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MARINE OUTFALL APPLICATIONS ON THE TURKISH COAST OF THE BLACK SEA

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ABSTRACT

This paper covers research results and construction techniques applied for marine outfall systems of three medium sized cities located on the coast of the Black Sea. The treatability and design data related to the pre-treatment and marine outfall system of a large pulp and paper mill on the same coast are presented. The preliminary studies and the development of the design criteria of the related marine outfall systems were carried out by the Department of Environmental Engineering of Istanbul Technical University. The scope of the project included oceanographic, hydrographic, and geotechnical surveys and water quality measurements. A construction method, which is widely applied in Turkey for laying of the glass reinforced pipes(GRP), has been evaluated. Pollution loads originated from the land based sources have been given and their probable environmental impacts in the receiving water body have been discussed.

KEYWORDS

Marine outfall systems; toxicity; pulp and paper mill effluents; municipal wastes; land based polluting sources; marine pollution.

INTRODUCTION

In the northern part of Turkey , the coastal band of the Black Sea is approximately 1400 km in length and more than forty important communities are located along the coast. Primarily, coastal waters of the Black Sea are used for fisheries, swimming and recreational purposes. Marine outfall systems are under construction for eight communities on this coast. Excluding these cities, more than 30 new marine outfall systems have been planned before the completion of the municipal sewer system constructions. Due to the limited available land, only mechanical treatment consisting of a screen and a grit chamber has been applied as a pretreatment before the sea discharge, at the beginning. These partial primary treatment units have been arranged so flexible that the system could be converted to any conventional primary or secondary wastewater treatment system. On Turkish coasts of the Black Sea, there are a few large industries which have their own effluent treatment facilities.
In this paper, marine outfall applications for both municipal and industrial effluents on the coastal zone of the Black Sea have been presented. The polluting loads of the rivers discharging into the Black

Sea and of the bottom flows of the Bosphorus have been presented and their possible environmental impacts in the marine environment have been discussed.

COASTAL WATER QUALITY STANDARDS IN TURKEY

Local discharge standards for municipal and industrial wastewaters to sea are given by Water Pollution Control Regulation dated 4 September 1988. Sea discharge of industrial effluents should meet the quality limits and the design criteria given in Tables:1 and 2. If receiving water body and/or wastewater characteristics are not appropriate, the marine outfall is not permitted.

Table 1. Required Characteristics of Industrial Wastewaters For Sea Discharge in Turkey

Parameter	Value	Remarks
pH	6-9	
Temperature, (oC)	35	
SS (mg/l)	350	
Oil and Grease (mg/l)	10	
Floating matter	None	
BOD_5 (mg/l)	250	
COD (mg/l)	400	
Total N (mg/l)	40	
Total P (mg/l)	10	
Surface active agents (mg/l)	10	
Other parameters	-	Special care for hazardous wastes

Table 2. Design Criteria for Marine Outfall Systems in Turkey

Parameter	Limits
Temperature	2°C (max) increase after initial dilution (D_i)
Total Coliform(EMS/100 ml)	1000 in 90% of samples
Initial Dilution (D_i)	40 (min)
Discharge Depth (m)	20 (min)
Discharge length (m)	1300 m (min) for discharge depths less than 20 m

CHARACTERISTICS OF THE TURKISH COAST OF THE BLACK SEA

Oceanographic characteristics. The seasonal variations of temperature, salinity, specific conductivity and density of the receiving water body are needed in design of marine outfall systems. Current and wave characteristics have also importance for dilution calculations and for the estimation of hydrodynamic forces acting on the discharge pipe line. Salinity, conductivity and temperature variations were measured at the same time with a salinometer in this study. Density values were calculated by the equations developed by Riley and Skirrov (1975). Temperature, salinity and density profiles at 2 different locations along the Black Sea were given in Fig. 1-2. These measurements have indicated a stratification in the Black Sea though it is slight in Summer, a submerged wastewater field forms in the receiving water body.

The Black Sea resembles an ocean rather than an inland sea especially in terms of the waves and currents. Turkish coasts are mostly affected by the northern, north-western and north-eastern winds. Wave heights

approaching 10 m are not rare in the Black Sea where the wind velocity reaches 140 km/hroccasionally and fetch distances are as long as 690 km. (Öztürk et al, 1989a) Surface currents of the Black Sea were analyzed in detailed by Neuman (1942). Surface currents of the Black Sea follow a counter clockwise trajectory both in the western and the eastern Black Sea regions. Surface currents are generally parallel to Turkish coasts but the current directions may be towards the coast depending on northern winds. Current speeds and directions were measured with a mobile current meter at four different locations where marine outfall systems were designed. Drogues were used for the determination of current trajectories in addition to the mobile current meters. These studies have indicated that the surface currents have velocities about 0.20-0.25 m/s and effective up to a depth of 15 m and the dominating direction is from West to East (parallel to coast) although there are some spatial changes in these values. Bottom currents are in the opposite direction to the surface currents, and have speeds in the range of 0.05-0.1 m/s (Öztürk et al 1987, 1989 b), (Eroglu et al, 1989).

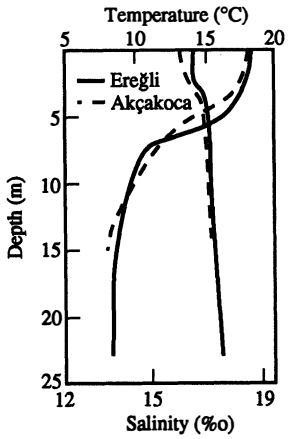


Figure 1: Temperature and Salinity vs. Depth for the Black Sea in Summer.

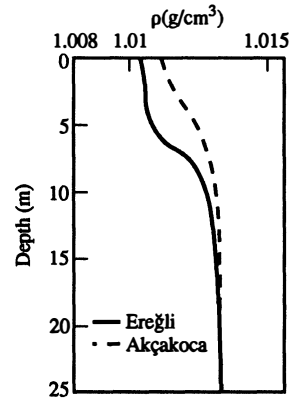
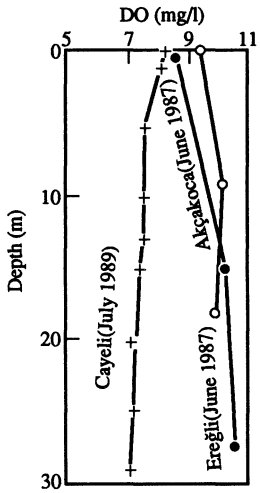


Figure 2: Density vs. Depth for the Black Sea in Summer.

Water quality Surveys. Water quality parameters like dissolved oxygen, BOD_5, Nitrogen and phosphorus were measured at the selected oceanographic research stations in order to determine the background pollution levels. The dissolved oxygen values, measured by Winkler method, of the samples taken at different depths are given Fig.3. As can be seen from the figure, dissolved oxygen values are close to saturation concentrations and because of this aspect they do not present a threatening situation for the aquatic life. Since anaerobic conditions prevail in deep waters of the Black Sea below 180 m, the environment is not suitable for the survival of fish and especially in some stormy weathers, due to the reach of H_2S saturated waters to the sea surface, massive fish deaths are encountered. The dissolved oxygen measurement, at the entrance of Bosphorus to the Black Sea, since 1963 have shown a distinct drop in the water quality (Fig. 4). This deterioration in the receiving water quality has been attributed largely to the pollution conveyed by the Danube and Dneiper rivers.

BOD_5, total Kjeldahl nitrogen (TKN) and total phosphorus parameters were found not to exceed 2.5, 0.42 and 0.03 mg/l respectively for the samples taken from the water surface at the diffuser locations of the marine outfalls of the 3 communities. T_{90} parameters measured by polyethylene bag technique were 2-2.5 hours depending on cloudiness factor and the season.



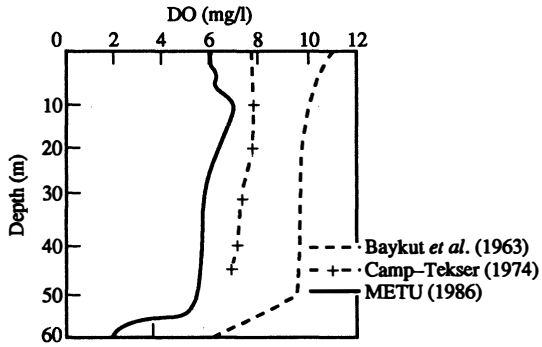


Figure 4: DO vs. Depth at a Station Near The Northern Entrance of The Bosphorus.

Figure 3: DO vs. Depth in the Black Sea.

Hydrographic and geotechnical characteristics. The shorelines of the Eastern Black Sea are irregular, generally with quite rugged background terrain. Rocky and cliff shores are common. The hydrography indicates steep slopes with irregular sea bottom. Short and narrow sand beaches are located approximately 5 to 10 km apart. There are no natural bays or havens between Sinop and Ereğli. The bottom of the sea is quite irregular with some unexpectedly high slopes in some locations. The nature of the sea bottom is sand in shallow waters and clay in deeper waters (Nisel, 1977).

Many small streams flow to the Black Sea along the coast. At some locations of deltas, the sea bottom is covered with mud sediments carried by the rivers. This structure at the bottom of the sea creates problems to sea discharge works since the communities are generally located around the river deltas. In the areas where salty soil does not dominate, the sea bottom is formed from graded gravel and sand material. In order to analyze the soil structure where the marine outfall pipe is located, standard penetration tests were performed by a specially designed apparatus. This apparatus with a conically closed tip has a diameter of 60 mm, a length of 70 cm, and an approximate weight of 7 kg. It is subjected to strikes by dropping a 5 kg weight from a distance of 30 cm above the apparatus by a diver and required number of strikes were recorded in order to penetrate it 30 cm through the soil or the penetration depth at 20 strikes in hard soils were taken into consideration. This way a rough soil classification was achieved . In addition to this, iron bars with a diameter of 16 mm were manually driven into the soil at the bottom of the Sea to determine the depth of the loose soil at the bottom.

MARINE OUTFALL APPLICATIONS

Pretreatment system. The coastal band is very narrow along the Black Sea and just behind the coast there are mountain chains. This geographic structure leaves a very limited area to the use of treatment plants. Reclaiming area from the sea by coastal filling is very expensive and difficult because of the destructive waves in the Black Sea. This application has also special drawbacks in terms of environmental protection.

Primary treatment systems before the marine outfalls are chosen as simple as possible due to lack of qualified manpower in the municipalities and

high operating cost. Grit chambers are generally constructed in circular form with mammoth or grit pumps for sand release due to high ground water table. The discharge pumping stations generally have a horizontal surge chamber with an air release pipe to protect the discharge pipe against water hammer.

Municipal marine outfalls. Pretreatment and marine outfall projects of the 3 towns and a paper mill located along the Black Sea coast were designed by the Environmental Engineering Department of Istanbul Technical University. Among these projects, construction of Ereğli marine outfall system has been completed and the others are still under construction. Technical specifications of the marine outfall systems of three municipalities (Ereğli, Akçakoca and Çayeli) and of the SEKA Aksu pulp and paper industry are given in Table 1.

Table 1. Design Summary of Marine Outfall Systems

Plant name	$Q_{av.}$ (l/s)	Discharge depth (m)	Pipe length (m)	Diffuser length (m)	Pipe diam. (mm)	Port diam. (mm)	Number of ports
Ereğli							
Discharge I	357	25	1300	92	700	100	24
Discharge II	49.4	19	950	27	350	80	10
Akçakoca							
Discharge I	59	18	1500	36	400	80	13
Discharge II	19	13	1000	10	200	80	5
Çayeli	87	25	1100	45	400	100	10
SEKA Aksu pulp & paper Ind.	222	25	1390	54	600	150	10

Preatrement units consist of a bar rack followed by a grit chamber as an urgent solution. In the future, sedimentation basins will be added to further improve the effluent quality.

Industrial marine outfall. The investigated industry, Turkish Pulp and Paper Association (SEKA) Aksu Pulp and paper factory, which is located in Aksu village near the province of Giresun in Eastern Black Sea region of Turkey , is a ground wood based pulp and paper mill. An annual average of 65000 tonnes newsprint paper is produced using 15000 tonnes cellulose per year and 100 m^3 process water per tonne of paper. Production of newsprint paper includes three separate processes, debarking, mechanical pulping and paper production. There is no cellulose production within the plant. The cellulose which is required for production is supplied from the other integrated establishments of SEKA.

Effects of pulp and paper mill effluents on macrofauna. Lethal or sublethal effects of pulp and paper mill effluents or of their constituent chemicals were determined with bioassay tests. In this study Lepistes reticuloris was used as the test organism, and 96-hr median tolerance level (96-hr LC_{50}), the volumetric lethal concentration at which 50% of fish are dead after 96-h exposure, was determined as 84%. Bioassay lethal data suggest the effluents from this industry are not particularly toxic. Considering a minimum initial dilution of 40, no toxic effect from these industrial wastes in the marine environment is expected (Öztürk et al, 1988).

Pretreatment system for SEKA Aksu pulp and paper mill. From the findings of the treatabilty studies, it was concluded that the aerated lagoon (AL) system with a 7 days HRT after chemical treatment with alum would produce a BOD_5 suitable for discharge into Aksu river. On the other hand, a high-rate AL treatment of effluents from the chemical treatment plant would be

employed to satisfy Sea discharge standards to the sea (Öztürk et al, 1988). Based on pilot-scale treatabilty studies, the full-scale wastewater treatment system including chemical pretreatment, high rate AL, mechanical sludge handling and marine outfall units were designed. In this treatment system, a 50 percent reduction in process water supply was proposed by recirculating white waters effluent from the chemical treatment units of the mill.

CONSTRUCTION METHOD OF MARINE OUTFALL SYSTEMS

In Turkey , glass reinforced plastic pipes (GRP) have generally been used in the municipal and industrial marine outfall applications. Although complete burial of the discharge pipes is preferred, economic considerations result in pipelines usually being on the sea bottom beyond the surf zone and the stability of the system is provided by reinforced concrete fixing blocks. At regions where mud dominates, the soil has been improved by forming a foundation consisting of sand and gravel. The discharge lines have been laid in trenches opened in the improved soil or directly on the sea bottom. A different method has been applied to prevent the scouring of the filling of the trench due to wave and currents damage of the GRP pipes during the back filling of the trench. Since the wave forces are extremely high in the Black Sea, use of stones with diameters of 30 to 40 cm is needed. In our applications instead, upper part of the trench opened at the sea bottom has been covered by the use of poly-ethylene (PE) sacks filled with dry mortar. In this way, it is possible to carry out the laying of the discharge pipes on the sea bottom rapidly and safely. Five pieces of the GRP pipes are joined on the land as a module of 30 m in length with flanges at both ends and then this module is floated and lowered down to the sea bottom and joined by the divers. This technology has been widely applied in Turkey as an appropriate method for underwater pipe works.

ESTIMATION OF LAND BASED POLLUTION LOADS FROM TURKISH COAST OF THE BLACK SEA

It is possible to classify the land based pollution loads discharged to the Black Sea in three groups. These sources are namely: a) Pollution loads from the communities along the coast of the Black Sea, b) Pollution loads from the rivers flowing into the Black Sea and c) Industrial pollution loads. These pollution loads were considered separately.

More than forty cities and towns are located along the Turkish coast of the Black Sea. In the pollution load calculation from the cities and towns, population projections to year 2020 were considered. The per capita BOD_5 was assumed to be 60 grams per day. The 1990 and 2020 year total populations of the above named towns and cities are 1,276,000 and 3,100,000 respectively. Due to the assumption that all these cities will be connected to sewer systems by the year 2020 and their wastewaters will be discharged to the sea after a mechanical treatment, the expected BOD_5 load would be 186 t/day. The 1990 BOD_5 load can be estimated as 50 t/day by considering 65% of the population of the named 43 settlements have connection to the sewer network system. The pollution load would reach 58 t/day assuming 15% increase due to the tourism and industrial activities.

The major rivers discharged to the Black Sea from Turkey are Sakarya, Filyos, Kızılırmak, Yeşilırmak and Çoruh. Pollution loads were calculated based on the measurements of flow rate and organic matter (TOC) at the stations, located just upstream of their deltas, the General Directorate of Electric Works Surveying Administration. In the calculations, average of the measurements for the period of June-October during which the pollution is maximum, were considered and the results regarding the year 1986 have been given in Table 4. Pollution load conveyed to the Black

Sea, by the major rivers born in Turkey , is about 60 t/day in the year 1986 (Table:4). This amount is expected to be probably 65 ton/day in the year 1990. The contribution of humic substances towards organic matter content of river waters is expected to be significant.

Table 4. Organic Pollution Transported to the Black Sea by the Major Rivers of Turkey.

Name of Rivers	Average Low flows (m^3/sec)	Average (TOC ≈ BOD_5) (mg/l)	Pollution loads (kg BOD_5/day)
Sakarya	52.31	2.55	11.53
Filyos	32.64	2.26	6.37
Kızılırmak	6.65	1.40	8.04
Yeşilırmak	119.93	1.62	16.79
Çoruh	89.15	2.25	17.33
Total			60.06

Industrial establishments along the Black Sea are few. Industries like SEKA Aksu pulp and paper mill, Samsun fertilizer industry and Ereğli Iron and steel establishment have their own private treatment plants. The industrial effluents are treated at a level dischargeable to receiving water body. The expected city and town based total pollution load would be 240 t/day in the year 2020 with a 30% increment due to the tourism and industrial activities. From these data, maximum pollution load is estimated to be about 312 t/year that may come from the coasts of the Black Sea of Turkey . However, the mentioned pollution load would be 218 t/day taking into consideration a 30% reduction in the total load due to the pretreatment before the discharge.

ENVIRONMENTAL IMPACT EVALUATION

General usages of the Black Sea coasts of Turkey are for fishing, swimming and recreation. Because of the high velocity of the currents in the receiving water bodies, there is always an effective dilution and thus the presence of organic matter like C, N and P, will not create a problem and eutrophication is also unlikely to occur in the short term. The most significant factors with respect to pollution and aesthetic view are settleable solids and floating matter. For this reason, the removal of these materials during mechanical treatment is of great importance. Compliance with the coliform bacteria standards is of prime importance in attaining acceptable water quality in the receiving waters. One of the most significant factors affecting aquatic life is coastal filling. As a result of this filling, the fish nets near the coastal areas and creeks are covered with soil and because of the increasing turbidity the fish migrate and their species decrease. Hazardous wastes from industrial discharges should be removed by effective control at the source. As long as the discharge of heavy metals and hazardous wastes is prevented, the pollution load of the domestic and industrial discharges from the Turkish coast does not exceed 2 million population equivalent. The significant portion of the organic matter coming from the rivers consistsof natural humic matters. The reason for this is the incomplete sewer systems in the settlements of these river basins, and the wastewater seepage occurs in significant quantities.

The pollution load coming from the Bosphorus into the anaerobic lower layer of the Black Sea is about 72 t/day for 1990 (Ozturk et al, 1990). This quantity is stabilized in these deeper layers which are renewed in every 3000 years and therefore does not affect the upper layer of about 180 m thickness. The major dangers for the ecological life in the Black

Sea and the Sea of Marmara, which is an inland sea of Turkey , are pollutants originating from the Danube, Dneiper and Done rivers and also hazardous wastes from ships. These effluents contain non-degradable and priority pollutants. In addition, one of the most dangerous situations arises due to illegal discharge of hazardous waste containers from unidentified ships.

CONCLUSIONS

The total land based pollution loads from Turkey to the Black Sea including municipal, industrial and river discharges have been estimated as 233 t BOD_5 per day for the year 2020. This corresponds about 0.2% of the total primary production of the Black Sea. The most important factors with respect to pollution and aesthetic value are settleable solids and floating matters. Coastal fillings have also affected significantly the aquatic life, especially the fish nets.

The real dangers for the ecological life in the Black Sea and the sea of Marmara are pollutants from middle Europe via Danube river and also hazardous wastes dumped illegally by unidentified ships.

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