Analysis of PM10 Pollutant in Istanbul by Using Kriging and IDW Methods: Between 2003 and 2012*

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Abstract—**Today, in many countries as a result of especially industrialization and urbanization, air pollution sometimes becomes endangering to human life and even causes deaths of chronic diseases. For this reason, this study was done in Istanbul in Turkey. The purpose of this study was the analysis of the spatial distribution of air pollution (based on PM10 data of different years) in Istanbul by using IDW and Kriging methods in GIS. PM10 pollutant data of the years 2003, 2006, 2009 and 2012 were obtained from eight different air pollution measurement stations and analyzed. The results were given as maps of the years 2003, 2006, 2009 and 2012.**

Keywords-air pollution, spatial anaysis, interpolation methods, distribution maps, GIS.

I. INTRODUCTION

Struggling with the environmental problems is one of the key issues that developed and developing countries provide local and global policies preserve the environment and aims to transmit to the future generation without any loss. Therefore, in order to solve existing and potential environmental problems, various studies are carried out and multiple cautions are provided against potential problems. In parallel to the developments in the world, The Turkish Ministry of Environment and Urban Planning have been attempting activities for environmental pollution in Turkey. In addition, students in all levels of education and society are tried to be aware of preserving environment by relevant public and social institutions.

There are numerous academic studies dealing with environmental problems and environmental protections in Turkey. Environmental problems in various cities of Turkey have been investigated in these studies [3, 19, 22, 28, 38]. Also, some of them directly studied air pollution [6, 7, 8, 9, 15, 16, 20, 27, 29, 32, 35, 39]. Moreover, some of them were conducted in Istanbul as the study area [2, 5, 12, 14].

Today, in many countries as a result of especially industrialization and urbanization, air pollution sometimes becomes endangering to human life and even causes deaths of chronic diseases. For this reason, the causes, ingredients and distribution of air pollution and the solutions for the problems are studied by researchers in many different disciplines and countries. In these studies, the most important issue which was studied under air pollution is the amount and distribution of particulate matter (pm10) that has an important role on determination of air pollution and human health. PM10 pollutant is referred as a pollutant which is under 10 microns and has a specific period consists of solid particles that remains suspended in the air. PM10 pollution has serious damage to human health and is studied in detail in many researches [13, 18, 21, 23, 26, 34, 36].

Recently, Geographic Information Systems (GIS) is one of the most important and efficiently used tool which is used to determine air pollution and its distribution. GIS is used as a tool in many studies in worldwide due to its functions of analyzing values easily and high mapping skills with advanced spatial statistics [1, 4, 10, 11, 17, 24, 25, 30, 31, 33, 37].

In this study, Kriging and Inverse Distance Weighting (IDW) methods were used to determine the amount of air pollution and a semivariogram or a covariance function was used to calculate the dependencies. The advantage of this technique is the estimation of spatial structures using with semivariogram diagrams. Also, it specifies the resulting errors from these estimates (İnal and Yiğit, 2003). In addition, Inverse Distance Weighted (IDW) method uses the average of face value in the fulcrum point and the surface value of the estimation point. This method is more efficient to analyze the data of temperature, pollution, etc. (Çolak, 2010).

Istanbul is Turkey's most populous city with its approximately 15 million populations and is the heart of Turkey. Also, located between the continents of Europe and Asia, Istanbul is the largest metropolitan area in the region. However, sometimes air pollution can arise as a problem due to dense population and economic activities in the city. Therefore, the temporal and spatial distribution of air pollution in Istanbul was studied in this study. The purpose of this study was the analysis of the spatial distribution of air pollution (based on PM10 data of different years) in Istanbul by using IDW and Kriging methods in GIS. For this purpose, following questions were asked:

(1) What is the temporal and spatial distribution of PM10 pollutants in Istanbul between the years of 2003 to 2012 according to Kriging method?

* This work was supported by the Scientific Research Fund of Fatih University under the project number P51061302_Y (3191).

(2) What is the the temporal and spatial distribution of PM10 pollutants in Istanbul between the years of 2003 to 2012 according to IDW method?

II. METHODOLOGY AND STUDY AREA

The study consisted of two stages including data collection and data analysis. During the data collection phase, data obtained from the Istanbul Metropolitan Municipality Provincial Directorate of Environment Protection for eight air pollution measurement stations and had a process of control for any error. The list of stations and locations were given below (Table 1).

Table 1. Data collection stations and their locations

Stations	Locations (Latitude & Longitude)
Yenibosna	40.990578°, 28.838012°
Esenler	41.040275°, 28.883836°
Beşiktaş	41.042616°, 29.007483°
Sarıyer	41.167644°, 29.056821°
Ümraniye	41.029824°, 29.097918°
Üsküdar	41.026414°, 29.015102°
Kadıköy	40.993360°, 29.024219°
Kartal	40.887740°, 29.186310°

At this stage, to have results that are more accurate the study area was limited to the districts where 8 stations are located in (Figure 1). In the data analysis phase, the prepared data were analyzed with interpolation methods of IDW and Kriging by using Arc Map 10.2 software. The results were given as maps of the years 2003, 2006, 2009 and 2012.

Figure 1. Study area and locations of stations

III. FINDINGS

As a result of the IDW and Kriging analysis of the data which were collected from air pollution measurement stations, the "PM10 pollutant distribution maps" were prepared. Accordingly, in 2003, it was revealed that the pollution has the greatest values with 70 µg/m3 or more, in the districts of Esenler, Güngören, Bayrampaşa, north of Bahçelievler and east of Bağcılar, in the European side (west of Bosporus) of Istanbul. On the other part, in the Asian side of Istanbul (east of Bosporus), the districts with the greatest values were identified as the southern parts of Kartal and Pendik. In addition, the pollution values have declined closer to the Bosporus in both sides and the districts with the lowest pollution values were identified as Beyoğlu, Şişli, Beşiktaş and Üsküdar (the southern entrance of Bosporus) with average of 40 - 50 µg/m3.

In addition, the districts, which are situated along Bosporus towards the north, had average values with 50 - 60 µg/m3. However, the pollution values were between 60 and 70 µg/m3 in the districts of Bahçelievler, Bakırköy and Küçükçekmece in the west and a portion of Kartal district in the east (Figure 2).

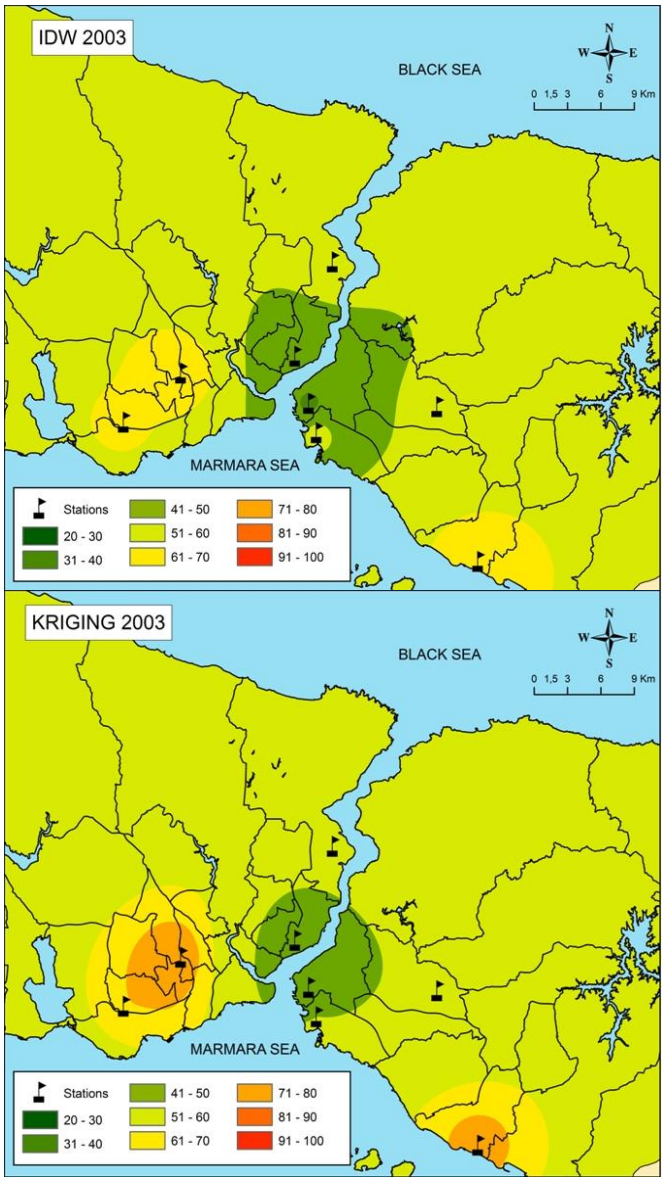

Figure 2. IDW and Kriging Maps of PM10 Distribution (2003)

In the maps prepared with the pollution data of 2006, the districts, which had the greatest values, were identified as Esenler, Güngören and Bayrampaşa in the European side of Istanbul. Also, in the Asian side of Istanbul, the greatest values were identified around Kartal and Pendik districts. These results were similar to the results of the year 2003. However, it was observed that the amount of pollution increased in both parts of Istanbul compared to 2003. Especially, the values reached to the values of 90 µg/m3 and over in the area south of Kartal and Pendik. In addition, similar to 2003 again, the pollution values decreased closer to the Bosporus in both sides of Istanbul but the districts with lowest values – healthy areas – shifted to north in European side (to Sarıyer and around). On the other hand, in the Asian side, the cleanest district was identified as Üsküdar but this area extended to Ümraniye in northeast direction and to the west after Ümraniye. Moreover, it was observed that the values increased in Şişli and Beşiktaş in the European side and in Maltepe, Kartal and Pendik in the Asian side (Figure 3).

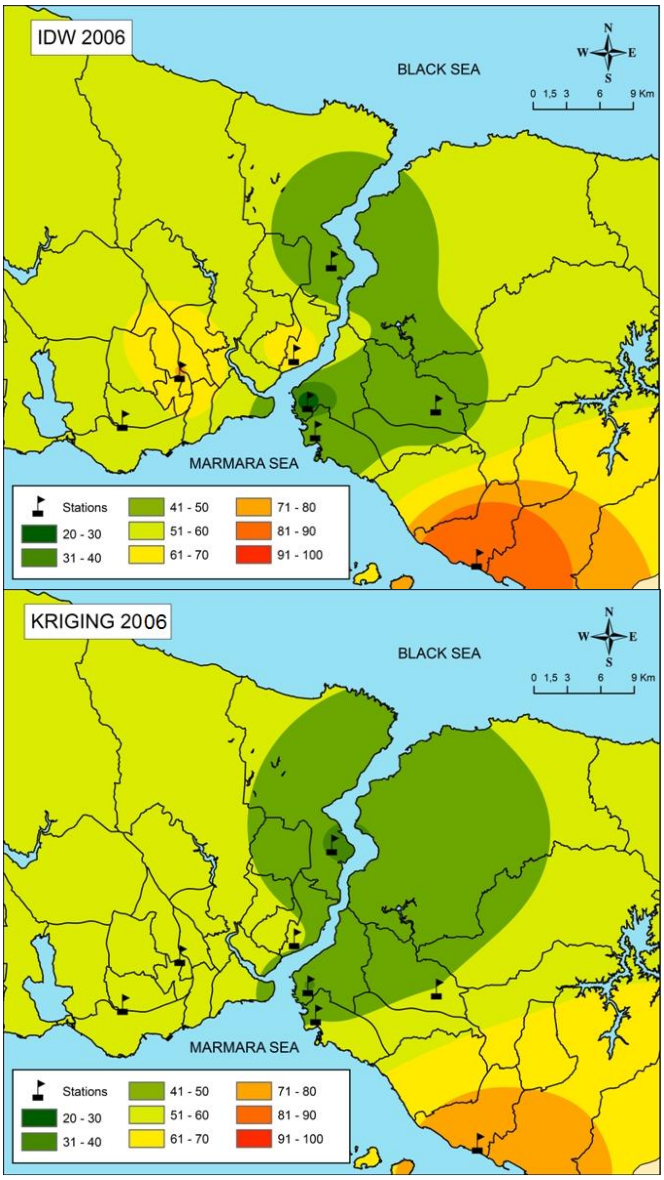

Figure 3. IDW and Kriging Maps of PM10 Distribution (2006)

In the year 2009, the places with the greatest values were identified in a large area including the districts of Esenler, Güngören, Bayrampaşa, Küçükçekmece, Başakşehir, Bakırköy, Zeytinburnu and Sultangazi with the south of Eyüp in the European side and the districts of Kartal and Pendik in the Asian side. However, the values around Kartal and Pendik

decreased about 20 µg/m3 compared to 2006 and the area narrowed. In addition, the districts with the lowest values extended to the northeast towards the interior of Asian side from the southern entrance of Bosporus (from Üsküdar and Kadıköy to Ümraniye, Çekmeköy and Beykoz) (Figure 4).

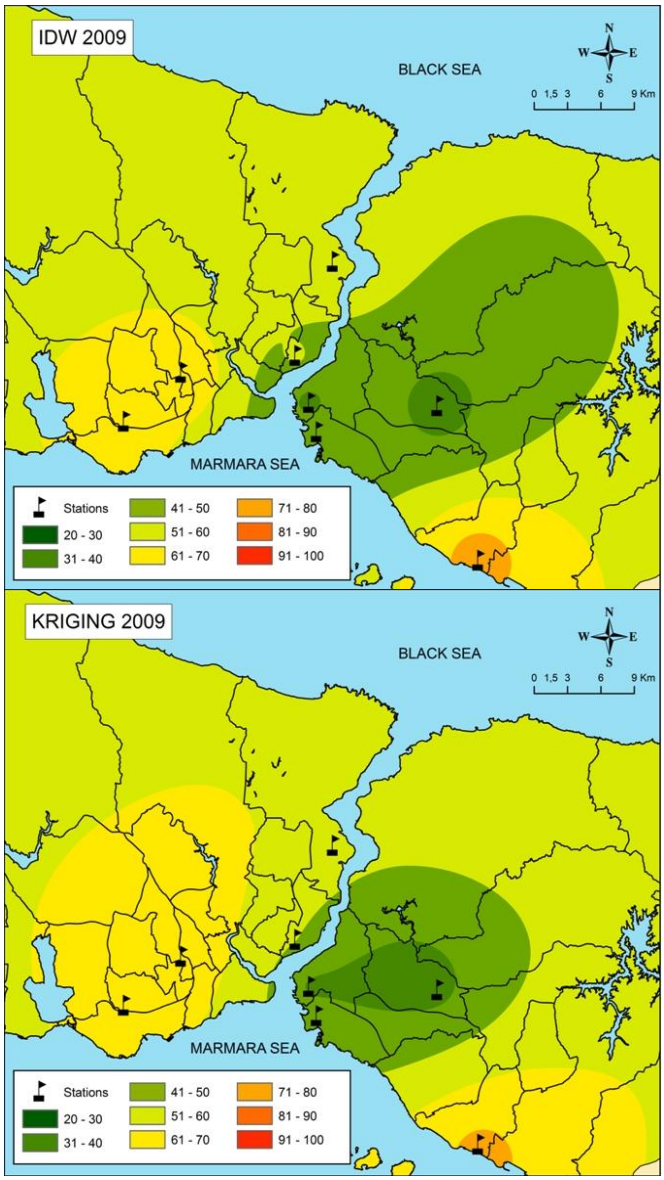

Figure 4. IDW and Kriging Maps of PM10 Distribution (2009)

Moreover, in the year 2012, it was revealed that the average pollution decreased and the PM10 values between 50-60 µg/m3 were identified in European side of Istanbul completely. However, the pollution values increased approximately by 5 µg/m3 in the area around Kartal and Pendik. Also, this area enlarged compared to 2009. On the other hand, the districts with the lowest values were identified as the districts along Bosporus, similar to 2003 and 2006. The cleanest areas shifted to north reaching to Black Sea and the district with the lowest value was identified as Sarıyer (Figure 5).

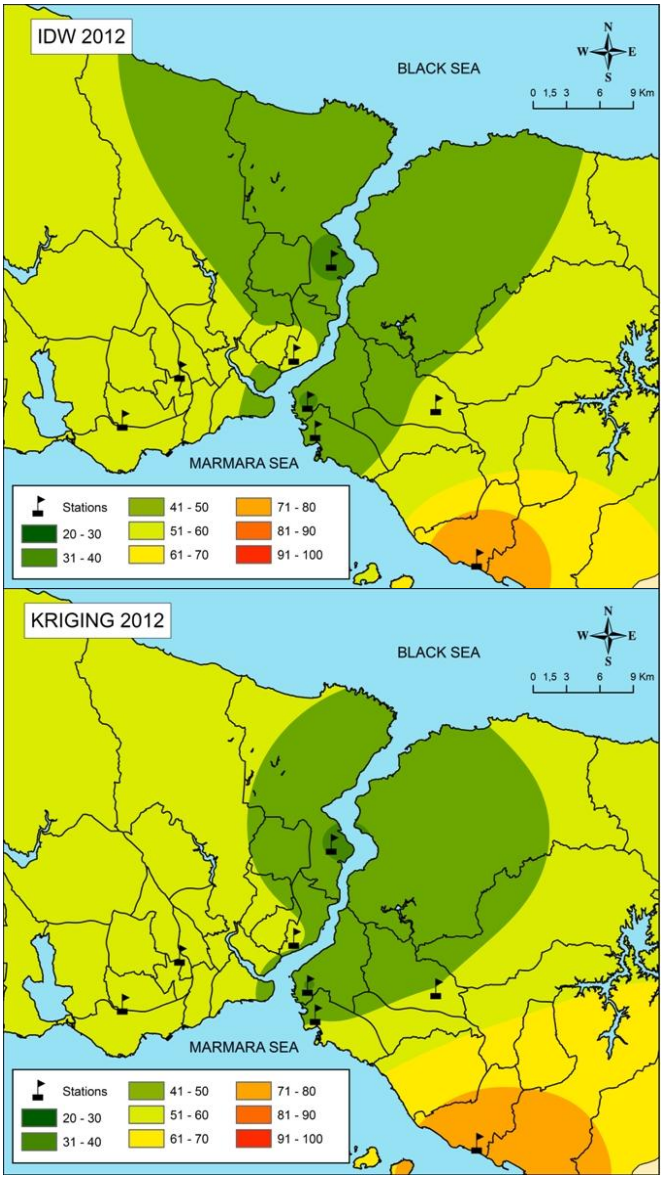

Figure 5. IDW and Kriging Maps of PM10 Distribution (2012)

IV. DISCUSSION AND RESULTS

Finally, following figures were revealed as a result of the study. In 2003 and 2006, the pollution was over 70 µg/m3, in the districts of Esenler, Güngören, Bayrampaşa, north of Bahçelievler, east of Bağcılar and the southern parts of Kartal and Pendik. The pollution values have declined closer to the Bosporus in both sides and the districts. However, the amount of pollution increased in both parts of Istanbul compared to 2003. Especially, the values reached to the values of 90 µg/m3 and over in the area south of Kartal and Pendik. Also, the districts with lowest values – healthy areas – shifted to north and northeast directions in both sides of Istanbul.

In 2009, the places with the greatest values were identified in a large area including the districts of Esenler, Güngören, Bayrampaşa, Küçükçekmece, Başakşehir, Bakırköy,

Zeytinburnu and Sultangazi with the south of Eyüp in the European side and the districts of Kartal and Pendik in the Asian side. On the other hand, the lowest values extended to the northeast towards the interior of Asian side from the southern entrance of Bosporus.

In 2012, the average pollution values decreased to 50-60 µg/m3 in the European side of Istanbul completely. However, the pollution values increased approximately by 5 µg/m3 in the area around Kartal and Pendik. Also, this area enlarged compared to 2009. On the other hand, the districts with the lowest values were identified as the districts along Bosporus, similar to 2003 and 2006. The cleanest areas shifted to north reaching to Black Sea and the district with the lowest value was identified as Sarıyer.

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