

Full Length Research Paper

Marine litter transportation and composition in the Coastal Southern Black Sea Region

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Marine litter problem has gained great attention in regional seas and lead to degradation and threaten aquatic life in marine environment. Coastal marine litter in the Black Sea is mainly caused by transportation and deposition of antropogenic waste resulting from river outflows. Measures and regulations remain inadequate to protect the coastal regions against pollution in the region. Geomorphology of the region creates many watersheds supplied by extensive stream networks. To estimate litter load on the Black Sea coastal areas 15 streams were surveyed. Study area is densely populated coastal region with scattered settlements toward steep higher areas. Dry solid waste load is triggered by settlement plan and leads to accumulation of marine litter in coastal areas. Regional precipitation characteristic of the region determines flood timing and frequency with very high rainfall records. Composition and distribution of sampled marine litter is carried out by identifying litter type proportionality to total load. Plastic has the highest ratio of 56% among all litter type. Yearly total litter load for Degirmendere stream is estimated 102.25 m³/year for 100 ha. Multispectral satellite images are used to assess transportation of floating or drifting litter from coastal areas to inner basin. Man made alterations of coastal areas are also evaluated in terms of aquatic living resources and pollution. Main problems are stressed and possible solutions and implications are given to reduce pollution problem in coastal areas.

Key words: Marine litter, Black Sea, satellite remote sensing.

INTRODUCTION

Wastewater discharges negative effects ecological, biological and landscape quality of coastal areas. Due to the increased population in coastal areas; a very significant amount of litter finds its way to the seashore and marine environments. The problem is even greater in developing countries, where main targets are to increase economic growth and production where issues related to protecting the environment are a minor priority (BSC, 2007). Stream environments are some of the most fragile, degraded and threatened environments in the world due to the strong interactions between aquatic and terrestrial environments and to the human disturbances that can affect either system (Gillies et al., 2003). River load is the factor least studied, in the Black Sea as in other regions. There are other associated issues here, too, such as erosion of riverbanks, artificial beach formation, pollution of the sea etc. (Jaoshvili, 2002). The Black Sea Rivers of Turkey are under heavy anthropogenic pressure. Dozens of large and small dams and

reservoirs have been constructed along them. Their flow is controlled and the water used in hydroelectricity schemes, for industrial and other needs and for improvement and reclamation programs. The natural course of fluvial alluvium transport is therefore completely altered. Generally, solid wastes and water wastes are given into the nearest river basin. The water wastes discharged into nature will flow into the steep areas and reach to the nearest basin and mixed to the river system or underground waters. Cesspool bores does not form an obstacle for these waste waters to reach rivers. The waste waters accumulated in these cesspools are left again to the areas which will reach the water system. By making drainage web, waste waters are given fast to the rivers with a high pollution parameter and a lot of municipalities store the solid wastes in river basins in a cruel way (Ucuncu, 2007) For domestic and industrial pollutants, the streams and rivers are the main sources of pollutants into the Black Sea (Bakan and Buyukgungor,

2000).

Marine litter constitutes a threat to coastal and marine ecosystems as well as to the health of coastal inhabitants by decreasing overall productivity and visual quality. The sources of marine litter include offshore marine, riverine and coastal. Litter in the marine environment gives rise to a range of adverse ecological impacts, including: entanglement, ingestion, smothering, disturbance and removal of habitat through beach cleaning activities, transport of invasive species and poisoning by breakdown products (Fanshawe and Everard, 2002). Plastics contribute the most significant part of marine litter deposits and solid wastes dumped into aquatic environments. Plastics are dumped in huge volumes in well-used beaches, lakes, navigation channels and other forms of water masses. In the north-western Mediterranean, plastics constituted most of the debris, at an average of about 77%. In a survey on the stranded and buried litter on beach in Japan and Russia along Japan Sea, it is reported that plastics contributed 72.9% by number and 53.8% by weight of the total litter deposits in the beaches of Japan and 55.1% by number 23.4% by weight in the beaches in Russia. The bulk of plastic materials are even bigger in developing countries with poor waste disposal regulations. As well as an aesthetic problem, marine litter threatens wildlife through entanglement, ghost fishing, and ingestion. The eventual fate of the plastic materials generally involves burial in adjacent sediments. The plastics are virtually indestructible and accumulate organic coatings which adsorb shells, sand and other debris and sink to the bottom where they create and act as partition inhibiting the transfer of nutrients and gases between water and sediments. Anoxia and hypoxia are the most common form of phenomena occurring at the sediment–water interface due to plastic partition. Such effects may seriously interfere in the normal functioning of the ecosystem and may alter the topographical and biological make-up of the sea floor (Islam and Tanaka, 2004). This paper attempts to describe the evaluation of South Eastern Black Sea region marine litter transport by major streams and possible transportation routes that can be examined by physical forcing of coastal eddies and currents. This is necessary in order to promote discussions on questions of effects on ecosystems and develop strategies to prevent Black Sea from pollution. Marine litter causes visual degradation in the Black Sea, moreover non-biodegradable characteristics of litter types remain unresolved and prolonged threat for marine biodiversity and aquatic life in the area. The Black Sea's sustainable environmental protection and management requires quantitative measures and actions to be taken for monitoring current situation.

Study area

The Black Sea is the largest anoxic, isolated basin in the

world. The Black Sea ecosystem, suffering ecological deteriorations through long-term changes induced by natural and anthropogenic factors, needs to be continuously monitored for its environmental state and ecological processes (Kopelevich et al., 2002). The Black Sea is subject to a considerable anthropogenic impact due to a large drainage basin accompanied by a high population density. The Black Sea is representative of human-impacted enclosed area. Severe changes have been documented in the ecosystem of the Black Sea over the last decades. Eutrophication caused a substantial modification of the phytoplankton community structure as well as increase in the intensity and frequency of microalgal blooms (Chami et al., 2005). The pronounced horizontal stratification of the Black Sea water column, caused by hydrophysical and hydrochemical factors suggests different density of water mass on the margins and within all these strata. Thus, it could be supposed that the distribution of marine litter is also stratified in the sea in accordance with density/flotation ability of different marine litter items. The most dense litter objects sink and accumulate on the sea bottom, while the least dense ones drift on the sea surface and in time, sooner or later, become washed ashore. The third group of litter items is suspended in the water column between the surface and bottom. The hypothesis of litter stratification consists in selective horizontal accumulation of certain suspended marine litter items following the thermocline, halocline and transitional layer between the oxygenated and anoxic waters (BSC, 2007). Study area is ranging from Trabzon to Rize and totally covering 180 km (Figure 1).

Legal issues

In Turkey, the Municipalities are the responsible authorities for the storage, transportation, recycling and disposal of the solid wastes. Outside of their authorization areas, the administrative district within the province has the responsibility. Municipalities are prohibited to dump solid wastes to river beds and coastal zones and Provincial Directorates of the Ministry of Environment and Forestry are in control of the issue. General Directorate of Borders and Maritinal Health of Ministry of Health monitor the water quality. Ministry of Environment and Forestry takes measures to prevent environmental pollution. According to the Law for Environment No. 2872, Amended Environment Law No. 5491, Law of the Metropolitan Municipality No. 5216 and Law of the Municipality No. 5393 the local district municipalities are responsible for the collection and transportation of all municipality solid wastes to the transfer stations. According to the Law of the Environment Article 8; 'Waste discharging is forbidden to the receiving environment'. Control and audit, with the authorization of Laws and Regulations, belong to Provincial Directorates of the



Figure 1. Study area.

Ministry of Environment and Forestry. According to regulations on the control of solid waste, discharging of solid wastes into the sea, river and other receiving environments, streets, forests etc. are prohibited (BSC, 2007).

Climate and oceanography of the region

Black Sea region is mainly dominated by large-scale synoptic cyclones originated from North Atlantic. They are carried by westerlies across Europe. High coastal mountains influence mesoscale atmospheric circulation and cyclone dynamics. The South Eastern Black Sea region is dominated by a more moderate and rainy maritime climate. The Black Sea climate occurs in the northern regions of Turkey especially on the mountain ridges facing the sea. The main characteristic of this climate is that it rains winter and summer due to high precipitation, south Eastern Black Sea is dominated by humid weather. The region has the highest rainfall in Turkey. The climate in the South Eastern Black Sea is wet, warm. Mean seasonal temperatures for summer and winter were 25 and 7°C respectively. The area which has the highest average rainfall in a year in Turkey is the Eastern Black Sea region. Besides the yearly average expanding to the whole year and reaching 2500 mm from time to time, the maximum rate of precipitation in this region reaches very high figures. In this area, the maximum rainfall in short intervals sometimes reach figures higher than monthly figures and often cause floods. This flooding caused by maximum rainfalls and other conditions result in huge damages owing to the characteristics of topographic structure (Guurgen, 2004).

The Black Sea is characterized by a predominant cyclonic and strongly time-dependent basin wide circulation that follows approximately the continental slope around the basin. This circulation pattern is mainly driven by the cyclonic wind pattern and is known as Rim Current (Figure 2). In summer, Rim Current meandering observed along Turkish coast intensifies and large meanders are created due to low wind stress factor (Poulain et al., 2005). Several forms of mesoscale features, Rim Current meanders and their interactions with Anatolian coast are important in terms of transportation coastal waters to inner basin. In a basin of relatively small size such as the Black Sea, cross-shelf exchange is of central importance because occasionally the horizontal scales in the burst of exchange is almost of the same scale as the basin itself and a significant amount of the fresh water, nutrients and other materials are input from major rivers and advocated along the coast by the boundary current and then injected in to the basin interior via turbulent exchanges.

MATERIALS AND METHODS

To investigate environmental pollution along the stream network and coastal areas, 3 surveys repeated to screen recent condition of the streams. 15 streams were surveyed from their mouth point to 2 km away along the drainage basin (Table 1). Totally 180 km coastal line covering Trabzon and Rize cities was surveyed. During the survey, litter type was classified and counted to find out proportional contribution of every type of litter to total load. Yearly litter load was estimated according to Armitage and Rooseboom, 2000. Calculation was adapted for the region.

$$T = \sum F_c (V_i + B_i) A_i$$

Where, "T" is the total litter load, "F_c" is a cleaning factor, "V_i" is

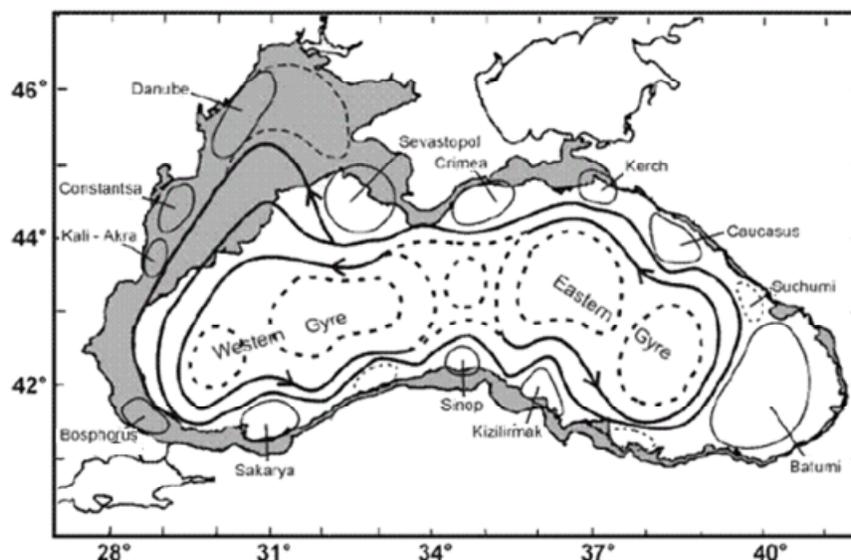


Figure 2. General circulation and eddies of the Black Sea (Korotaev et al., 2003)

Table 1. Estimated total yearly load of litter for the study area.

Stream name	Total litter load estimation (m ³ /year) (100 ha)
Sogutlu Stream	62,95
Fol Stream	75,73
Degirmendere Stream	102,25
Yomra Stream	64,55
Yanbolu Stream	53,25
Karadere Stream	63,72
Kucukdere Stream	52,13
Surmene Stream	64,50
Solakli Stream	56,91
Baltaci Stream	54,50
Iyidere Stream	56,90
Hemsin Stream	51,98
Taslidere Stream	62,88
Firtina Stream	51,31
Buyukdere Stream	62,90

vegetation load for each land use, "B_i" is load factor for each land use and "A_i" is the area of each land use.

Total litter load for every stream is based on four land use types that they were found sufficiently represent the study area. Land use types were commercial, residential, industrial and agricultural areas.

Satellite remote sensing is a convenient way for monitoring coastal areas in terms of water clarity and plume formation as well as oceanographic tracing of marine litter transportation. Satellite remote sensing data is used to show coastal intensification and characteristics of river plumes. Modis (Aqua) multispectral images of the region were processed. Chl-a and K490 parameters derived from Modis data were evaluated. The diffuse attenuation coefficient (K490) in water indicates how strongly light intensity at a specified wavelength is attenuated within the water column. K490 directly related to the presence of scattering particles in the water column

which can be used as an indication of water clarity. Coastal water clarity is also determined by organic and inorganic load of material transported to sea by rivers and can be related to plume intensification which is further a hint for marine litter accumulation in any region of interest.

RESULTS AND DISCUSSIONS

South Eastern Black Sea region is suffering from environmental pollution despite all legal regulations and authorities. The main pollution source in coastal and stream network is anthropogenic. Litter resulting from inhabited areas within buffer zones and banks of stream network is



Figure 3. Streamside industries and pollutants.

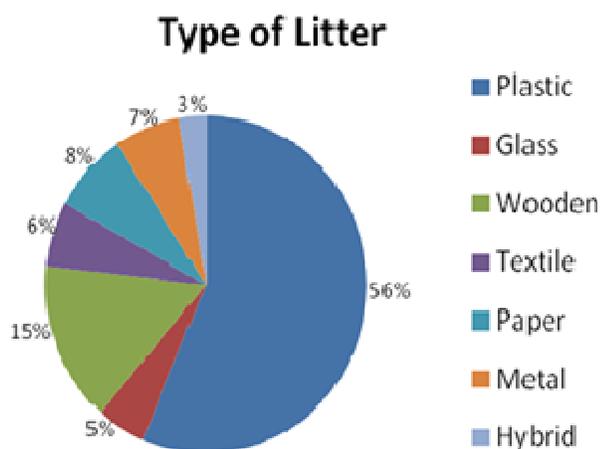


Figure 4. Proportional rate of litter type in total load.

reducing visual quality of the region (Figure 3). Among all solid waste pollutants, plastics have the highest ratio by 56%. Similar results were found in studies carried out in Gulf of Oman and California Coast (USA) (Moore et al., 2001; Claraeboudt, 2004). Figure 4 shows the litter type proportion determined during the survey. Identified ingredients of main solid waste was mainly dominated by plastic bags, wrapping materials, plastic bottles, cardboard, cans, construction scraps, old clothes, shoes, glass bottles, tree branches and tires. Such as old fishing nets and some plastics lead to vast amount of fish dead in the sea. Ghost fishing by old fishing nets is very known problem that recognized by fisheries scientist all around

the world. Ingestion of plastics by fishes must also be stressed as a catastrophic impact on aquatic ecology.

There are many industrial establishments such as asphalt construction sites, stone crushing units, concrete stations, milk processing industries and car maintenance Industries along surveyed streams (Figure 3). Those establishments are reducing aesthetic value of the region and negatively affect the flora and fauna of the river ecosystems. They also use the sand and gravel from stream channel that is very devastating for habitats of living resources.

Among all surveyed streams Yomra Stream has the highest ratio of plastic litter by about 64%. This can be attributed to the location of the stream and industrial establishments alongside of stream banks. Yomra Stream basin is also one of the most densely populated basin of the surveyed area. Caglayan Stream has the highest ratio of textile litter (15%) which can be result of garbage of tea transportation bags since the area is very famous with tea cultivation. Figure 5 shows percentage litter composition for all surveyed streams in the region.

Recently, highway construction along the sea shore of the South eastern Black Sea region is completed. Unfortunately, sandy sea-sides and shores were lost as well as some special habitats for coastal aquatic species. It may take many years to recover from current situation (Figure 6). As a result of coastal degradation, ecological and socio-economic situation of the region is negatively effected. Moreover, manmade alterations created an ugly barrier between sea shore and people living in this area. This is also supported by personal communications with local people. Construction of highway is done by using sea shore filling techniques and as a filling material

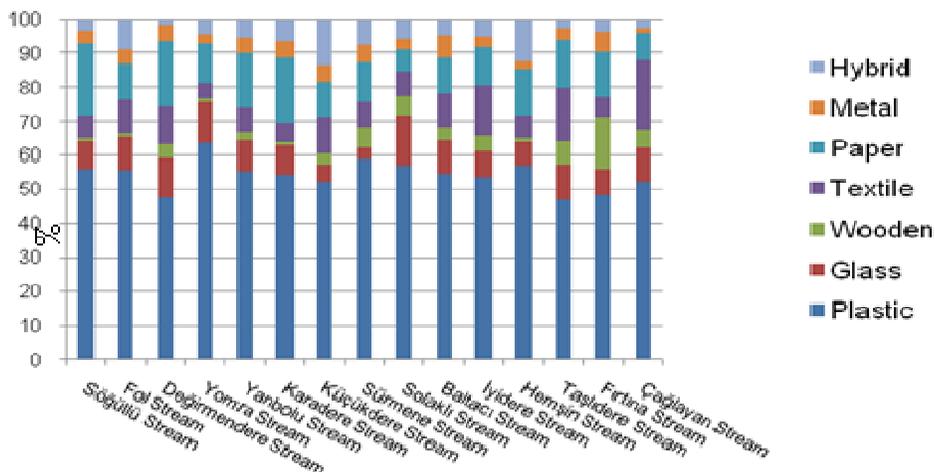


Figure 5. Percent (%) litter type composition of total load.



Figure 6. Highway and land filling practices.

million tons of solid waste is buried along coast line (Figure 5). This may cause very hazardous impact on marine living biota (Petzold-Bradley et al., 2002). Soluble part of these wastes may already be accumulated in tissues of some coastal fish and crustacean species. This problem must urgently be monitored in terms of public health conservation because the region is one of the biggest fish consuming areas in Turkey.

Table 1 shows the estimated yearly load of litter from stream catchment area. Uncontrolled dumping is not considered in calculations. Probably actual litter load would be at least 2 - 3 times higher than estimates. Moreover, regular cleaning is assumed to be done regularly during the calculations. The quantity of marine litter is strongly related to the handling of solid wastes throughout the world, wastes that remain in the environment for a very long time, and wastes transported for long distances by winds, rivers, rain and marine currents (Iniguez and Ficscher, 2003).

Anthropogenic eutrophication is another pollution problem that is also interconnected with litter transportation. As well as very dense fertilization activities in region,

some organic and inorganic compounds emanating from degradation of litter contribute to trophic state of the stream and coastal waters. Public support and stake holders willingness are major factors that effect sustainable clean environment concept and practical steps toward to prevent such activities (Daoji and Daler, 2004). Tracing the river plumes can give very important clues about deposition, dissemination and transportation of the litter. Remotely sensed images show both circulation characteristic and water clarity of area of interest (Figure 6). Moreover, spatially and temporal characteristics of the stream plumes and their dilution zones can be determined by using satellite imaging techniques. This could be very important in case of any operational activities to prevent pollution, determining hotspots and cleaning operations. Exploiting merged information from different sensors can give advantage of tracing plume formation and its interaction with mesoscale processes such as meanderings and eddies. It can be seen from the Figure 7 that Chl-a and K490 seasonal trends are very useful to understand coastal processes. Strong mixing during the winter season

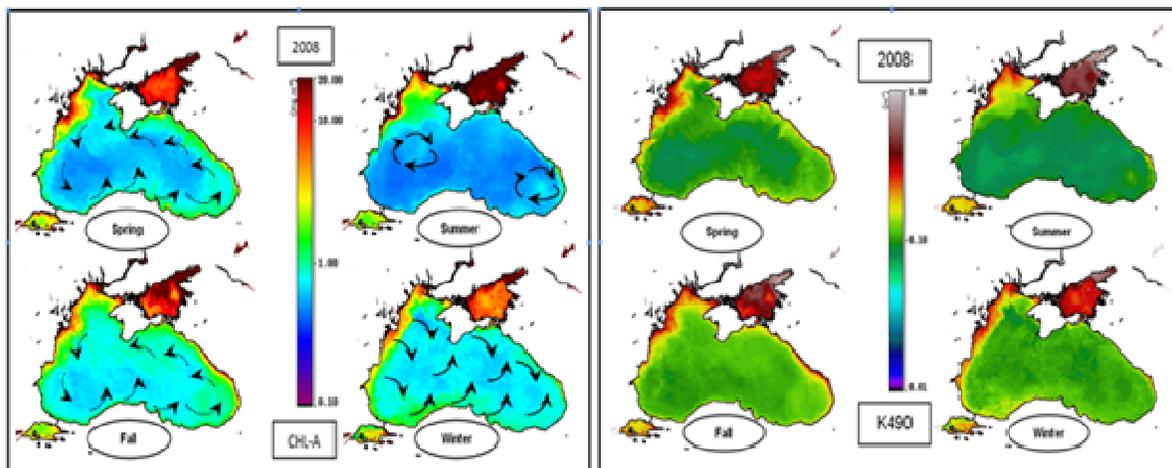


Figure 7. Modis-Aqua Chl-a and K490 Black Sea seasonal distribution.

results in horizontal and vertical movement of water masses. Summer stratification causes meandering and eddy structure to become intensified and transport coastal waters to inner basin. Fall and Spring seasons are transition periods in terms of physical forcing of coastal water mass transportation. Batumi gyre formation in Spring season is one of the most important periods of transition for South Eastern water circulation. Coastal water exchange with main cyclonic gyres lead to transport of marine litter from coast to coast and between neighborhood countries. Where Chl-a can be used to relate physical circulation and mesoscale features, K490 parameter can be regarded as a hint to trace plume formation and timing and seasonality of rainfall system of the region. Higher values of K490 indicate very turbid waters that potentially with very high load of marine litter.

Conclusions

Finally, some actions and measures must be taken to prevent litter disposal and mitigate the current situation in the region. Illegal dumping along the stream networks and banks must be strongly prohibited. Litter collecting nets can be considered at least for major streams to reduce litter load and collect scientific data periodically. Solid waste cleaning and removal must be strictly coordinated and organized in the region. Raising public awareness by organizing workshop seminars and television programs should be considered by the authorities. Non Governmental Organization (NGO) activities can be financially and mentally supported by government and volunteers. Environmental protection logic and information must be educated in preliminary schools for healthier and clean environments. As well as giving a start to National River monitoring programs legal rules must be applied for all law violation circumstances without exception. A rehabilitation program for coastal areas and

river beds can be also considered after mitigation of current situation.

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