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Investigation of Enteric Bacteria of Surface Waters in the Southwestern Coast of Istanbul by means of GIS

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Abstract

Istanbul, which is the largest megacity of Turkey with a population over 12 million, tries to solve encountered environmental problems such as severe coastal erosion, shoreline recession and over pollution has been exposed mainly last 20 years due to response of the coast to human activities. The aim of this study was to investigate the bacteriological water quality and occurrence of enteric bacteria of surface waters on the southwestern coast of Istanbul by means of GIS. Seven sampling stations were chosen to conduct measurements on a monthly basis during the year of 2008. The physicochemical parameters were measured *in-situ* at all sampling stations and to determine the density of the species in *enteric bacteria*, the DAFOR scale was used. During the spring and summer period, the bacterial density was reduced. From September to November, a unique genus is generally observed in all stations through seawaters getting cold and effect of the streams. However, when the environmental factors started to change, such as temperature increase, different genus were observed. In January, central density in bacteria values has been determined to be only at 5th station. Similarly, in the rainy seasons, being added to the washed solid inputs, the seasonal genus appeared. At the stations 1 and 2, the density of the enteric bacteria has been determined as the higher values almost every months except cold season, due to negative effects of anthropogenic pollutant carried by different streams. The results reveal that the study area faces bacteriological pollution and the existing pollution level in this area is above the criterion specified for aquaculture, fishery and recreational activity. Employing modern tools like GIS helps us better understand the spatial distribution of enteric bacteria of sea. These tools might also be used as the initial steps of determining and providing the input data for water quality modeling studies.

Keywords: Water quality, GIS, Enteric bacteria, Istanbul, Turkey.

İstanbul Güneybatı Sahili Yüzey Sularındaki Enterik Bakterilerin CBS Desteği ile İncelenmesi

Özet

Nüfusu 12 milyonu aşan İstanbul, son 20 yıldır kıyısal alanlardaki insan aktivitelerinden kaynaklanan kıyısal erozyon, kirlilik ve tahribat gibi benzer çevresel problemleri çözmeye çalışmaktadır. Bu çalışmanın amacı, İstanbul'un güney-batı sahili yüzey sularında bakteriyolojik su kalitesinin ve enterik bakterilerin dağılımının CBS desteği ile incelenmesidir. 2008 yılında yedi istasyonda aylık örnekleme yapılmıştır. Tüm istasyonlarda fizikokimyasal parametreler yerinde ölçülmüş ve tespit edilen enterik bakteri türlerinin yoğunluğunun belirlenmesinde DAFOR skalası kullanılmıştır. Yaz ve bahar ayları boyunca, bakteriyel yoğunlukta azalma gözlenmiştir. Eylül-Kasım ayları arasında, tüm istasyonlarda nehirlerin ve sulardaki soğumanın etkisi ile dayanıklı tek genus varlığı belirlenmiştir. Bununla birlikte çevresel faktörlerin değişmeye başlaması ile genellikle sıcaklığın artışına bağlı olarak farklı türlerinde gözlenmesi ağırlık kazanmıştır. Ocak ayında, özellikle 5. istasyon bakteri seviyesinin merkezi yoğunluğa rastlandığı dönemdir. Benzer şekilde, yağışlı dönemlerde, atık suların etkisi ile türlerde mevsimsel farklılıklar belirlenmiştir. Özellikle 1 ve 2 nolu istasyonlar, akarsularla taşınan antropojenik kirleticilerin olumsuz etkileri nedeniyle enterik bakterilerin yoğunluğunun, soğuk aylar haricinde hemen hemen her ay en yüksek değerleri aldığı istasyonlar olarak tespit edilmiştir. Sonuç olarak; çalışma alanı bakteriyolojik kirlenmeyle karşı karşıyadır ve mevcut bakteriyel kirlilik seviyesi akuakültür, balıkçılık ve rekreasyonel aktiviteler için belirlenen değerlerin çok üzerindedir. CBS gibi modern araçların kullanılması da, enterik bakterilerin denizdeki konumsal dağılımlarının daha iyi anlaşılmasına yardımcı olmaktadır. Aynı zamanda bu araçlar su kalitesinin belirlenmesi ve modelleme çalışmaları için başlangıç verisinin belirlenmesi ve sağlanması amacıyla da kullanılabilir.

Anahtar Kelimeler: Su kalitesi, CBS, enterik bakteriler, İstanbul, Türkiye.

Introduction

Approximately 70% of the Earth is covered with various water based ecosystems and they contain different micro-organisms like other systems as well, besides numerous macro-organisms found in nature, the micro-organisms living in sea water, which play an important role in contributing to the continuation of life cycle, have both advantages and disadvantages. Similarly, many micro-organisms act as separators as well as decomposers while aiding in the continuation of ecosystem. A diseased animal spreads its disease most commonly from body to soil and soil to water through fecal discharge (Rose *et al*., 2001). In order to prevent the direct discharge of fecal matter into sea water close to residential areas, the preferred methods of water refinement should include sea water discharge systems. Compared to other refinement systems, the sea water discharge systems are much more economical. In order to prevent further damage to the sea ecosystem due to pollution, the location choice, technical project planning and construction of sea water discharge systems must be done carefully (Hall *et al*., 1978). The main purpose of sea water discharge systems is to protect the sea ecosystem. Generally, the primary focus lies on protecting public health from infection diseases, preserving sea life quantity and quality (Sivri *et al*., 2004; Toroglu *et al*., 2005). To detect fecal contamination of water is a prerequisite to the maintenance of public health. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from a source. The presence of fecal coliform bacteria, whether they have the agents of diseases, indicates the presence of disease-carrying organisms which live in the same environment (Alhaj *et al.,* 2007; Ozgumus *et al*., 2009; Danishta *et al*., 2010).

Today, most countries encounter some major problems such as over population, pollution, deforestation and natural disasters (Hardoy and Satterthwaite, 1991). Being the largest city of Turkey, Istanbul where the population is more than 12 millions of people has been exposed to severe coastal erosion and shoreline recession for the last 20 years. The reaction of the coast to human-made activities is one of the most important reasons.

In this study, the enteric bacteria of surface waters on the southwestern coast of Istanbul has been investigated by employing GIS which is a computer-based tool for mapping and analyzing spatial data and events that take place in the earth. This study is mainly dealing with the occurrence of enteric bacteria of the surface water in the selected seven stations which represent spatially to the study area during the year 2008. GIS is used to analyze monthly and seasonal variation of the enteric bacteria in the selected stations during the one year period.

Materials and Methods

Water Sampling and Bacterial Isolation

The southwestern coast of Istanbul was selected as a study area with seven sampling stations, chosen to conduct measurements on a monthly basis during the year of 2008 as seen in Figure 1.

Water samples (100 ml) were collected at each station using sterile screw capped glass bottles, and stored in cold bags at 4°C up to analysis procedure in the laboratory within 3 hours after collection. Coliform bacteria were enumerated by multiple-tube fermentation (MPN) methods within Lauryl Sulphate Broth (Oxoid, UK). Water samples were diluted ten times (10x) when necessary. Fecal growth was achieved by monitoring the acidification and gas production during growth in Brilliant Green Lactose Broth (Oxoid, UK) at 44±0.5°C for 24±3 h and sub-cultured on Eosine Methylene Blue agar (Oxoid, UK) plates from the fermentation tubes in order to isolate the coliforms (AWWA, 1998).

In terms of being another way of controlling, the samples were incubated in UTI agar (HiCrome) at 37±2°C for 24 hours. Standard water and wastewater

Figure 1. Location of study area and stations.

methods were applied for the detailed analysis for identification (AWWA, 1998) and following the identification of enteric bacteria, DAFOR scale was used to identify the density of species.

Thanks to its ability to tolerate an alien set of biological, physical and chemical conditions, a micro-organism can survive in a non-indigenous environment. So, in the present study, the physicochemical parameters were measured.

The views that emphasize the importance of the studies on enteric bacteria for public health necessitated further research. There have been many studies on the survival of *Escherichia coli* and other indicators of fecal pollution in freshwater, marine and estuarine habitats (Vasconcelos and Swartz, 1976; Flint, 1987; Alkan *et al*., 1995). Mancini (1978) suggests that temperature is the major factor in the disappearance of fecal bacteria in fresh- water.

GIS Analysis

Data related to water quality are obtained from various organizations and institutions in Istanbul, where the study has been conducted. Many times, it may not be possible to get available data for the studies. At this point, the significance of storing environmental data in a reliable systematic manner and of serving the updated data to users becomes important. It is for sure that the application of Geographic Information Systems (GIS) to fulfill the requirements of the planning strategies is of utmost importance and is a useful management tool. It has well been recognized in most of the studies that GIS is a tool that can enhance spatial assessment of water quality since spatial data from a variety of sources can be integrated, manipulated and transformed to produce new derived maps that aid to understanding spatial inter-relations.

Such successful application of GIS, however, must evolve from an inventory tool to an analysis tool, and in turn, to a management tool. In general, GIS provides facilities for data capturing, data management, data manipulation and analysis, and the presentation of results in both graphical and report form with a particular emphasis on preserving and utilizing inherent characteristics of spatial data. The ability to incorporate, manage and analyze spatial data and answer spatial questions are the distinctive characteristics of GIS. It provides input data to calculate and estimate the water quality.

The developed GIS database contains basically two layers, the administrative boundaries of the related districts and the locations of the sampling stations. Spatial data used in this study have been collected from various sources and scales. All data were transferred into the same scale and UTM coordinate system. In this study, 7 sampling stations were selected and the parameters used in GIS were obtained on a monthly basis during the year of 2008. Obtained data were used as input data to produce different maps which represent the spatial distribution of enteric bacteria on the southwestern coast of Istanbul. Spatial distribution map was prepared for 12 months to display the differences occurred during the different seasons and months.

Results and Discussion

As a result, the expected seasonal variations of the values from the measured physical parameters were displayed in Figures. As can be seen in Figure 2, air and sea water temperature values varied between 4°C and 33°C and between 8.9°C and 26.7°C, respectively. The lowest sea water temperature (6°C) was recorded in 7th station and the highest value in August (31°C) at 5th station. However, mean surface temperature did not differ considerably among the sites ($P<0.001$). The data show that survival was greatly enhanced in sea water than the lagoon water. pH values were recorded between 7.7-8.4 during the sampling period (Figure 3). The values did not show any considerable sudden changes which could have affected the bacterial growths. Similar results were also obtained for salinity. Salinity fluctuated between 0.56–1.07%. Slightly higher salinity was measured at 7th station, representing the typical seawater characterization; the minimum value was 0.32% in 5th station, where the lagoon is connected to the Marmara

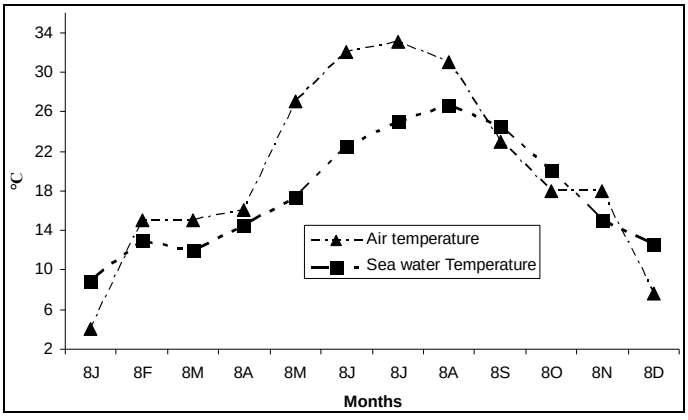

Figure 2. Monthly average values of air and sea water temperature.

Sea via a narrow channel.

The bacterial contamination level was found to be fairly high in all the sampling stations. Monthly average values of enteric bacteria members were shown in Figure 4. The MPN were recorded in values between 10^1–10^5 MPN/100 ml. The maximum value was $13x10^5$ and obtained at 5th station and the minimum value was in 3rd station. The unexpected variances in values were observed at 3rd, 6th and 7th stations and in particular, were found to arise from the temperature parameter.

During the study, the evaluation has been done for every obtained species. In accordance with the DAFOR scale, the determined species were aligned from intensive to rare, and evaluated in mathematical ways. As to make a general evaluation, the most intensively apparent species was *Escherichia coli* (36.7%) and the second one was *E. fecalis* and the distribution was found to be 32.9% (Figure 5). When the density frequency is evaluated, the other species are in order as follows: *Proteus, Klebsiella, Pseudomonas*. Meanwhile, some species have never been considered in evaluations, in spite of their apparent presence in some periods. Some of these

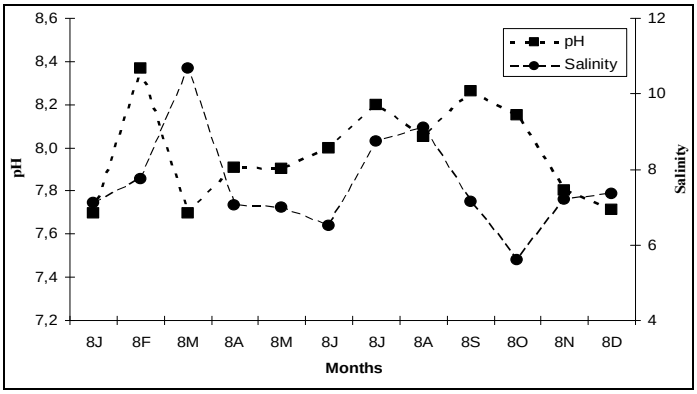

Figure 3. Monthly average values of pH and salinity.

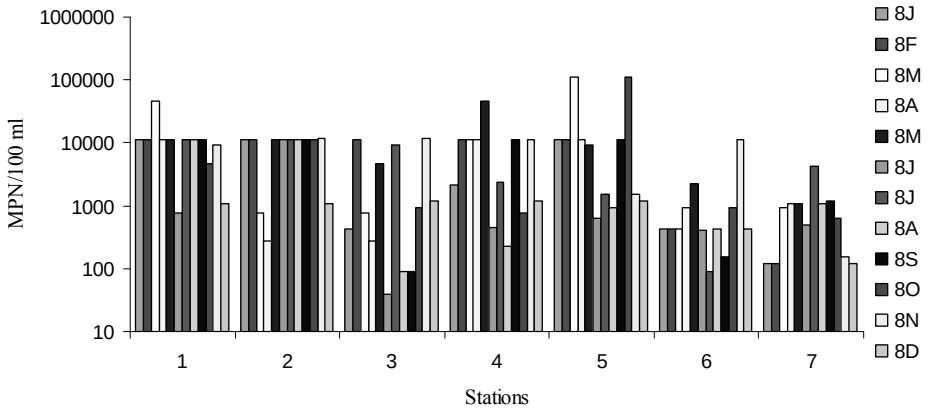

Figure 4. Monthly average values of enteric bacteria (MPN/100 ml).

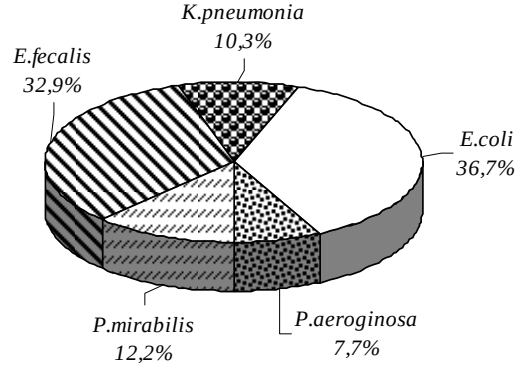

Figure 5. Discrimination of the species during 2008.

species were non-fermentating bacteria; such as Gram negative (which live unrestrictedly in nature) and sporeless bacilli. For non-identified Gram negative in biochemical test, enteric was excluded from the bacteria. It is important to note that the Gram negative had different environmental bacteria; however, fecal coliform bacteria were not detected in this test.

In the present study, for the first time in literature, the density and bacterial identification of the genus of *Enterobacteriaceae* and *Pseudomonaceae* were determined on the southwestern coast of Istanbul. When the results were examined for the narrow channel of the Kucukcekmece Lagoon and the Marmara Sea, the obtained values were found to be over the standards. It is interesting that there were no refining activities, even though the anthropogenic pollutants were at the level of threatening the human health. In the period of the investigation, the bacterium species were altered. On the other hand, their density values did not show any change.

As shown in Figures 6 and 7, the monthly average density of bacteria values of the station was determined through GIS analysis. When the changes observed in the stations are examined in terms of bacteria distribution, hot and rainy seasons draw the

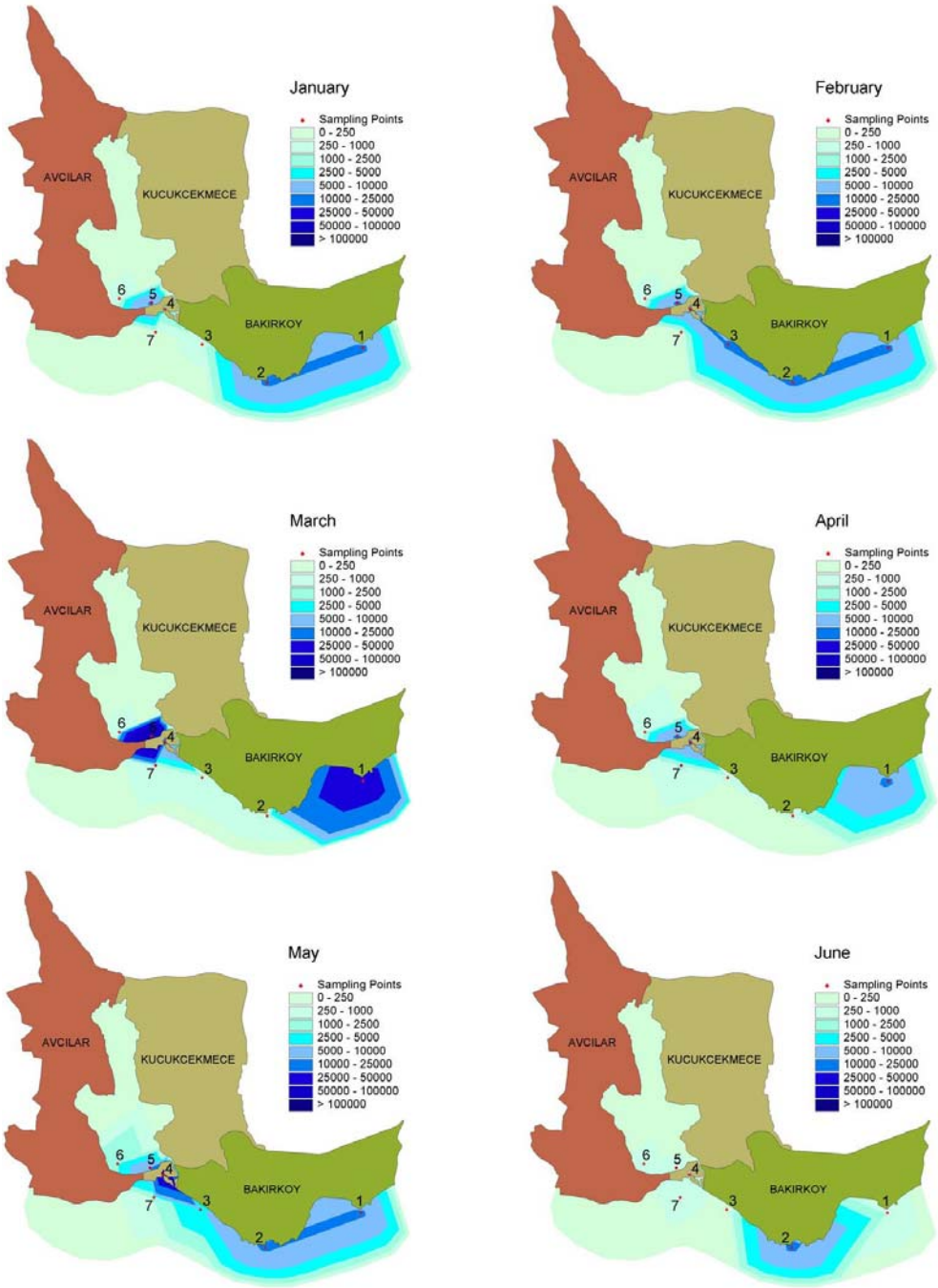

Figure 6. Distribution of enteric bacteria on the southwestern coast of Istanbul by means of GIS.

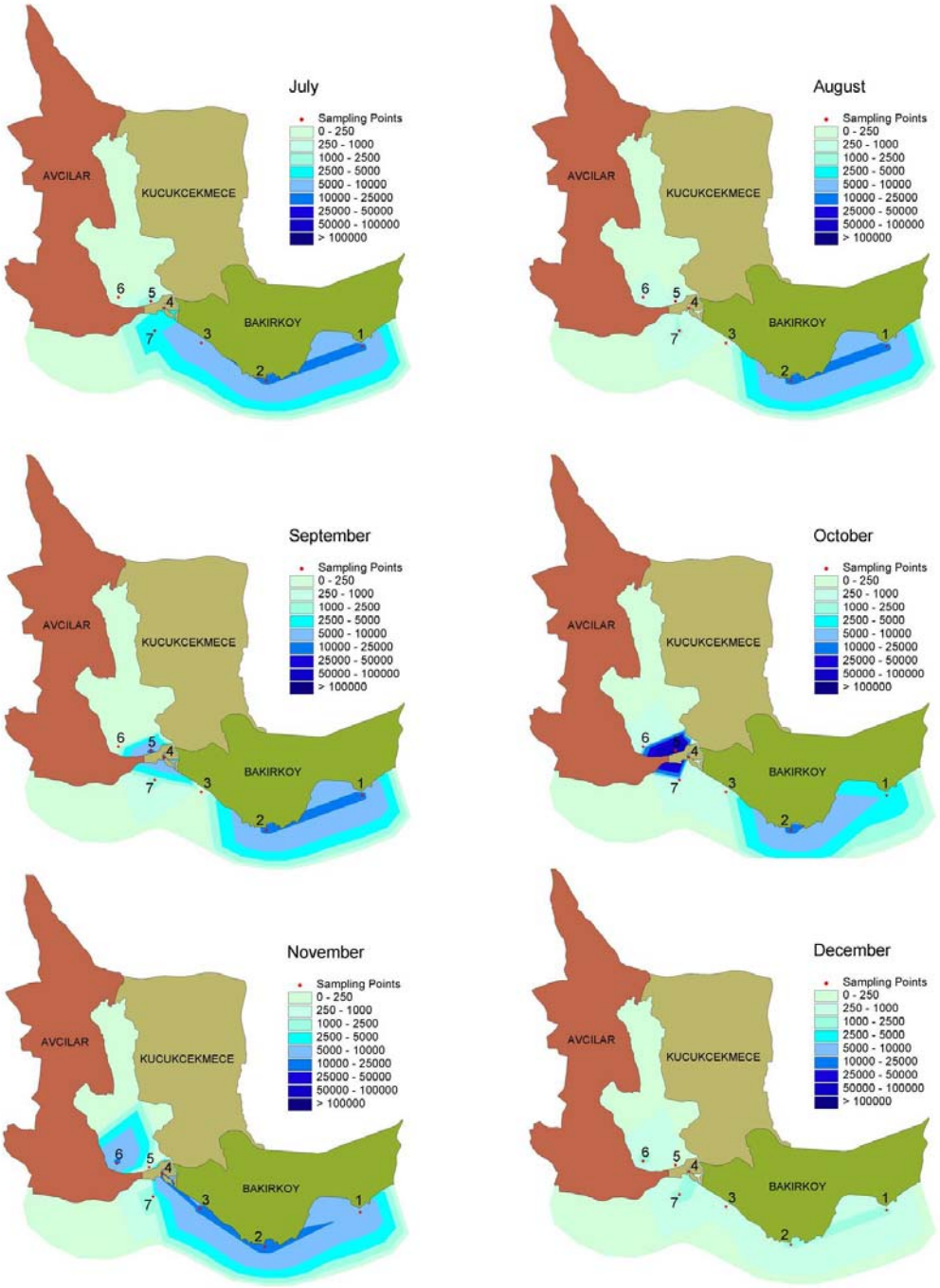

Figure 7. Distribution of enteric bacteria on the southwestern coast of Istanbul by means of GIS July 2008- December 2008.

attention. In January, central density in bacteria values has been determined to be only at 5th station. Bacterial density during the spring and summer period was reduced, in summer in particular.

Especially in the autumn period from September to November, a unique genus is generally observed in all stations through seawaters getting cold and effect of the streams. However, when the environmental factors started to change, particularly in the periods of temperature increase, different genus were observed. Similarly, in the rainfall periods, being added to the washed solid inputs, the seasonal genus also appeared.

Conclusions

In this study, the distributions and the density of enteric bacteria of the surface water in the southwestern coast of Istanbul were determined using GIS. Due to difficulty of the determination of all kind of bacteria in the surface water, *Enterobacteriaceae* family was identified as dominant species, and their bacterial composition in the coastal area was also investigated in detail. In the period of the investigation, the bacterium species were altered. On the other hand their density values showed a

significant change by means of GIS.

Due to negative effects of anthropogenic pollutant carried by the Ayamama Stream and Atakoy wastewater treatment plant, at the stations 1 and 2, the density of the enteric bacteria has been determined as the higher values almost every month except cold season. At the same time, effects of physiochemical parameters and rain should be considered.

On the other hand, the reason of the increase in the enteric bacteria level at the stations of 5, 6 and 7 in different period, is the untreated wastewater which is the source of Kucukcekmece Lagoon and human activities occurred on the coastal line. The negative affects of these bacterium groups on coastal ecosystem that reach the sea directly have been searched by means of investigating antibiotic resistance plasmids (Alhaj *et al*., 2007; Ozgumus *et al*., 2009; Danishta *et al*., 2010). No refining activities were observed, although anthropogenic pollutants were at a level to threaten the human health.

Employing a modern tool like GIS helps the users better understand the spatial distribution of enteric bacteria of the sea. As seen in this study, affects and source of anthropogenic pollutants can be easily visualized by means of GIS. In addition, the direction of the local current without measurement can be estimated. Besides, it has the ability to create maps, integrate information, visualize scenarios, solve complicated problems, and develop ultimate solutions for decision makers. These tools might also be used as the initial steps of determining and providing the input data for water quality modeling studies.

As a result of this study, it has been found that study area faces bacteriological pollution. It has been proved through the results that the pollution level in this area was above the criterion specified for aquaculture, fishery and recreational activities.

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