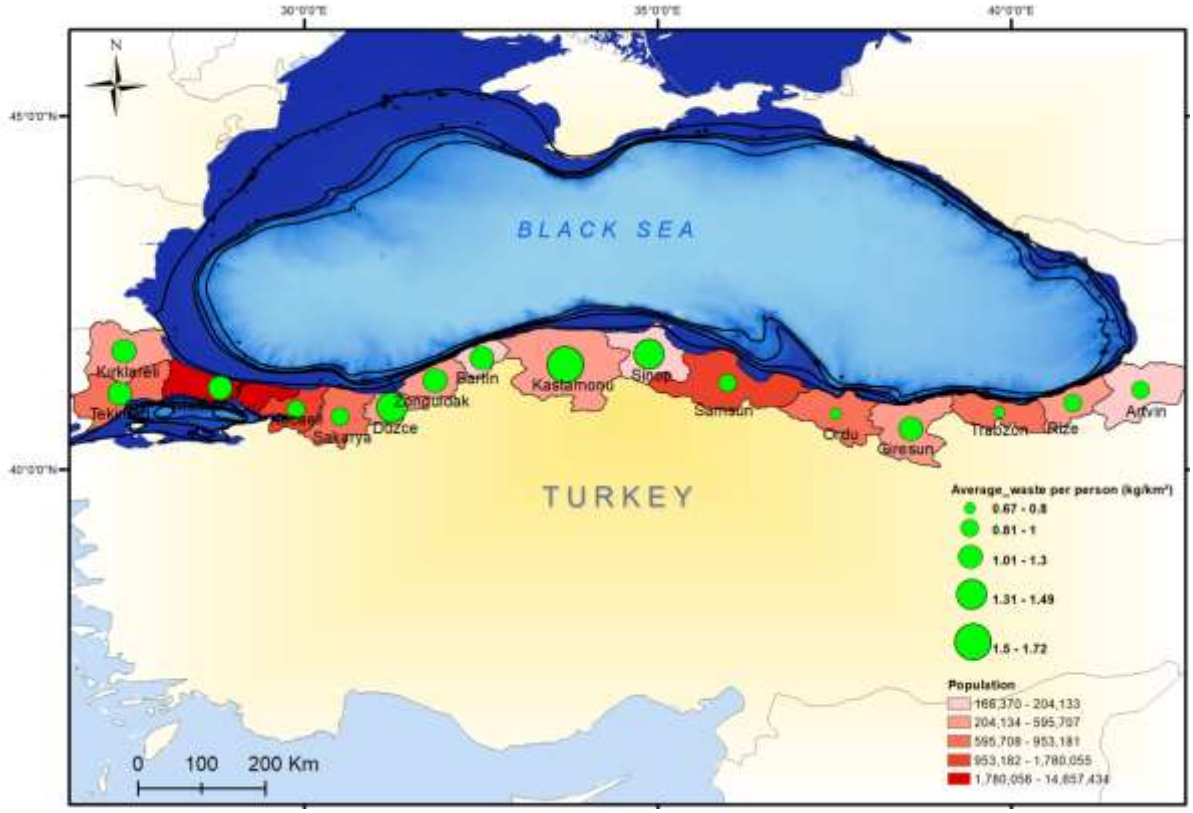


**Figure 3.** Population and waste generation along the Turkish Black Sea coasts (data taken from TURKSTAT, 2016 dataset)

**Biomonitors of the Black Sea pollution**

Being semi-enclosed, and often having slow rates of water renewal, the Black Sea does not have the same cleaning capacity as the open oceans. Until recently, several cases of on the ragged edge of ecological disaster as a result of industrial and municipal discharges including direct dumping from ships, oil pollution and agricultural run-off have been observed (Figure 4). The Black Sea is one of the largest areas of brackish water in the world, eutrophication, combined with industrial pollution, has degraded marine ecosystem (Zaitsev and Mamaev, 1997; Zaitsev, 2008). Because of its high rates of slow rate of water renewal, the Black Sea is particularly vulnerable to pollution namely, the

contaminants tending to accumulate without degrading. Industrial pollution, particularly from rivers, mining and the dumping of dredging and industrial waste, has also worsen the situation for fragile ecosystem of the region. Pollution is usually associated with anthropogenic activities, but how does it affect the aquatic environment, for the biota that live in it?

Research in the Black Sea has revealed that human inputs and discharge from sewers as well as industrial discharges directly flow into the rivers and the sea (Bakan and Büyükgüngör, 2000; Bakan and Özkoç, 2007; Altaş and Büyükgüngör, 2007; Bat et al., 2009). Aquatic pollution may be defined as multitude of human activities that in some way degrade the environment, from unsightly rubbish tips to the less obvious addition of chemical and organic waste to rivers and seas. There are many different types of pollution that change the living potential of an aquatic ecosystem. Using water for cooling changes the temperature of the water and warm water holds less oxygen than cold, creating a problem for the aquatic organisms. It may also affect the life cycle of the organisms that are dependent on a temperature stimulation to start reproduction or tolerance.

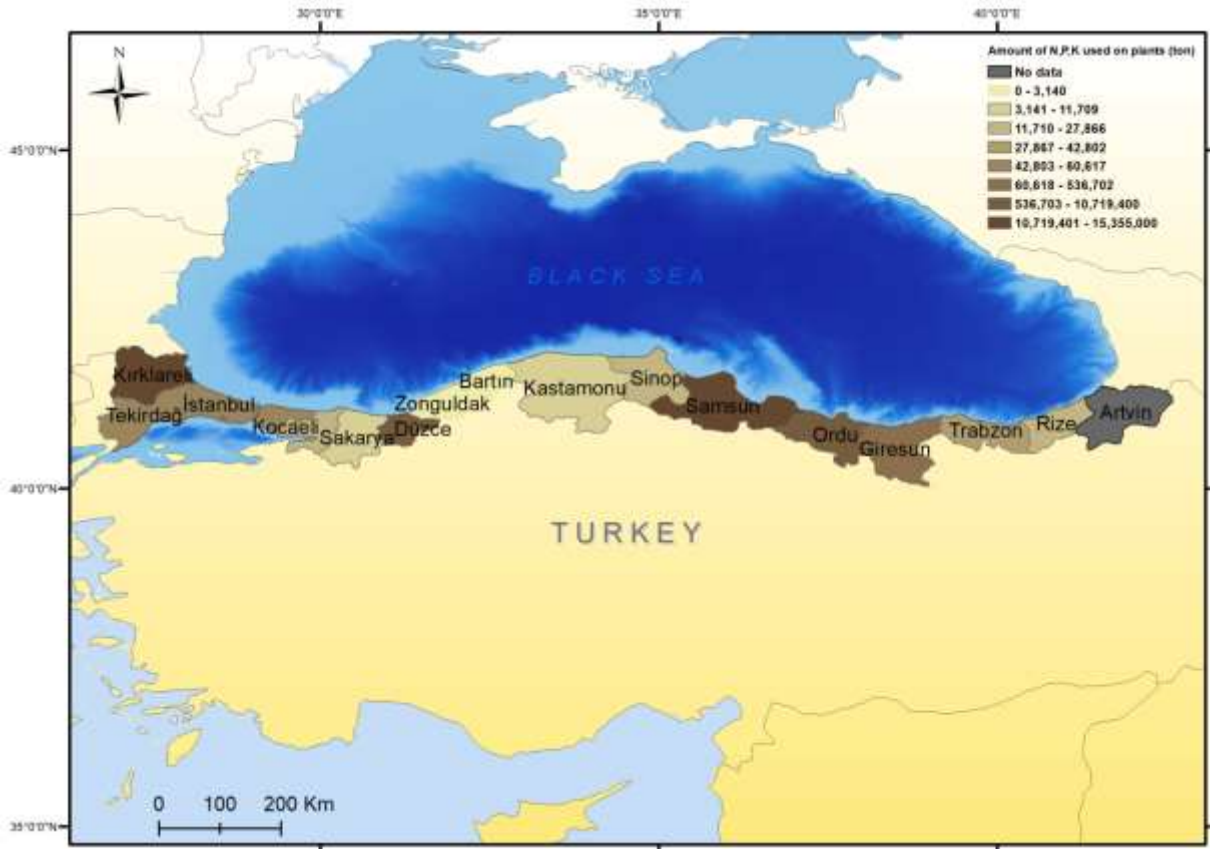


**Figure 4.** Amounts of Commercial Fertilizer Consumption (N, P and K on Plant Nutrient Substance) along the Turkish Black Sea Coast (data taken from Ministry of Environment and Urbanisation, ÇŞB, 2016)

Chemical waste may be added by factories, changing the pH of the water as well as its mineral composition. However, by far the major sources of pollution in the rivers are detergent and organic waste from domestic and farm sewage. Biggest freshwater supplies of the Black Sea came from the North shore (Borysova et al., 2005). River Danube, Dnieper and Dniester are the major rivers flowing into the Black Sea, Danube being the most pollutant one. Wastes from the European countries carried by the Danube and pollutants carried by rivers flowing through Russia and Ukraine to the Black Sea have been cited as playing a very big role in increasing the metals in the Black Sea (Zaitsev and Mamaev, 1997; Zaitsev, 2008).

The prime effect of organic pollution is nutritional, causing an increased population of detritus feeders, scavengers and bacteria that break down organic material. These use much more oxygen for respiration, the oxygen level is lowered, and the stream can no longer support the populations of biota with a great oxygen requirement. Major rivers that become so continuously polluted in this manner first change the structure of those hot spots when they are discharged into the Black Sea. The balance of the system is lost, and the more sensitive fauna disappear. It might seem that plant biomass would be increased with the increased organic content in the water, but it also causes instability and the more sensitive plants disappear. An additional effect of domestic sewage is the increase in oxygen deficiency of the water. Even the opportunistic species become abundant at the expense of others. The large effect of organic pollution is to cause an imbalance in the environment which changes the competitive status of the species living in it, so a few species become abundant and those that are characteristic of the ex-community disappear. Thus, there is always a degradation of species diversity of a habitat when pollution occurs. Most of the evidence for changing fauna will be found in the benthic organisms. As organisms also vary according to the type of deposit on the bed, it is necessary to sample each bottom type at any sample point.

Marine ecosystem is threatened by oil spillages, the disposal of domestic, agricultural and industrial waste, including the discharge of pesticides, warm water and heavy metals. The sea has long been regarded as a bottomless dustbin into which man can throw all his wastes in the belief that it will disappear. As the population throughout the Black Sea coast has increased, and the communities have grown more affluent, it has become clear that the sea cannot absorb all the wastes. In this case, it causes radical changes in the Black Sea.

**Urbanization and Industry**

Farmland in the Black Sea region, which is threatened by loss or occupation due to its potential for non-agricultural use, is also being damaged or badly polluted by factory emissions. Another point not to be overlooked here is the fact that smooth, level land, which is suitable for farming is also very attractive for urbanization and industrial development because it entails much lower building costs. Level land is rare in the Black Sea region, and is observed mainly along the coast, where fruits and vegetables are intensively cultivated. It is virtually certain that the whole of this rich narrow plain, is so valuable to the region, will be lost entirely in the near future. The flat, wide strip, for example, between the city of Trabzon and the county seat of Yomra to the east is being rapidly covered with factories and their subsidiary plants on the south side of the road. Hotspot domestic discharge points (GEF BSEP, 1996) and the major Turkish industries and their types of wastes in the Black Sea region (Bakan and Büyükgüngör, 2000) are displayed in Table 3.

**Table 3.** Domestic discharge points (GEF BSEP, 1996) and industrial wastes in the Black Sea region (Bakan and Büyükgüngör, 2000)

| Type of pollutants sources | Probable pollutants | Location |
|---|---|---|
| **Domestic** | Municipal wastes and waste waters | Samsun City Center and Bafra, Zonguldak City Center and Ereğli, Giresun, Ordu and Trabzon City Center |
| **Industrial** | Food manufacturing (slaughtering, dairy products, canning of fruits/ vegetables/fish, grain mill and bakery products, sugar factories, etc.) | Giresun, Ordu, Samsun, Sinop, Sakarya, Trabzon, Zonguldak |
| | Manufacture of paper | Giresun, Zonguldak |
| | Manufacture of non-metallic mineral products (mainly cement factories) | Ordu, Samsun, Trabzon |
| | Manufacture of wood and cork products | Ordu, Sakarya |
| | Non-ferrous metal basic industries | Samsun, Trabzon |
| | Manufacture of industrial chemicals (fertilizers and pesticides, resins and plastics) | Samsun, Sakarya |
| | Manufacture of textile | Samsun, Zonguldak |
| | Beverage industries (soft drinks) | Giresun, Ordu, Trabzon |
| | Tea plant factories | Rize, Artvin, Trabzon, Giresun |
| | Cigarettes | Samsun, Sinop, Trabzon |
| | Coal mining | Zonguldak |
| | Hazelnut | Trabzon, Ordu, Giresun |

In general, residential district in the Black Sea coasts have major issues of handling solid wastes, especially Zonguldak, Samsun and Trabzon have the great difficulties. Common operation in these regions is dumping solid wastes into the Black Sea. Again, there are solid wastes troubles induced by accumulations of sludge and ashes at the iron and steel plants at Karabük and Eregli. Sludge and stacked ashes besides pose an issue in the nitrogen plant at Samsun, owing to the usage of lignite at the Çatalagzı thermal power plant, ashes and slag are deposited in the environment making a soil pollution problem there (Environment Foundation of Turkey, 1995).

Every year, millions of tonnes of pollutants enter the atmosphere from industry, vehicles, households and other sources at enormous cost to the environment. Hg can accumulate in high amounts in the sediment via the atmosphere. An example of this is the partially high level of mercury found in sediments on the shores of the Sinop peninsula, which is not industrially developed (Bat et al, 2015a). As a result, local people who consume the benthic organisms such as fish, mussels, crabs, prawn can end up having accumulated levels of Hg that may prove toxic. Fortunately, recent reviews show that the amounts of Hg in the fish and edible shellfish are low and below the tolerable values on the Sinop shores (Bat, 2017; Bat and Arici, 2018; Bat et al., 2018a). Many other metals are discharged into the Black Sea from mining and industry. Waste water discharge status (TURKSTAT, 2016) and mining activities (ÇŞB, 2016; MTA, 2010) in the Turkish Black Sea region are given in Tables 4 and 5, respectively. Heavy metal accumulation in fish (Bat et al., 2014, 2015b, 2017a,b,c) and shellfish (Bat et al., 2016; Bat and Öztekin, 2016; Bat et al., 2018b) have been recently studied.

**Table 4.** Waste water discharge status of the Turkish Black Sea region (TURKSTAT, 2016)

| City | Number of Wastewater Treatment Plant | Rate of municipal population connected to wastewater treatment plant to total municipality population (%) | Number of Municipalities with Deep Sea Discharge | Industrial zone with wastewater treatment plant | Amount of wastewater discharged to the sea without treatment (thousand m³/year) |
|---|---|---|---|---|---|
| Artvin | - | - | | - | 1.518 |
| Rize | 1 | 2,8 | 4 | - | 10.248 |
| Trabzon | 9 | 38,4 | 1 | - | 11.332 |
| Giresun | 10 | 22,2 | 2 | No data | 4.600 |
| Ordu | 13 | 20,6 | 1 | - | 7.816 |
| Samsun | 11 | 28,5 | 1 | - | 27.350 |
| Sinop | 1 | - | 1 | - | 4.175 |
| Kastamonu | 8 | 6,9 | 1 | 1 (Tosya) | 370 |
| Zonguldak | 4 | 30,2 | 4 | - | 2.609 |
| Bartın | - | - | | - | 540 |
| Düzce | 4 | 48,9 | | - | - |
| Sakarya | 3 | 40,9 | | 2 | - |
| Kocaeli | 16 | 98 | 1 | | - |
| İstanbul | 41 | 97,8 | 1 | - | 26.249 |
| Kırklareli | 5 | 43,9 | | yes | 35 |
| Tekirdağ | 9 | 10,9 | 1 | | 8.141 |

Pollutants such as heavy metals and some synthetic chemicals are readily absorbed with food, but they are not easily excreted, and even organisms low in the chain can be affected. The higher the position of the specimen in the food chain and longer life span, results in higher accumulation. Top predators can gather levels of pollutants millions of times greater than those in the sea water. These may kill them directly or reduce their ability to cope with disease.

Industrial pollution is particularly marked in Istanbul. Untreated effluent flow into rivers, streams and to the sea. The planned nuclear power station in Inceburun is raising environmental concerns. The Black Sea coast is largely unspoiled, but both tourism and industrial are developing. The Black Sea coasts thus face a bleak future unless environmental standards are drastically improved and development carefully planned.

Erosion strongly affects the areas around the cities such as Trabzon and Samsun with high population densities. In these areas, fields cleared for planting come following removal of the natural plant which have suffered enormous damage from erosion. The same process of destruction is continuing today with slightly less severity around these areas.

**Table 5.** Mining activities in the Turkish Black Sea region

| City | Facility Name | Processed Ore | Waste Amount (tons/year) | Disposal Method | References |
|---|---|---|---|---|---|
| **Artvin** | Eti Bakır A.Ş. Murgul İşletmesi | Copper | 3.242.086 | Storage | ÇŞB, 2016 |
| **Rize** | Çayeli Bakır İşletmeleri A.Ş. | Zinc | - | Deep sea discharge | ÇŞB, 2016 |
| **Trabzon** | Copper ore enrichment plant and flotation plant | Other mineral wastes outside 010306, 010304 and 010305 (Wastes from physical and chemical processing of metallic minerals) | 22.552,7 | Regular storage, requiring special engineering | ÇŞB, 2015 |
| **Giresun** | Eti Bakır A.Ş. | Copper-Zinc | 101.200 | Regular storage, requiring special engineering | ÇŞB, 2016 |
| | Nesko Maden | Lead-Zinc | 80.000 | Regular storage, requiring special engineering | ÇŞB, 2016 |
| **Ordu** | - | Bentonite | - | - | MTA, 2010 |
| **Samsun** | Ladik Cement Plant | Cement raw materials | - | - | MTA, 2010 |
| | Past years ore deposits | Lead-Zinc | - | - | MTA, 2010 |
| **Sinop** | Operated ore deposits | Lignite | - | - | MTA, 2010 |
| **Kastamonu** | Eti Bakır A.Ş. | Cooper- Pyrite | 812,403 | Regular storage | ÇŞB, 2016 |
| **Zonguldak** | Armutçuk TİM Launder Facility | Coal | 70.067 | Regular storage | ÇŞB,2016 |
| | Üzülmez TİM Launder Facility | Coal | 135.282 | Regular storage | ÇŞB,2016 |
| | Karadon TİM Launder Facility | Coal | 170.289 | Regular storage | ÇŞB,2016 |
| | Kozlu TİM Launder Facility | Coal | 156.845 | Regular storage | ÇŞB,2016 |
| **Bartın** | - | - | - | - | - |
| **Düzce** | Past years ore deposits | Manganese | - | - | MTA, 2010 |
| **Sakarya** | Past years ore deposits | Copper- Lead-Zinc | - | - | MTA, 2010 |
| **Kocaeli** | Past years ore deposits | Copper- Lead-Zinc | | | MTA, 2010 |
| **İstanbul** | Total 38 Facilities in Istanbul | Sand Stone, Sils, Limestone | 657.500 | Storage in Minefield | ÇŞB,2016 |
| **Kırklareli** | Past years ore deposits | Copper, Molybdenum, Wolfram | - | - | MTA, 2010 |
| **Tekirdağ** | Past years ore deposits | Manganese | - | - | MTA, 2010 |

## Marine Litter

Total population in the Black Sea catchment area exceeds 160-170 million, and daily activities of all these people in some way or another affect the Black Sea environment and, presumably, contribute to marine litter problem which is originated almost completely (but not only) from the problem of solid waste pollution. The marine litter problem is closely linked to major problems of public health, conservation of the environment, and sustainable development in the Black Sea region. Marine litter originates from various land- and sea-based sources as a result of manifold human activities and, evidently, causes negative impact on the population, wild life, abiotic nature and some sectors of economy. Floating marine litter and their items suspended in the water are transported by currents and winds throughout the sea and, thereby, causing transboundary spread of solid wastes and basin-wide enlargement of the problem (BSC Marine Litter Report, 2009).

The unsuitable use, storage and transport of all types of waste, including toxic and dangerous materials, are growing problems all around the Black Sea. Toxic industrial waste is often stored in municipal dumps along with household refuse, which itself contains hazardous substances. Rain flushes the toxins into the soil, contaminating the

earth and ground water. From there they find their way into the rivers and eventually into the sea. Together with the discharge from boats, coastal dumps are the principal source of plastic in the sea; they cause serious problems in the Black sea and can be lethal to marine life. Plastic floating in the sea, beaches covered with rubbish, dump sites beside the roads, along the river banks and on the clifftops, refuse burning in the open air; this picture can be seen throughout the Black Sea region. Scientific studies on this issue have gained speed in recent years. Presence of marine litter in beaches (Topçu et al, 2013; Terzi and Seyhan 2017), sea surface (Suaria et al., 2015) and sea floor (Topçu and Öztürk 2010; Öztekin and Bat 2017) have been reported by various researchers in the Black Sea.

Even when the plastic itself is not poisonous, it can cause the death of the fauna by obstructing its digestive system. Plastics can kill in other ways, birds are strangled by plastic can holders; dolphins can suffocate in plastic sheeting; and seals die a slow death when they become wrapped in the remains of packaging that tightens around them as they grow. Fish have been found to have plastic debris in their intestines (Bråte et al., 2016; Güven et al. 2017). It was reported that microplastics were consumed by filter-feeding at the base of the food web (Cole et al., 2013), and it was proved by experimental studies that the transfer was in the trophic level (Setala et al., 2014; Farrell and Nelson 2013). Thus, there is a bio-accumulation risk of chemicals associated with plastic debris, additives to plastics during manufacturing process and compounds that plastics absorb from environment.

Moreover, the scale of the rubbish problem has attracted attention on the potential for recycling and reducing the amount of waste material produced. Incineration of rubbish as a means of recycling, which uses the heat from the incinerator to generate electricity is promoted as an energy recovery system. In reality, the forms of rubbish incineration used have caused considerable pollution through the release of gases and ash have proved to produce energy in a very inefficient way. It is not a solution to think that incineration can change the nature of the pollution by shifting it from the land to the atmosphere.

Recycling, together with reductions in the amount of waste material produced in the first place, forms the only real solution to the problem of urban waste. It can help significantly to conserve natural resources and to protect wildlife and natural habitats. Given the consequences for the environment of dumping and incineration, recycling is a necessity rather than an option. Solutions to the Black Sea's marine litter problems require that uniform strict rules be approved and implemented by each country along the Black Sea coasts (Bat et al., 2017d).

**Eutrophication and Sewage**

The Black Sea is the most important sea in terms of biodiversity (Bat et al., 2011), due to its richness in plankton biomass (Bat et al., 2007), and therefore, in fish that feed on this biomass. Consequently, the Black Sea provides 70-90% of the Turkish marine capture fisheries products. The noted main threats to biodiversity in the Black Sea are eutrophication, chemical contamination and oil pollution, overfishing and alien species. Human-induced nutrient enrichment in the Black Sea can be caused by input of nutrients in form of riverine inputs from activities in the catchment, direct inputs from sewage treatment plants, industries and atmospheric deposition. Eutrophication is the most visible danger facing the Black Sea and also has the greatest impact (Figure 4). Troubles began in 1960s, with a major change in agricultural production called Green Revolution, decomposition of organic matter used up the oxygen in the water and destroyed many living biota on the bottom (Mee, 1992). The immediate cause of eutrophication is an overabundance of nutrients originating primarily from agriculture and municipal sewage: approximately 80% from agriculture, 15% from urban water and 5% from other sources (Borysova et al., 2005). Several resources of eutrophication may rule over a particular area depending on local conditions. In cases where there is a major city located near a bay or a gulf, municipal sewage inclines to be the major source of eutrophication (Zaitsev and Mamaev, 1997).

A rich and diverse community of organisms normally thrives in the sediment of the Black Sea.

However, over an area of several hundred square kilometres, the oxygen virtually disappeared from the bottom anoxic waters and within days a coating of mucus smothered much of the life on the seabed.

The impact they have ranges from gradual changes in plankton species, to toxic effects on the eggs, immature and adult forms of shellfish and fish. Marine plants grow using dissolved minerals and energy from the sun. Herbivores feed on the plants and fall prey to other animals. The top link in this food chain comprises mammals and birds. However, as this material passes up the food chain, less and less is directly used as food. The rest is converted back into minerals, partly by bottom and partly by the continuous process of excretion throughout the food-web. Anthropogenic eutrophication has a similar indirect effect on the zooplankton through its impact on the phytoplankton (Zaitsev and Mamaev, 1997).

The most obvious sign of pollution is that of untreated sewage. Sewage discharges into the sea, which become particularly heavy during the tourist season, are suspected to be the cause of this catastrophe. For the shore inhabitants, the effects of sewage are different. In summer, there is the risk of contracting infectious intestinal disease s such as typhoid, paratyphoid, polio or diarrhoea from swallowing contaminated sea water for the swimmer. However, this input of rich organic matter can rise up the turbidity of the water and decrease the maximal depth at which seaweeds can grow. It also increases the biochemical oxygen demand (BOD) of the water, as bacteria require oxygen to destroy the organic substances in the sewage. In some habitats, notably muddy shores and estuaries, it widely increases the possibility that the mud will become totally devoid of oxygen. Under these anoxic conditions, it becomes black and very smelly, stinking of hydrogen sulphide. This black layer is almost mostly lifeless, since there are few species that can exploit such anaerobic conditions. Pollutant loads of the Black Sea coasts of Turkey are shown in Table 6.

**Table 6.** Pollutant loads of the Black Sea coasts of Turkey (GEF BSEP, 1996)

| Pollutant Sources | BOD (tons/year) | TSS (tons/year) | TN (tons/year) | TP (tons/year) |
|---|---|---|---|---|
| **Domestic** | 38,687 | 161,369 | 1,577 | 2,188 |
| **Industrial** | 6,119 | 6,540 | 7 | 69 |
| **Riverine** | 18,090 | 4,120,000 | 1 | 3,600 |

The rapid growth of coastal towns and cities in the Black Sea, coupled with shortage of funds for proper urban development and infrastructure, resulted in discharge of untreated sewage into the sea and intensified the pollution problems. The discharges will still contain nitrogen and phosphorus, which will continue to fuel the growth of algae and still result in the removal of oxygen from the water.

Sewage could also be treated as a resource, and the nutrients recovered for use as fertilizer. However, this is not practical, because sewage is contaminated by wastes containing many toxic chemicals from both industrial and domestic sources. It has been very well known for many years that heavy metals can be extremely toxic even at low concentrations. Human activities discharged insignificant amounts into the environment compared with natural geological processes.

**Oil spillages**

The Black Sea is one of the world's busiest waterways and in 2005 over 55,000 ships, including almost 6,000 oil tankers passed through the Bosporus Strait, most carrying Russian oil. The Danube River accounts for 48 percent of the 110,840 tons per year of oil entering the Black Sea each year (Zaitsev and Mamaev, 1997). Total oil from the Black Sea coastal countries are 57,404 tons /year. However, accidental oil spills were reported

as 136 tons /year, but there is no information for illegal discharges from shipping (National Reports, 1996; GEF BSEP, 1996). Table 7 gives oil pollution of the Black Sea.

**Table 7.** Oil pollution of the Black Sea (GEF BSEP, 1996)

| Source of Pollution | Bulgaria (t/y) | Georgia (t/y) | Romania (t/y) | Russia (t/y) | Turkey (t/y) | Ukraine (t/y) | Total (t/y) |
|---|---|---|---|---|---|---|---|
| **Domestic** | 5,649.00 | - | 3,144.10 | - | 7.30 | 21,215.90 | 30,016.30 |
| **Industrial** | 2.72 | 78.00 | 4,052.50 | 52.78 | 752.86 | 10,441.00 | 15,379.86 |
| **Land-Based** | - | - | - | 4,200.00 | - | 5,169.20 | 9,369.20 |
| **Rivers** | 1000.00 | - | - | 165.70 | - | 1,473.00 | 2,638.70 |
| **Total** | 6,651.72 | 78.00 | 7,196.60 | 4,418.48 | 760.16 | 38,299.10 | 57,404.06 |

On any shore suffering from heavy oil pollution, all communities of fauna and flora may smother and die. Indeed, a considerable damage may occur to the commercially exploited shellfish, which become tainted with oil, though these can usually be cleaned up by keeping them in non-polluted water for a few weeks. Although some of the components of oil are gradually biodegraded, the major natural detoxifying mechanism is by dispersion. However, in most cases, and particularly on sea shores, both natural dispersal and biodegradation are intolerably slow and some other method must be used to reduce the level of contamination. Various types of detergent are used for this purpose, but they create an added hazard. If the wrong detergent is poured directly on to beaches, it will kill intertidal and sublittoral life as effectively as the oil. After marine life has been destroyed, recovery by means of recruitment from neighbouring shores may be quite fast-within three years-for species with planktonic larvae. Reinvasion takes much longer, however, for the species which lack a planktonic dispersal phase in their life history.

**Toxic waste**

Pesticides are used more or less as a synonym for biocides. This category includes; herbicides, insecticides, fungicides, acaricides which kill mites, nematocides which kill nematode worms, molluscicides and rodenticides. Unfortunately, pesticides cause widespread pollution of the environment, seeping into the rivers, killing off fish life, and contaminating groundwater, drinking water and food, most of which now contains pesticide residues. Though in general, levels of pesticides in the environment are usually low, pesticides tend to concentrate as they move up the food chain, a phenomenon known as bio-concentration. The consequences for wildlife and human health are severe. Human body fats also now contain pesticides, as do ova and spermatozoa. Most modern pesticides are synthetic organic chemicals, a category that includes many known or suspected carcinogens, mutagens and teratogens. Unfortunately, the literature on the health effects of pesticides is scanty (Table 8). If pesticides contaminate food items routinely they will contain dangerous levels of pesticides which pose an increased risk of cancer, neuro behavioural damage and other health problems.

More insidious forms of pollution are those of heavy metals and organic compounds such as DDT and polychlorinated biphenyls (PCBs). These pass into the marine environment by river run-off, or through the atmosphere in the form of dust, or in rain water. Insecticides like DDT, and lead compounds added to petrol as an anti-knock agent, enter the sea from the air. Emission of smoke from stacks of smelting works and other industrial complexes are monitored, but they still release

significant quantities of toxic compounds into the atmosphere.

**Table 8.** Chemical Substances Excluding Fertilizers Used in Agriculture in 2015 (ÇŞB, 2016)

| City | Insecticide | Herbicide | Fungicide | Rodenticide | Nematicide | Acaricides | Others | Total |
|---|---|---|---|---|---|---|---|---|
| Artvin | - | - | - | - | - | - | - | - |
| Rize | - | - | - | - | - | - | - | 0.36 t |
| Trabzon | 6.71 t - 11,629.18 l | 1,816.5 l | 18.218 t - 73.2 l | 0.011 t | - | 0.405 l | - | 24.939 t - 13,519.285 l |
| Giresun | 34.9 t | 52.7 t | 5.5 t | 0.003 t | - | 0.06 t | 0.057 t | 91.566 t |
| Ordu | 117.711 t | 18.222 t | 10.309 t | 0.00025 t | - | - | - | 146.24 t |
| Samsun | 41,693.41 t | 52,702.96 t | 57,570.05 t | 16.4 t | - | 158 t | - | 158,148.82 t |
| Sinop | 0.47 t - 1,147.47 l | 0.17 t - 14,489.52 | 3.32 t - 20.65 l | 0.0005 t | - | 1.215 l | 188 l | 3.96 t - 15,846.96 l |
| Kastamonu | 938.79 kg 2171.02 l | 164.51 kg 8067.96 l | 11868.86 kg 564.73 l | 42.86 kg | - | 110.87 kg 230.78 l | 675 l | 13,125.8 kg 11,710.4 l |
| Zonguldak | 6.65 t | 15.81 t | 3.87 t | 1.14 t | - | 0.16 t | 1.9 t | 29.53 t |
| Bartın | 0.83 t-500 l | 1.60 t | 1.53 t-105 l | 0.000006 t | - | 0.01 t-40 l | 310 l | 3,97 t-955 l |
| Düzce | 13,322 t | 56,459 t | 3,208 t | 2,890 t | - | - | - | 76,277 t |
| Sakarya | 113.777 t | 133.630 t | 133.937 t | 2.623 t | - | 9.802 t | 13.286 t | 407.055 t |
| Kocaeli | 30,600 t | 7,500 t | 42,570 t | 0.013 t | 0.1 t | 5.350 t | 1.250 t | 80.677 t |
| İstanbul | 13.113 t/ 10,540.43 l | - | 25.428 t/ 2,001.96 l | - | 0.130 t/ 80 l | 0.510 t/ 1,328.41 l | 0.04 t | 39.182 t/ 31,965.8 l |
| Kırklareli | 3.930 t | 170.620 t | 105.549 t | 0.009 t | - | 0.593 t | - | 280.704 t |
| Tekirdağ | 18.11955 t | 171.226 t | 154.24525 t | 0.4848 t | - | 0.3394 t | - | 344.415 t |

Discharges of chemical wastes into rivers and estuaries have been known to cause numerous deaths in man, notably in Japan where both mercury and cadmium poisoning have killed people eating fish and shellfish from heavily polluted water. Many heavy metals are rapidly absorbed in sediment particles suspended in the water, which settle out at slack tide. Mercury, copper and many of the radioactive isotopes are discharged from the nuclear waste processing plants. However, some heavy metals, such as cadmium, are not removed by sediments and tend to stay dissolved in the sea water, where they are more available for animals or seaweeds to absorb. Certainly, dangerous pollutants are those that are accumulated by organisms, especially those that are taken by food. DDT and PCBs are both accumulated in this way, with the result that the top predators in the ecological pyramid accumulate vast quantities in their body tissues, quantities that are either directly toxic or prevent them from reproducing successfully. Evidence suggests that, whereas mercury and lead may be concentrated up the food chain (but fortunately tend to get removed from the marine environment by other processes), the vast majority of radioactive elements discharged from nuclear plants, such as caesium, polonium, uranium and thorium, are not accumulated in the food chain (Zaitsev and Mamaev, 1997).

One of the main sources and kinds of anthropogenic influence on ecological system of the Black Sea was via Chernobyl Nuclear Power Plants. This area is a land-based source of radionuclides chronic pollution of the Black Sea through the Pripyat River and the Dnieper River (Polikarpov et al., 2004). It is the world's worst nuclear reactor accident. The accident occurred at on Saturday, April 26 1986. Initially, some 135 000 people living within a 30km radius of the plant were evacuated, as well as local livestock. Later, however, the evacuation zone was extended as the extent of true contamination became known. Three years later, 100 000 people had to be moved because decontamination procedures was not sufficiently effective. Gross deformities have developed among farm animals in the region, and the level of disease

amongst the human population, including cancers, increased markedly. The genetic effects are not known yet. Undoubtedly, those affected by the nuclear waste outside the Ukraine and Russian were namely, the northern parts of Norway, Sweden and Finland. In these countries, radiation levels rose more than sevenfold. High doses of radiation during the Chernobyl accident, caused vomiting, loss of hair, bleeding and death. Debates will continue regarding the radioactive contamination from Chernobyl**,** and the number of people in the Black Sea countries and Europe who would die of cancer over the next 50 years (The Earth Report 3, 1992).

As far as Black Sea contamination is concerned, no consensus has been reached among the countries on its coasts. Together with the known fact that Black Sea is in any case a dead sea below 180-220 m., developed European countries secretly dumping their dangerous and toxic wastes into the Black Sea (Environment Foundation of Turkey, 1995). One of the most conspicuous examples of this is the poisonous barrels that turned up along the Turkish coast at Sinop in 1987-1988. The officials set to investigate the contents of these drums had never been able to provide a satisfactory explanation of this phenomenon, which was a subject of public attention throughout 1988. Consequently, serious suspicions have been raised concerning the level of pollution of the Black Sea. According to unofficial reports, along with the cases reaching the media, there are also other incidences not addressed by media. These include industrial wastes of various kinds, DDT and its derivatives as well as PCBs (Polychlorinated biphenyls) and HCB (Hexachlorobenzene) compounds, all of which can become deposited in fish and therefore, have carcinogenic effects on humans through the food chain. The results of the official investigation on the other hand, have never been made public (Environment Foundation of Turkey, 1995). In most cases, concentrations of pesticides and PCBs were relatively low (Zaitsev and Mamaev, 1997).

**Heating up the water**

Man's use of energy adds other pollutants namely heat and carbon dioxide into the ecosystem. The cooling water used by coastal and power stations is released as warm water above the ambient water temperature. This warm water is lethal to organisms living adjacent to the outfall and it also reduces the oxygen carrying capacity of the water. However, it is rapidly cools down as it enters the mass of cooler water, and, compared with much smaller water bodies, heated effluents entering the sea have a minimal effect. Increased outputs of carbon dioxide are potentially more frightening. The long-term consequences of higher carbon dioxide levels in the atmosphere are controversial. Most meteorologists agree that the initial effect would be a small rise in atmospheric temperature throughout the world as a result of additional insulation provided by the carbon dioxide against overnight heat loss. If this increase continues, there will be a noticeable shift in the climatic zones of the earth, resulting in major environmental changes on land, in fresh waters and in the sea. However, it is difficult to completely specify the effects of climate change on marine biota (Sezgin et al., 2010).

**Dredging**

Dredging is an activity centred on ports and clearly needed for shipping and fishing activities. The dredge slurry is either got in hopper barges which dump their unwanted loads in deep water or piped onshore to server with land reclamation. These activities affect both the organisms that are dug up from the bottom and dumped in the habitat and the communities that are living down current of the dredging operations. Filter-feeders need a modicum of suspended material in the water on which to feed, but a dense turbidity of clay and fine sand clogs their filters and their gills. Dredging is also carried out to supply gravel for building, particularly now that gravel deposits on land are being depleted.

The dredge scour marks remain as sea bed structures which constitute problems for fishermen trawling these sediments. Gravel excavation can also cause erosion elsewhere on the sea bed as sediments are carried along to fill in the dredging holes. The laying of pipelines to bring oil and natural gas ashore creates only temporary environmental disturbance since the pipes are normally laid in trenches which are then filled in.

Pipelines which have to be laid through sand wave systems are sometimes uncovered by the waves moving through them. Consequently, they become vulnerable to damage by storms and fishing gear. Exposed pipelines are a bonus, however, for organisms which normally inhabit rocky bottoms, since they present a hard surface on which they can settle.

**Alien species**

The southern of the Black Sea shelf is only a narrow intermittent strip. There is no hydrogen sulphide in the coastal area, but concentrations rising up rapidly under the thermocline owing to the restricted ventilation of deeper shelf water. Consequently, the number of biota especially macro-benthic species decreases rapidly with increasing depth. The wide diversity of biotopes provides favourable conditions for invasions of alien species in the Black Sea. The composition and structure of the marine communities is constantly changing with the decline of certain species and the expansion of others (Sezgin et al., 2010). Benthic assemblages are the main components of the Black Sea ecosystem (Kırkım et al., 2006). Ever since man moved from one country to another by boat, both unintentional and deliberate introduction of exotic species into coastal waters were the case. Deterioration of some marine habitats and lack of regulations and technology for regulating the introduction of alien species, such as via ballast waters, have allowed the invasion of such species. In 1968 a new bivalve species *Anadara inaequivalvis* was seen in the Black Sea. This indo-pacific species is spread in the Black Sea basin, constantly becoming the dominant species (Zolotarev, 1996). Immigration of this alien species was most likely due to the accidental transportation of juvenile stages in the ballast water of ships coming from the Pacific (Chikina and Kucheruk, 2005).

Another prominent example of an alien species is that of the comb jellyfish *Mnemiopsis leidyi*. In 1980s, eutrophication of the coastal waters caused phytoplankton blooms, increasing sedimentation and lowering transparency. In 1988 as a result of *M. leidyi* invasion, photic zone depth and intensification of sedimentation was lowered. These have produced mass populations, that have changed the equilibrium of the native marine ecosystems. However, there is an observed decrease in the production level due both to the changing ecosystem of the Black Sea and to the overfishing fishing.

A drastic increase in the number of *Rapana thomasiana* which to great extend feeds on rocky form *of Mytilus galloprovincialis*, covered with *Cystoseira* spp. has been reported (Chikina and Kucheruk, 2005). However, in 2000, the situation again changed radically. A sharp decline in the quantity of *R. thomasiana* and the complete absence of *M. galloprovincialis* on the rocky substrate were observed. Thus, *Rapana* completely consumed the *Mytilus* on the rocks and moved to the sands where it almost eliminated large individuals of *C. gallina*, repeating the story with the oyster banks in the 1950s (Chukhchin, 1961a,b). On the soft bottom, the amount of *Rapana* was almost 1 specimen per square meter and no adult *Chamelea gallina* were registered. Such mass settlement of bivalve larvae was suggested to be the result of an abrupt decrease in predacious ctenophore *M. leidyi*, which their massive development in the 1990s led to a catastrophic decline of zooplankton, including bivalve larvae (Gordina et al., 2005). This decrease in *Mnemiopsis* abundance happened because of the invasion of obligate ctenophorophagous ctenophore *Beroe ovata* in 1999, which led to a recovery of the previous planktonic food chain (Svetlichny et al, 2004; Anninsky et al., 2005; Chikina and Kucheruk, 2005).

**Seaside visitors**

Access to the coast has now been made easier throughout the Turkish Black Sea coasts by improved roads; meaning that the coastline is under increasing pressure for recreation. Repeated trampling can destroy the ground cover of plants, also, blow-outs occur in sand dunes on which plants stabilize, such as marram-grass. This would prevent such plants to establish themselves. Marine ecosystems are in danger or risk from the pressure by human. Even rocky shores, which are generally useless for development, can suffer from pollution.

**Conclusions**

Sources of the Black Sea's pollution problems are various (Mironescu, 2008). Polikarpov et al. (2004) stressed the main sources of anthropogenic influences on ecosystem of the Black Sea as; 1) from rivers by way of reduction of freshwater outflows, input of inorganic and organic matters, toxicants; 2) from agriculture, by fertilizers, pesticides, fragments of soil; 3) from industry, mainly by heavy metals, detergents, oil; 4) from settlements, by wastewater, detergents, oil, pathogenic microorganisms; 5) from atmospheric fallout, input of dust, mercury, lead, nitrates, phosphorus; 6) by navigation, through oil, exotic species, sound pollution; 7) via ports, contamination of water, recess of bottom, dumping; 8) fishery, damage to and destruction of benthic ecosystems; over catching of biological sources; 9) output of mineral sources; 10) beaches, change of conditions, creation of dead regions; 11) recreation and tourism, microbial pollution of coastal water, litter of coastal zone; 12) via Chernobyl Nuclear Power Plant area which is a land-based source of radionuclides chronic pollution of the Black Sea through the Pripyat River and the Dnieper River.

As a result of man's activities, marine habitats have been altered both below low water mark and higher up the shore. Such changes may allow only few adaptable species to thrive, but they often tend to reduce the natural diversity of species. In recent years, marine pollutants have been responsible for major impacts on life in coastal waters. The sophistication of fishing techniques, including the use of sonar devices to locate fish shoals accurately, has led to the over-fishing of commercial species. Other major areas in which man's impact had effects on marine life include; building coastal structures, dredging the sea bed, introducing alien species, and pressure from seaside visitors.

In harbours, there is usually an increase in the pollution level, which would restrict the range of species, but those organisms that are able to withstand the pollutants can abound. The best solution to the problem of hazardous wastes lies in reducing their production.

Only two European Union Member States, Bulgaria and Romania, fish in the Black Sea. These are also the only Member States which have direct access to this basin. Turkey, like industrialized European Union nations is attempting to develop comprehensive rules and regulations regarding the use, storage and disposal of chemical wastes. In developing environmental regulations, the European Community has focused on pollution control and support of Marine Strategy Framework Directive. This is particularly stated for the Dangerous Substances Directive which has led to European standards for contaminants including heavy metals. Turkey has also released standards for pollutants.

However it can be seen that there is no much considerable pollution in the Black Sea coasts of Turkey. The lack of comparable data on the Black Sea coast countries would make it impossible to evaluate future trends in pollution or to adequately save ecosystems and human health. The available data are the outcome of different investigations using methodologies that are not inter-comparable. It can be concluded that the situation in the Black Sea calls for urgent actions. Therefore, the Riparian countries should cooperate for the protection of the Black Sea. Serious sanctions and penalties should be implemented for the polluters of the Black Sea. Permanent measures against pollution should be taken and solutions should be produced.

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Maps throughout this review were created using ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license.

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