REMOTE SENSING APPLICATIONS ON ENVIRONMENTAL POLLUTION OF THE BOSPHORUS

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ABSTRACT

As the result of population growth and industrial development in İstanbul,the Strait of İstanbul (Bosphorus) are being affected negatively by the waste discharged from industrial plants and residental areas. The Bosphorus was investigated using satellite digital data (TM and SPOT) and water quality observation which are total suspended solids,humic materials, chemical oxygen demand,polyaromatic hydrocarbons.Digital multispectral data were recorded and co-registered for a portion of Bosphorus and Golden horn.Matrix overlay analysis was then used to combine the oceanographic station classes generated from minimum distance and maximum likelihood classification for the water cover area.

1. INTRODUCTION

Life and physical process on the planet earth are greatly affected by oceanic and estuarinal areas. Water comprises about 70 percent of the earth`s surface and the oceans are important both for the exchange of mass and energy within the terrestrial as well as solar systems. Operational and research satellite systems now provide global synoptic measurements of climatic and environmental parameters relating to major processes of the oceans. Satellite system can also provide local scale measurements that are of interest to oceanography, even though these remotely-sensed measurements are more amenable when coordinated with collected water quality data. Today studies conducted by examining various satellite data are carried out in order to determine sea pollution levels and surface temperatures. Numerous studies conducted thus far have shown that remote sensing techniques can be used for assessment of water quality data.

Remotely sensed-data must be combined with sea control measurements due to the downward reflection of the incident energy on the water surface because of non specular reflection absorption and scattering. Absorption and backscatter are highly influenced by inorganic and organic substances within the water body and these produce special signatures. Unlike specular reflection, the amounts of absorption and backscatter from a water body are highly dependent on the wavelength intervals being sensed by the recording instruments. Reflectance and backscattering are not only a function of the properties of the sediments present. Distinctive spectral signatures obtained from digital satellite image data correspond to different types of water bodies.

Consequently, collected water quality measurements is necessary.

Many of the developing nations' rapidly urbanizing major cities, especially those which lie along the edge of a body of water, are being affected negatively by the waste discharged from industrial plants and residential areas, in addition, to other natural occurrences. Since these cities need clean water supply, the necessity has arisen to develope a technique which can be used to obtain reliable data to permit more correct interpretations of water quality assisting in the management of existing water resources. The remote sensing technique has a high potential for such a goal.

The Istanbul (Bosphorus) Strait runs through the ancient city of Istanbul. Not only is this strait a site of incredible beauty, it is also an area steeped in history and myth. Today this strait is under extreme threat due to the pollution load being dumped along its coasts. Water quality in the Bosphorus is being strongly affected by waste discharges from many industrial and residential areas. The Bosphorus receives domestic and industrial wastes from about thirty large and small scale towns. Because of this rapid increase in pollution levels, a monitoring program must be instituted to measure coastal pollution.

2. STUDY SITE

The Istanbul Strait, is located between the Marmara Sea and the Black Sea, forming part of the Turkish Strait System which consists of the Dardenelles Strait, the Marmara Sea, and the Istanbul Strait. This system, which is approximately 300 km in length, connects the Mediterranean Sea, via the Aegean Sea, to the Black Sea. The system has an important influence on oceanographic conditions in the Black Sea and in the Marmara Sea.

The Bosphorus Strait is a meandering strait some 31 km in length, with widths varying from 0,7 to 3,5 km averaging about 1,6 km. The average and maximum depths are 35,8 and 110 m. The bathymetry and the locations in the Strait, derived from Turkish Chart TR-2921 (Fig.1) . Its bed is a drowned river channel, more than 50 m deep, extending beyond a sill of 32 to 34 m depth located at the southern entrance of the Strait, between Kabata¦ and Üsküdar. One of the distinct characteristics of the Bosphorus Strait is a two-layer current and density distribution. Less-saline, Black Sea surface-water is carried into the Marmara Sea at the surface of the Strait, while underlying bottom water from the Marmara Sea, which is originally from the Mediterranean, is carried in the opposite direction towards the Black Sea. The surface current follows(Fig.2) the Strait's meandering path and forms numerous small circulations in several bays on both sides. The bottom current follows more closely the windings of the channel.

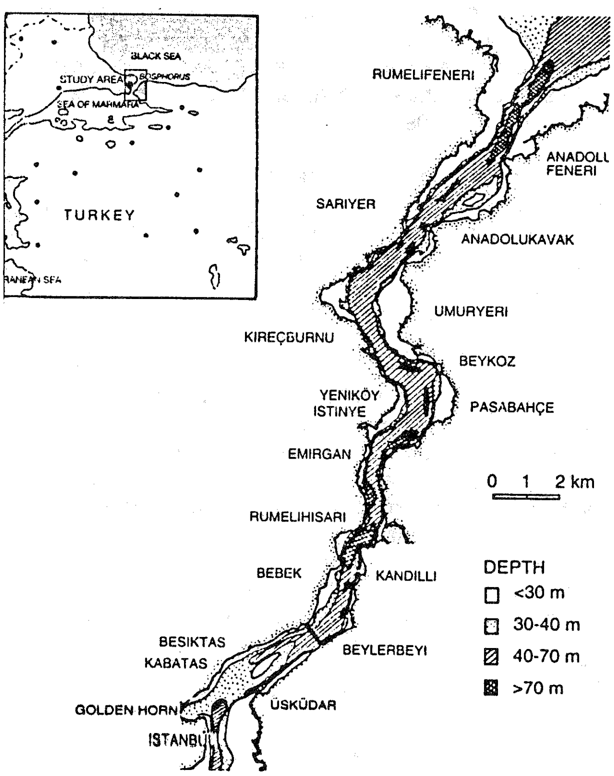

Figure 1 : Location map and Strait of Istanbul bathmetry derived from Turkish Chart (2921)).The southern sill is located between Kabataş and Üsküdar

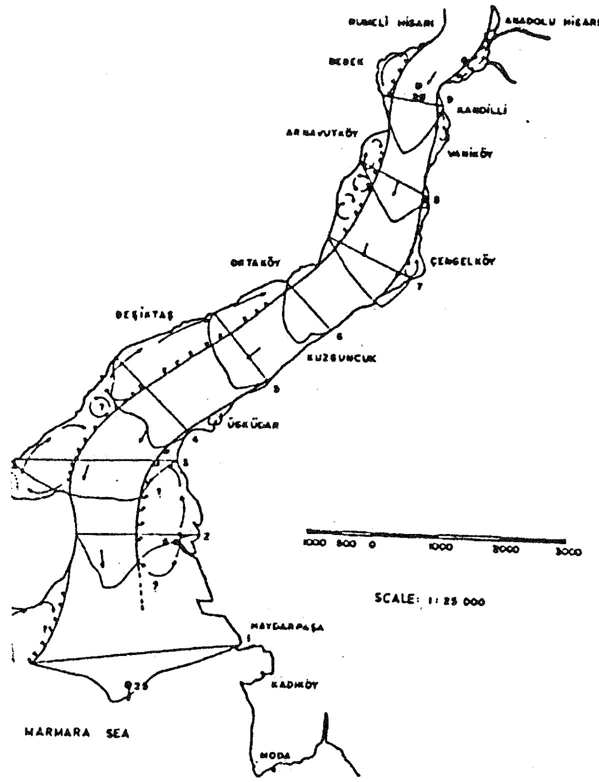

Figure 2 . Bathymetry and flow direction at certain cross sections of Bosphorus

Vertical stratification has been investigated by many researchers in order to understand the important role of water exchange throughout the Bosphorus Strait in determining the oceanographic regime, especially that of the western Black Sea and the Marmara Sea. Studies of water exchange, vertical stratification and current characteristics were first conducted by English, Russian and German observers in the early 1800's.

The Golden Horn which flows in anorthwest-sout-east direction,joins the Bosphorus at İstanbul.It is approximately 7.5 to 8 km in length ,and also has a two layer current and density distrubition.The upper layer is about 2 to 3m deep and is higly polluted by wastes diascharged from many industrial plants and municipalities and by many polluted tributary streams.

Industrial plants contribute approximately 200,000 m^3 of polluted water per day to the Golden Horn. Of the total ,67 percent are chemical substances.The water quality is further degraded by salt water incursions from the sea of Marmara .In addition to the industrial and domestic pollutants,pollution sources in the sttdy area include agricultural irrigation water containing large amaunts of nitrogen and phosphorus compounds ,rain water carrying soil removed by erosion ,waste products discharged by ships and boats and varius solid wastes.

Water quality reference data for Bosphorus and the Golden Horn were collected by Middle East Technical University's Institute of Marine Sciences (METU/IMS).

The monthly surface and 20m depth of measurement values of TSS, HM, COD and PAH measured at the oceanographic stations(Fig.3A,Fig3B) in the Bosphorus.

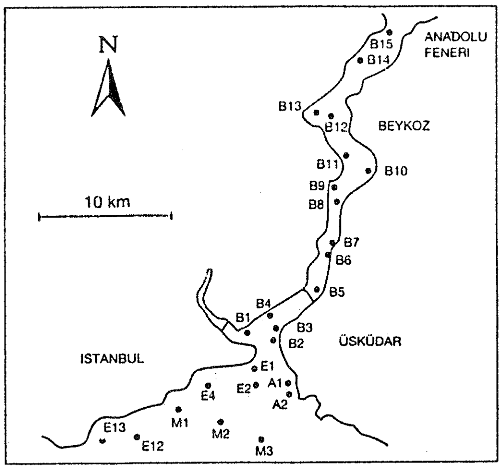

FIGURE 3A Oceanographic stations in the Bosphorus

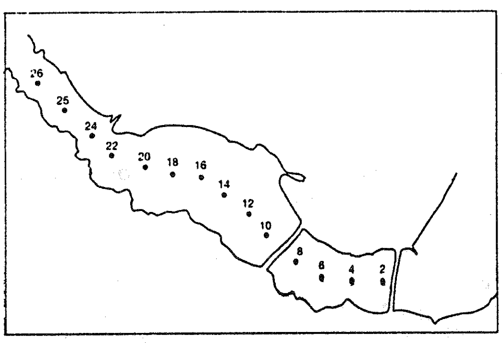

FIGURE 3B Oceanographic stations in the Golden Horn '

Environmental pollution including water pollution can be defined as the damage to water and air due to misuse of such resources by human beings. Residential sources of water pollution are the liquid sewage disposal discharged into the water by domestic and industrial organizations. Pollution sources such as agricultural irrigation, water carrying soil shifted by erosion, the discharges from ships, boats, and the solid wastes can be included in this category. The pollutants considered in this work are described both technically and aesthetically, as follows:

Total Suspended Solids (TSS): These are precipitating solids and small pieces dislodged from the soil and either carried by or suspended in water. Measured in milligrams per liter Chemical Oxygen Demand (COD) is organic substances which are both suspended in water and deposited at the bottom of the sea forming an oxygen-free medium. When in suspension, these particles cause water turbidity and a grayish color. They also prevent sunlight from reaching acquatic plants. The organic components of TSS can be determined by collecting and separating them with 0.7mm glass filters. The unit of COD is measured in milligrams per liter.

Humic Materials (HM) and *Polyaromatic Hydrocarbons* (PAH): HM consists of organic matter including the products of biological decomposition of plants, living matter, and industrial paints and pigments. PAH consists of oil grease and heavy petroleum particles. PAH is deposited into the water either from the land or discharged from boats and ships.

3. DETERMINATION OF THE HYDRODINAMIC STRUCTURE AND THE WATER POLLUTION OF THE BOSPHORUS

The hydrodynamic conditions in the Bosphorus are quite complex. With its synoptic view capabilities and image processing methods, remote sensing data combined with ground truth measurements can be regarded as a useful tool for monitoring the coastal zones.

This study investigates the water pollutants with hydrodynamic conditions in the Bosphorus using satellite images based on Landsat 5 Thematic Mapper data on visual, near infrared and thermal bands and Spot data on multispectral bands with different dates (For TM,1986, 1992; for Spot , 1993,).

Image processing of the satellite data related to the Bosphorus was performed by using the *Decision Image-Resource Image Analysis and ERDAS Systems* located in the Faculty of Civil Engineering at Istanbul Technical University. As the first step, the radiomatically corrected satellite data were geometrically corrected.

Regression analysis was used to examine the relationship between the water quality parameters(Table 1A,Table 1B) and the reflectance values. The necessary values are provided in. Single pixel and 3 by 3 pixel window_ average values for each band at the station point in the Bosphorus and the Golden Horn.The two data sets that means reflactance and water quality measurements are analyzed and the regression coefficients (a,b) are tested.During the regression analysis water quality measurements on hydrologic station point are taken as X; and the values of reflactence on same points are Y . In the results of the regression analysis of the bands have obtained; coefficient of correlation(R) on TM data (24th October 1986)was taken in the last week of October and the water quality reference data were collected in the first week of November.The coefficients of correlation on the first band are observed as 83% for TSS, 86% for HM, 47% for COD, 80% for PAH and on the second band ,also are observed as 68% for TSS ,63% for H M, 49% for COD,68% for PAH . For the SPOT data (13th June 1993) also had taken not simultaneously water quality observationswhich are near date. As the result of regression analysis are obtained on the first band 1%for TSS, 89% for HM , 46% for COD , 92% for PAH .

TABLE 1A The monthly surface water measurement values of TSS, HM, COD, PAH at Bosphorus oceanographic stations (mg/l)

Sta	*TSS*		*TM*		*COD*		*PAH*	
	Sept	*Nov*	*Sept*	*Nov*	*Sept*	*Nov*	*Sept*	*Nov*
B9	0.80	1.12	1.40	0.50	0.37	0.27	-	-
B8	1.20	1.34	1.55	0.57	0.24	0.30	0.52	0.09
B7	0.90	1.12	1.10	0.55	0.39	0.32	0.07	1.12
B6	0.95	1.24	1.35	0.75	0.18	0.37	-	-
B5	1.10	1.40	0.30	0.70	0.18	0.28	-	0.09
B4	5.30	1.33	1.40	0.83	0.39	0.56	1.20	0.56
B3	-	1.50	-	0.67	-	0.45	-	8.64
B2	-	-	-	-	-	-	-	-
B1	1.50	1.96	2.25	1.70	0.91	0.42	0.34	5.76

TABLE 1B The monthly measurement values at 20 m depth of TSS, HM, COD, PAH at Bosphorus oceanographic stations (mg/l)

Sta	*TSS*		*TM*		*COD*		*PAH*	
	Sept	*Nov*	*Sept*	*Nov*	*Sept*	*Nov*	*Sept*	*Nov*
B9	0.80	1.10	-	0.55	-	0.27	-	-
B8	1.20	1.20	1.40	0.70	0.22	0.29	0.37	0.08
B7	0.60	0.37	0.30	0.73	0.41	0.29	0.05	0.27
B6	2.00	-	1.15	0.70	0.26	-	-	-
B5	0.60	1.30	1.70	-	0.24	0.31	1.40	0.08
B4	1.70	1.05	1.60	0.85	0.30	0.54	0.54	0.11
B3	-	1.53	-	0.52	-	0.31	-	-
B2	-	-	-	-	-	-	-	-
B1	1.70	1.60	0.40	0.55	0.27	0.36	0.46	-

Bosfhorus's final image ,(Fig.4A,Fig.4B)which are formed by controlled min-distance classification methot usingTM data is compared with the ground data sets(Fig.1,Fig.2).It is observed that the image in Fig.4A is compatiple ground truth data given in Fig.1 and Fig.2. The pollution caused by Istinye Stream and the Shipyard in İstinye Inlet,the Baltalimanı Stream,Bebek Inlet,the Coal Depot in Kuruçeşme ,the registered or unregistered waste discharges till Beşiktaş ,Fig.4B shows the turbidity distributionin the Golden Horn.The northwestward flowing surface water carries pollution from the Bosphorus,which is supplemented by local discharges in to the Golden Horn.

TABLE 2 The monthly surface water measurement values of TSS, HM, COD, PAH at the Golden Horn oceanographic stations (mg/l)

Sta	*TSS*		*TM*		*COD*		*PAH*	
	Sept	*Nov*	*Sept*	*Nov*	*Sept*	*Nov*	*Sept*	*Nov*
2	12.00	21.90	10.80	0.65	4.26	7.64	550	470
4	4.20	22.60	12.60	7.50	4.55	7.10	-	265
6	6.90	14.90	8.00	7.74	6.35	7.97	-	190
8	9.00	12.50	16.40	7.74	6.54	8.27	680	265
10	9.70	12.00	14.80	8.70	5.37	9.71	100	-
12	1.27	16.60	16.20	10.00	0.98	11.11	170	-
14	1.35	11.00	8.20	9.50	0.72	9.68	380	395
16	1.12	11.00	9.60	9.30	0.55	8.23	220	400
18	0.39	27.30	8.40	11.10	0.40	9.40	-	-
20	3.40	17.80	11.60	13.60	0.57	9.50	140	-
22	-	22.40	11.60	15.66	0.16	12.97	150	470
24	3.55	33.20	12.00	17.20	-	-	290	-
26	-	-	12.00	20.68	1.08	-	110	190

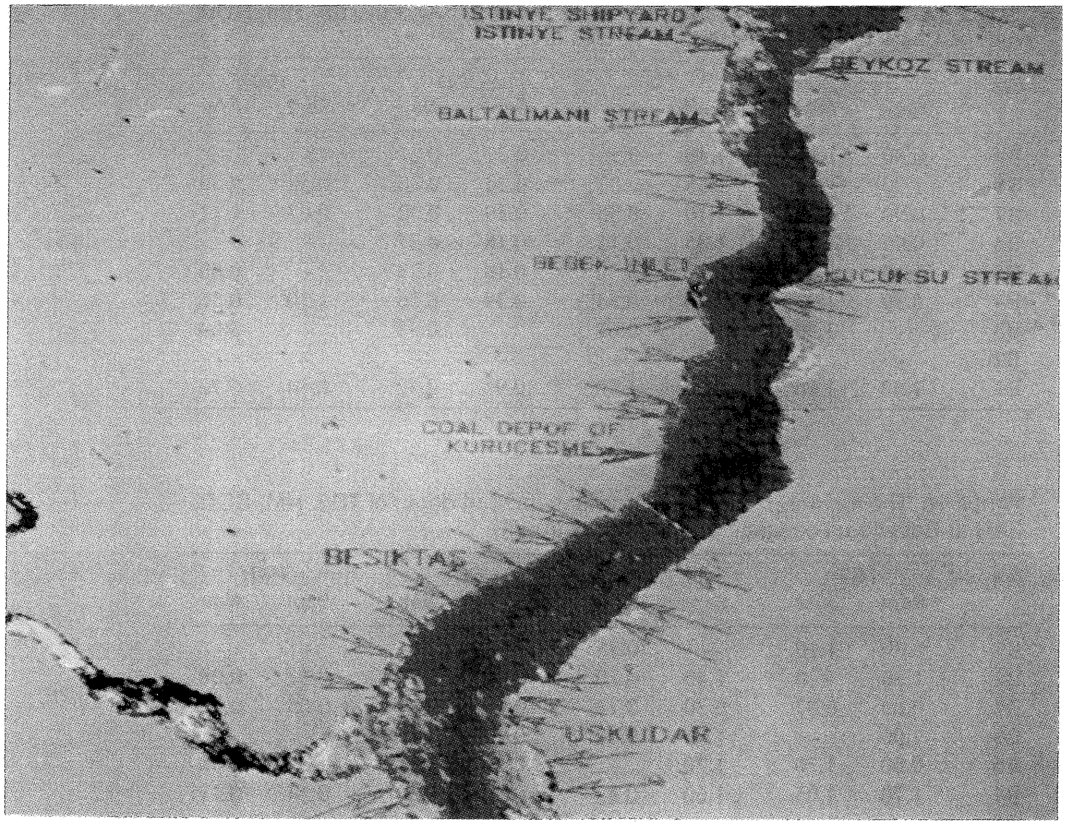

Figure 4A Turbidity distribution map of Bosphorus derived from Landsat 5 TM data of 24 October 1986,formed by controlled classification method. (Colors indicators Fig. 4A and 4B : yellow= waste discharges from textile factories;orange=organic materials,including products of biologic decomposition (HM) and industrial paints and pigments;blue= Black Sea water (>10° C); darkblue= Black Sea water (<10° C) ;pink= Marmara Sea water ;red= domestic wastes ; black= wastes discharged from heavy industries (including metals))

Figure 4B .Turbidity distribution map of the Golden Horn derived from TM data of 24.October 1986(arrows show İstanbul's domestic and industrial discharges)

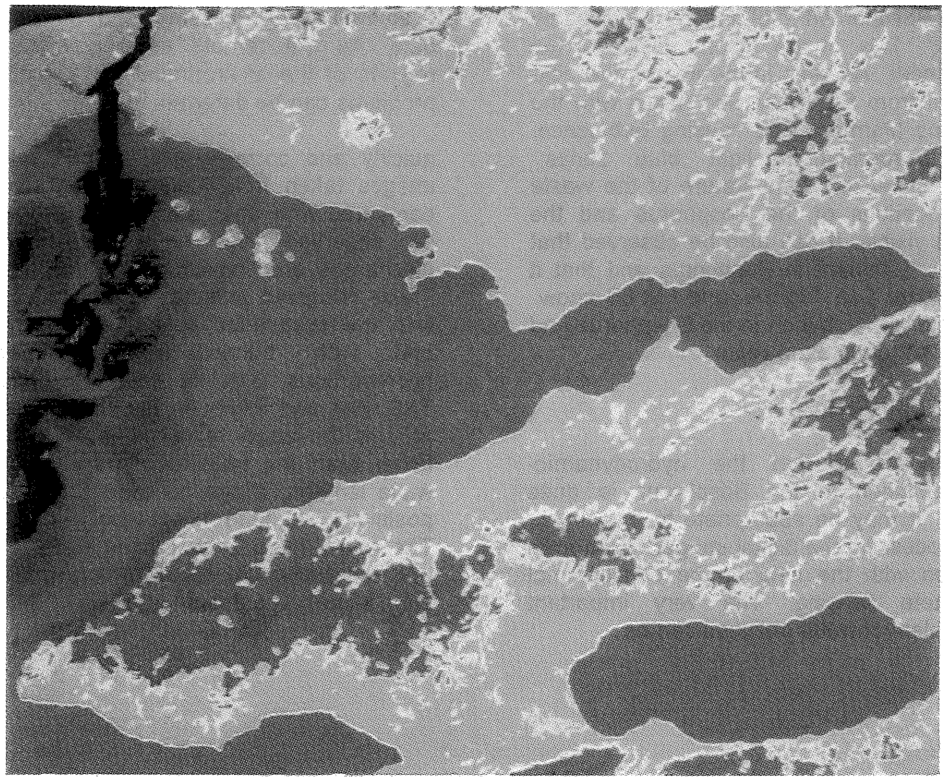

Figure 5. The Bosphorus entering the Sea of Marmara (Landsat5 TM thermal band).Light blue=water temperature between 15and 20° C ;medium blue=water temperature between 10 and 15° C ;dark blue=water temperature < 10° C.

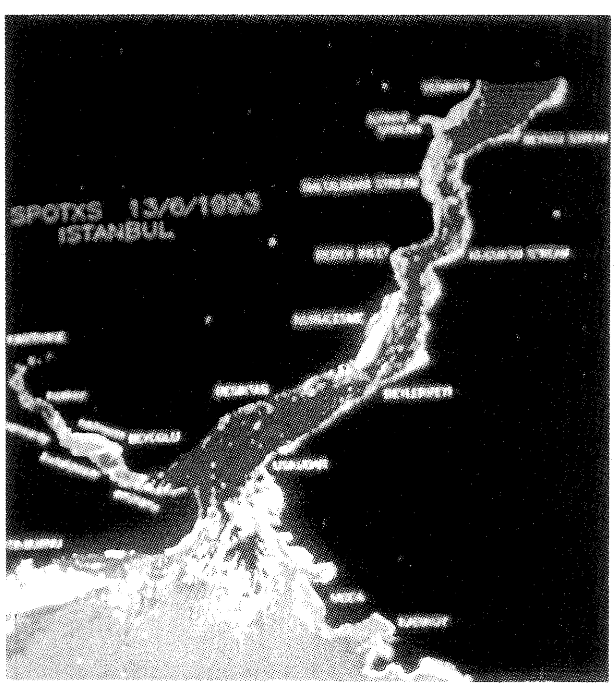

Figure 6A. Turbidity distribution map of Bosphorus derived SPOTXS 13 June 1993 formed by maximum likelihood classification.

Figure 6B. Turbidity distribution map of the Golden derived SPOTXS 13 June 1993 formed by maximum likelihood classification

The image of the Bosphorus(Fig.5) has been formed by the Thermal Band. This image clearly displays the temperature differences. As seen in the image, the cold water coming down from the Black Sea mixes with the warmer water of the Marmara Sea causing turbulence. When the image is zoomed, the light blue zones representing the increasing temperature of the waste water discharge locations of the Bosphorus and the Golden Horn are visible. It can also be observed that Black Sea water is dominant in Bosphorus and that it flows into the Marmara Sea. Fig 6A and Fig 6B show the increased turbidity distribution in the Bosphorus and the Golden Horn depending to the years.

4.CONCLUSION REMARKS

This study demonstrates that the hydrodynamic-condition water pollution in the Bosphorus is quite complex in nature. It may be appropriate to investigate this pollution by processing the digital images taken from data in conjunction with the help of the conceptional methods of remote sensing. The very important environmental problem of water pollution can be examined by processing and classifying the satellite data. As the remote sensing method permits large regions of the environment to be studied, the pollution problems can be determined both

quickly and correctly. When conceptions of the final images taken from Landsat-5 TM and Spot data are compared with the water quality reference data, it can be observed that both residential and industrial discharges are correctly displayed on Stellite imagery. These observed reflectance shows a strong relationship with the suspended solids, chemical oxygen demand, and with humic materials and polyaromatic hydrocarbons. Satellite data provide a useful index of TSS, HM and PAH. As the reflectance (in the turbidity area) in the longer red and near IR wavelength increases faster than the reflectance in shorter blue and green wave lengths, it can be seen that turbidity levels are positively related to reflectance.
The relationship between the water quality parameters and the individual band reflectance are supported by simple linear regression analysis.

REFERENCES

Bhargava,D.S and D.W.MARIAM,Effect of suspended particle size and concentration on reflectance measurament .Photogrammetric Engineering& Remote Sensing, 57 (5),519-529 (1991)

LATHHROP,R.G.Jr. and LILLESAND,TM, Utility of thematic mapper data to asses water quality in Southern Green Bay and West and West Central Lake Michigan, Photogrammetric Engineering& Remote Sensing,52,671-680(1996).

METU / IMS ,İstanbul Sewerage Project Marina Studies on Observations of Sewage disposal Systems Before and After Operations 1st Interim Report January,1986-1993

BAŞTÜRK,O,A.Yılmaz,C.Saydam and İ.Salihoğlu,Health of the Turkish Straits Chemical and Enviromental Aspects of the Sea of Marmara and Golden Horn, Institute of marine Sciences Middle East Tech. Univ,1988

COŞKUN (AYDOĞDU) H.G ,Macro Level Determination of the Water Pullution in Bosphorus and Golden Horn Using TM data,Tech.Univ. of İstanbul,Doctora Thesis,1992