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URBAN AIR POLLUTION MONITORING BY USING GEOGRAPHIC INFORMATION SYSTEMS: A CASE STUDY FROM SAKARYA, TURKEY

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Abstract: In many rapidly growing cities, due to increasing of fossil fuel using in transportation, industry and heating, air pollution reached to critical levels. In controlling this pollution, particulate matter materials (PM) and sulfur dioxide (SO_2) emission group are underlined. In this study, the objective is to create a supportive model for decision makers by showing distribution of the two emission groups with respect to districts of Sakarya province by using geographical information system (GIS) and by preparing an emission inventory related to domestic heating SO_2 and PM emissions in Adapazarı and mapping through GIS. In the first stage of this three-stage research, the region with the highest amount of pollutant concentration throughout city of Sakarya has been detected. According to this stage results that Adapazarı is the most polluted area. In the second stage based on 11 quarters located in Adapazarı, the most polluted city, domestic heating emission inventories have been put forward. For the 11 surveyed quarters, SO_2 and PM values originating from natural gas and coal were calculated individually for preparing of emission inventory. As for Adapazarı, coal-origin SO_2 emission inventory value has been found as 154.030 kg/year, PM 269.906 kg/year. Employed emission calculation method, unlike several other studies in literature, was not merely based on the data of measurement stations but it also included gathering and calculating current data in the field through surveys. Emission inventory is created with face-to-face survey. In the third stage, concentration differences within quarters have been presented by using GIS techniques according to emission inventory results for not only Sakarya in general but also Adapazarı in particular. Finally to air quality control, some scientific and technical assistance have been given to administrators. Since employed data gathering and GIS techniques are applicable for different regions as well and the study following this method is a vanguard for city of Sakarya, this research is unique.

Key Words: Air pollution, sulfur dioxide (SO_2), particulate matter (PM), inventory, Geographic information systems

1. INTRODUCTION

Air pollution is a chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. The harmful chemical compounds from burning puts into the atmosphere are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_2), sulfur dioxide (SO_2), and particulate matter (PM). Among many sources of air pollution one can count factories, industries, domestic heating, transportation and power plants. Pollutants can also come from decomposing garbage in landfills and solid waste disposal sites. In urban areas, heating and transportation are the dominant factors. In more detail, domestic heating emissions, e.g., from coal and fuel-oil, use of coal with low-calorie but high-value sulfur and ash fuels, incomplete combustion in heating systems, and the combination of these factors with meteorological conditions can give rise to high levels of air pollution. During the winter months domestic heating emissions is at the origin of 80% of the total pollution (Bayram et al. 2006). For instance PM emissions, one of the air pollutants, are generated whenever full burning conditions are not provided in heating chambers and thus volatile fuels, soot and fuel ashes are mixed with chimney gas. SO_2 emission on the other hand, depends directly on the amount of sulfur that the fuel possesses and partially on the sulfur retention quality of ash (Incecik 1994).

In the literature there are various studies illustrating emission distributions related to air pollution and air quality control based on GIS. The growth of GIS technology has provided a powerful tool and enabled novel analysis capability to model air quality. In the sequel we briefly mention the studies that explicitly use the GIS system. Patil et al. (2003) investigated GIS based air pollution surface modelling. Ferreira et al. (2000) presented distribution maps of hourly average NO_2 concentrations. Hallmark & O'Nell (1996) developed an applicable micro air quality model. Tayanc (2000) conducted a study on determining spatial distribution of daily SO_2 concentrations in Istanbul. Jenssen (1998) tried to the model the hazards of air pollution exposure on the population. Daylan & İncecik (2000) studied emissions and emission distribution inherent in Istanbul's air pollution**.** Similarly, Matejicek (2005) has studied spatial modeling of air pollution in urban areas. In another study, maps of traffic-related air pollution were developed within the framework of GIS and established a scheme to monitor air pollution levels (Veen et al., 1997). A model for pollutants plumes was designed through GIS to calculate the dispersal of total suspended particulate and to estimate its spatial distribution (Fouda, 2001). Sengupta et al. (1996) determined the population and risky areas facing air pollution via GIS. Fiala et al. (2001) found out sulfur accumulation in atmosphere by employing annual SO_2 concentration and rainfall data. Elbir (2004) studied about a GIS- based decision support system for estimation, mapping and analysis of air pollution for large Turkish cities. Gumrukcuoglu & Soylu (2007) has studies about calculation of traffic-related air pollution in urban areas.

In this study we focus on the Sakarya region in Turkey, a highly industrialized and densely populated area. We set out to determine the origins of the total SO_2 and PM among the factors of industry, transportation and heating. We studied the data gathered from fixed measurement stations in Sakarya and we observed that the district with highest pollution ratio was the city of Adapazarı according to the GIS map. Afterwards we selected 11 quarters of the city of Adapazarı where pollution was densest, and calculated SO_2 and PM emission concentrations based on the inventory information of buildings, settlements, fuel type, amount of fuel used and combustion technology, employed for domestic heating. A database was formed and by using GIS techniques distribution of air pollution was illustrated. The goal of this paper is to develop a case study of GIS-based decision support and planning tool in monitoring air pollution levels and improving air quality. The study will be a good step which is includes many details for regional air quality studies.

2. MATERIAL and METHOD

The study area, the province of Sakarya is situated on the northwest of Turkey between 29-27 eastern meridians and 40-41 northern parallels (Fig. 1). Its population is 851.000 according to the year 2008 census, its area covers 4817 km^2 resulting in a relatively high population density of 176 persons per km^2. The average height of the province is only 31m, which is a consequence of the fact that the major part of the province consists of plains and of low altitude hills. Adapazarı is the central district of the Sakarya province. The population of metropolitan Adapazarı is 382.226 (Population statistics, 2007). The whole city is located on plane ground with very few noticeable heights. Rapid rise of urban population, growth of manufacturing industries, location of a dense city on a plain are believed to be the main factors leading to the degradation of air quality in Sakarya in general and Adapazarı district in particular.

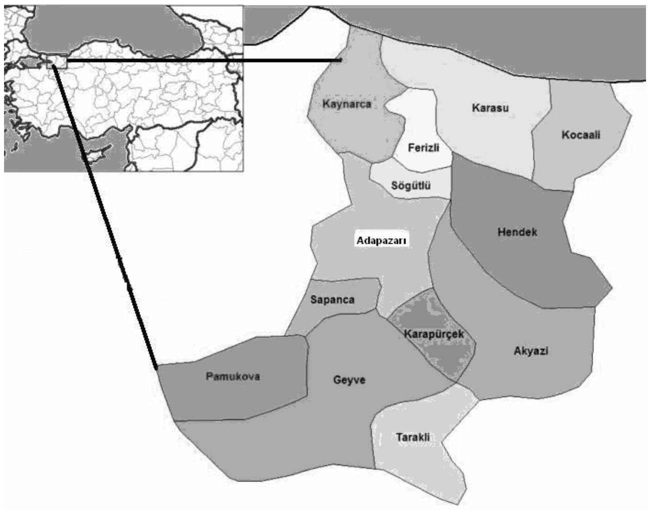

Figure 1. Sakarya City Map

This study is conducted in three stages. In the first stage, the district with the densest SO_2 and PM concentrations in the entire Sakarya province has been determined. These SO_2 and PM concentration data were obtained from the measurement stations of the Sakarya Provincial Department of Environment and Forestry, which functions throughout the whole year. Each district of Sakarya has a measurement station (Figs. 2, 3). These data belong to the month of March of 2007, one of the months that emissions of domestic heating reach their peak. In addition to emissions due to domestic heating, the SO_2 and PM emissions also originate from such sources as traffic and industry. These data have been organized in a database and the distribution of SO_2 and PM concentrations per district of Sakarya in this period has been mapped via MapInfo software, a GIS software.

In the second stage of study, we have

concentrated on the Adapazarı district as it has to the highest SO_2 and PM concentrations. By means of the survey data from selected houses in 11 quarters of Adapazarı city in that year, and an emission inventory (1) of SO_2 and PM concentrations originating from domestic heating has been prepared.

$$E = A \cdot EF \qquad (1)$$

E = Emission
A = Activation
EF = Emission factor

We calculated SO_2 and PM emission concentrations based on the inventory information of buildings, settlements, fuel type, amount of fuel used and combustion technology, employed for domestic heating. The detailed survey determined both of the domestic heating material (natural gas, coal, fuel-oil), the consumption levels and the combustion technology (combi boiler, stove, central heating etc.). In the emission inventory, we used the emission factors of bitumen coal, which according to the European Environmental Agency data has chemical and physical qualities most resembling to the coals consumed in Adapazarı, namely, Tunçbilek Soma, Siberian and Istanbul coal (EPA data). Emission values have been measured by assuming that in any one day heating was used for 12 hours. Since during warm season (May-September) fuel use is negligible, emission release was ignored, and data has been actually collected for 7 months while the study period has been taken as one year.

Notice that we have selected the streets, quarters and houses randomly.

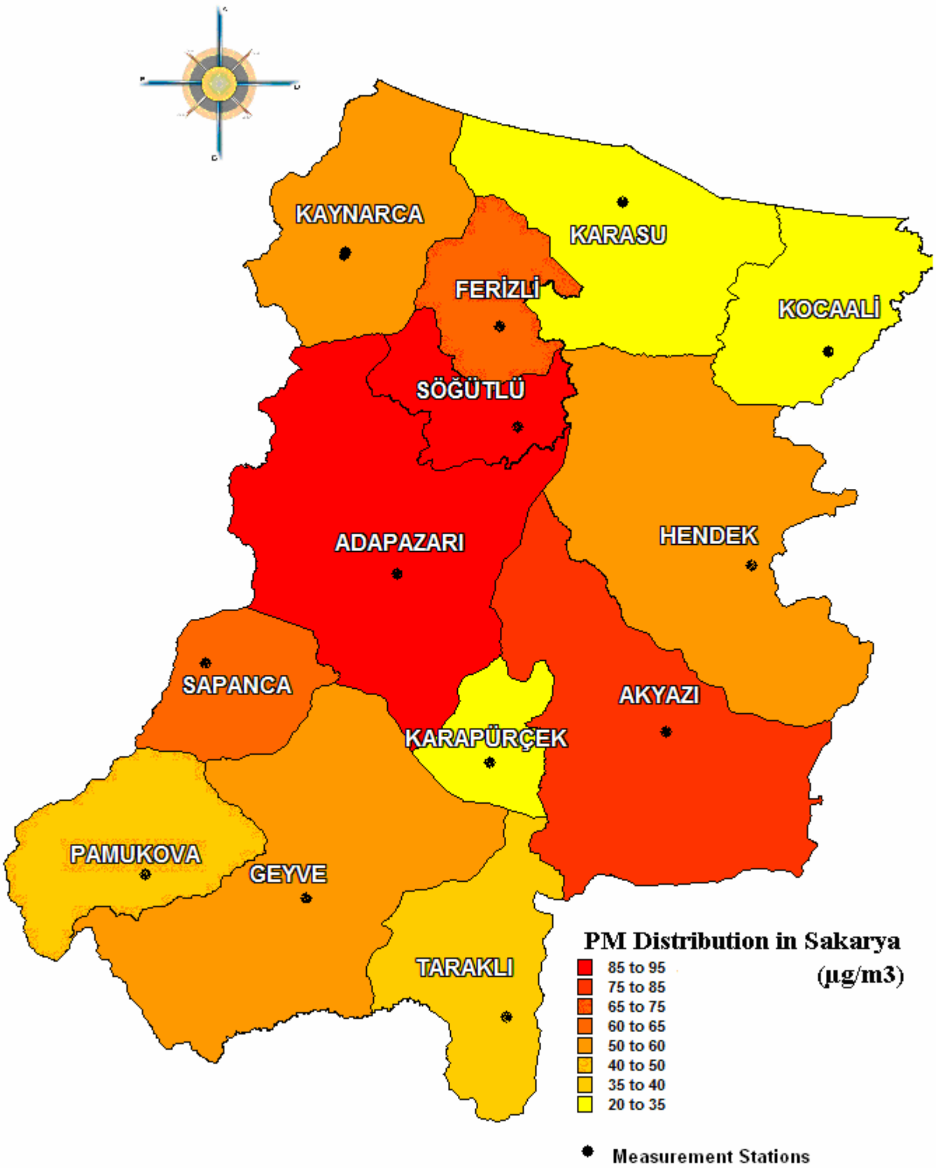

Figure 2. PM values Distribution for Sakarya Districts (Year of 2007)

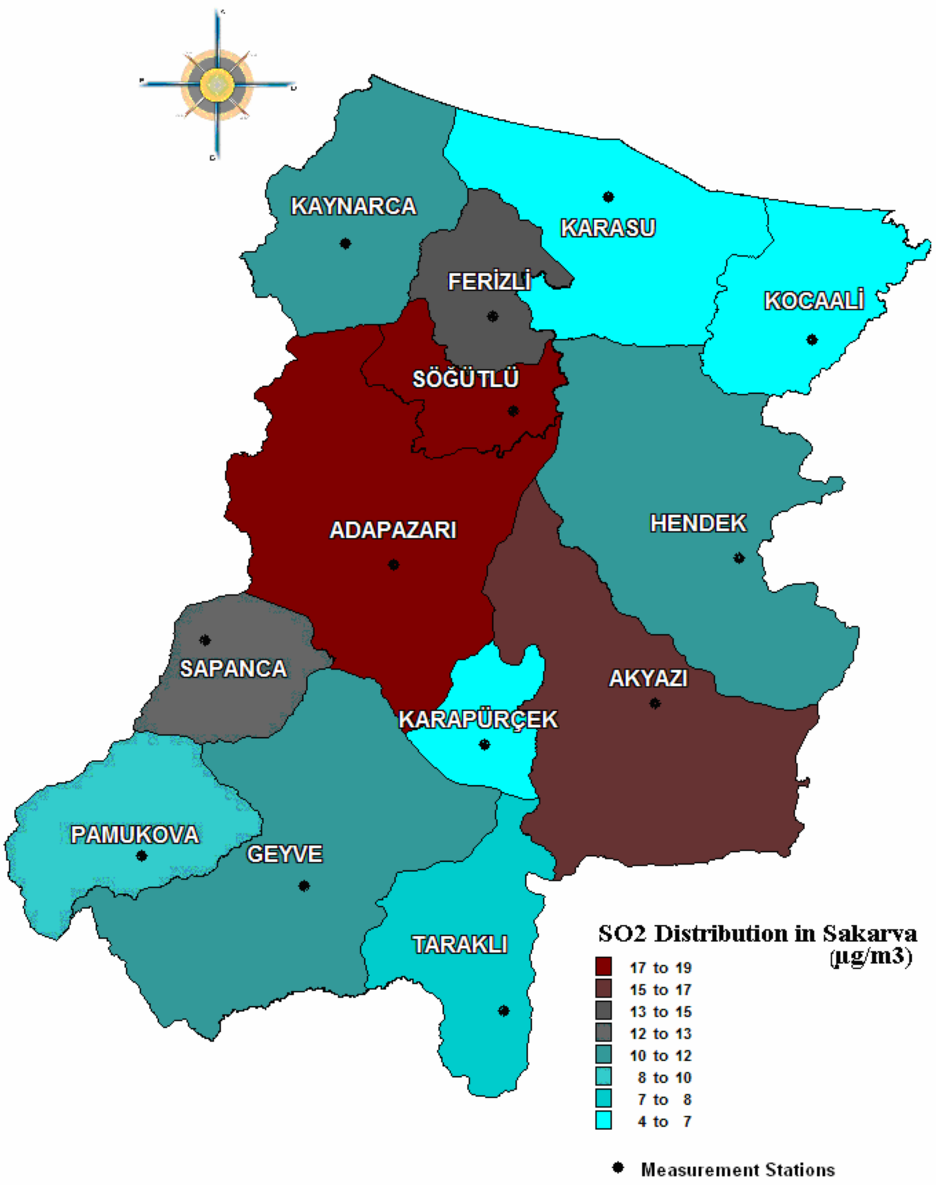

Figure 3. SO_2 values Distribution for Sakarya Districts (Year of 2007)

For instance, 116 out of 3637 houses in the Cumhuriyet quarter of the city were randomly selected according to the number of available houses given by the municipality. Since streets and houses where survey study would be conducted were randomly picked out, sampling equation was used in the error margin due to the random sampling can be calculated as in (2) (Ersoy & Erbas, 1996).

$$d = \sqrt{\frac{Nt^2PQ - nt^2PQ}{n(N-1)}} \qquad (2)$$

d = sampling error
P = Using of natural gas ratio
N = House number
Q = Using of coal ratio
t = Theoretical value according to t table

In the third stage of this study, the concentration differences within quarters have been mapping by GIS techniques. The satellite image Adapazarı from Google Maps has been overlaid on the digital map and the boundaries of the city quarters have been outlined. All the SO_2 and PM data gathered via surveys and measurements have been transferred to MapInfo software to form a database and it has been classified according to heating originated pollutant concentration values. Selected streets, quarter borders and surveyed houses have been indicated in separate layers, houses that use natural gas and coal have been painted in different colors. These layers have been overlaid and shown on a separate layer and all objects have been labeled. Information screens where the whole data are transferred have been created. The data types which are shown on the screen are: name of the quarter, street name, total number of houses, total number of surveyed houses, the proportions of heating types (central heating, flat heating, stove), the proportions of the heating material (coal etc.), and finally, SO_2 and PM values. By matching population data with SO_2, PM emission values originating from natural gas and coal usage in quarters, can make queries Besides, with respect to coal usage ratio, emission values can make queries together. For the 11 surveyed quarters, SO_2 and PM values originating from natural gas and coal were calculated individually and exhibited in table 3.

3. RESULTS

Not very surprisingly, SO_2 and PM were found to be emission values were found to be higher in the city of Adapazarı as compared to all other districts of the Sakarya province (Table 1).

Table 1. Measurement and population data for each district

Name of District	March 2007 SO2 (µg/m3)	March 2007 PM (µg/m3)	Population (2007)
Adapazarı	19	95	237259
Akyazı	15	75	83747
Ferızli	13	65	24157
Geyve	10	50	46629
Hendek	10	50	74607
Karapurçek	6	30	12548
Karasu	6	30	53275
Kaynarca	10	50	23376
Kocaalı	4	20	24622
Pamukova	8	40	26757
Sapanca	12	60	36916
Sogutlu	17	85	14193
Tarakli	7	35	7693

The reasons for this outcome can be relegated to such factors as denser population "Table 1", and higher numbers of industrial facilities and vehicles. A linear positive relation (D**a**ylan & Incecik, 2002) was conjectured between population density and SO_2 concentration, and indeed the data of this study verified this fact. While the denser population of Adapazarı is reflected in its higher SO_2 emissions the low SO_2 and PM concentrations in the Kocaali, Karasu, Karapürçek districts is related to the fact their vegetation is denser. Using the data given in table 1, SO_2 and PM emissions have been classified per district on the whole of Sakarya province. On the maps in Figure 2 and 3, darker color indicates higher concentrations and lighter colors indicate lower concentrations.

Population data, SO_2 and PM emission values can make queries on the maps. These thematic maps can be easily updated when the database content is changed. At this stage, our purpose is to visualize the distribution of such pollutants as SO_2 and PM and the related factors such as population density, and to point out on the map districts with the excessive pollution levels. We intend to provide visual assessment of the pollution vis-à-vis air pollution standards.

Furthermore, we prepared the inventory of heating originated emissions and presented it via GIS, district of Adapazarı, which had the highest amounts of SO_2 and PM values. The inventory was prepared based on face-to-face surveys conducted within 11 densely populated and randomly selected quarters of Adapazarı. In these surveys we have observed that the preferred heating type and technology varies from detached houses to apartment houses. In detached houses, usage of stove burning coal is as much as 70% while in apartment houses, combi boilers burning natural gass 43% "Table2". The apartment buildings had, on the average, three storeys.

Table 2. Distribution of technology types in 11 quarter of Adapazari city

Heating technologies types	Stove (%)	Central heating, (%)	Combi boiler (%)
General rate of using technology in residences	58	9	33
Rate of using technology in house	70	7	23
Rate of using technology in apartment house	46	11	43

Another observation was that in all of the 11 surveyed quarters of Adapazarı, coal was the predominantly used while natural gas was not widespread. To give an idea, the total number of houses in the surveyed quarters was 31,815 with 17,476 of them using coal, which amounted to a yearly total of 34.025,08 tons. A comparison in terms of coal usage within quarters indicates that Maltepe Quarter occupies the first place with approximately 7563,58 ton per year. Kemalpaşa Quarter comes second (Fig. 4).

The calculation covering the whole of the district of Adapazarı shows that coal consumption is 119,778,7 ton/year. In the 11 quarters selected, total amount of coal usage is 34.025,08 ton/year, the natural gas usage amounts to 29.849.960 m3/year.

According to emission inventory results total emissions amounts are as follows: natural gas originated SO_2, 306 kg/year, PM 5606,8 kg/year, coal originated SO_2 426.820 kg/year, PM 615.310 kg/year. For the 11 surveyed quarters, SO_2 and PM values originating from natural gas and coal were calculated individually and exhibited in table 3.

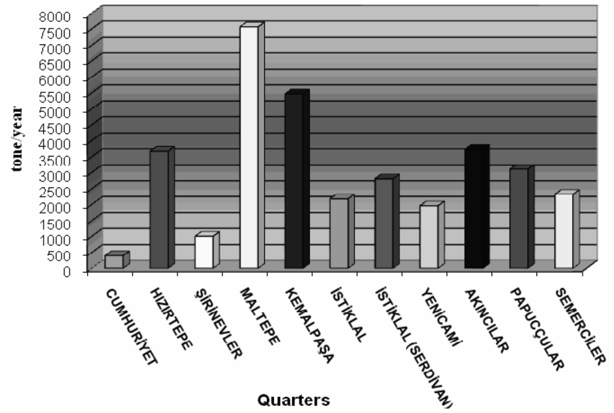

Figure 4. Using coal amount in 11 quarters of Adapazari city (Year of 2007).

As indicated in table 3, natural gas originated emissions are highest in Istiklal (Serdivan) Quarter, with a total SO_2 emission of 77,2 kg/year, which accounts for 25% of the total of 306 kg/year out of 11 quarters. In addition, PM value of this quarter is higher than all the other quarters. In districts such as Maltepe and Kemalpaşa SO_2 emissions originating from coal usage are also higher. Kemalpaşa Quarter's PM emission value which is 210.030 kg/year is rather high compared to other quarters. As regards SO_2 emissions, Maltepe Quarter has a higher emission rate than Kemalpaşa Quarter. Although in Maltepe Quarter more coal is burned, it has lower PM emission value than Kemalpaşa district, and. this fact can be explained in terms of the more advantageous topographic location of the Maltepe Quarter.

Although in this study, emission values were studies in terms of heating type and technology and topographic effects were disregarded, the above explanation follows from general information concerning the study area. In fact, Maltepe Quarter is situated on one the few elevated locations in the Adapazarı plain. As for the natural gas emission statistics, Pabuçςular Quarter has the lowest emission due to its sparse population and low ratio of natural gas usage.

When the monthly proportional distribution of emission values of quarters are considered with respect to total values in Adapazarı, it can been seen that 2007 December is the month with the highest emission value. For the general Adapazarı, the December SO_2 emission due to natural gas consumption is 97,33 kg/month, PM dispersion is 1784,35 kg/month. In December of 2007, emission due to coal consumption: SO_2 emission 354.270 kg/ month, PM dispersion 620.790 kg/month.

With the calculated emission inventory values a database has been prepared. By processing this data base over the satellite image which is used as base map, domestic heating originated SO_2 and PM emissions are classified per 11 quarter (Fig. 5) and thematic maps are prepared. Once the maps are analyzed, it surfaces that Istiklal (Serdivan) Quarter is the one where natural gas originated emission is highest.

Table 3 Emissions values of quarters of Adapazari city

Quarter Name	Population (2007)	Natural Gas consumption amount (m3/year)	Natural Gas Emission (kg/year)		Coal consumption amount (tone/year)	Coal Emission (kg/year)	
			SO_2	PM		SO_2	PM
Cumhuriyet.	7000	5.718.000	54,9	1006,9	402	11.320	27.790
Maltepe	17.000	1.837.000	17,7	323,5	7563,58	86.340	71.830
Kemalpaşa	15.000	229.233	21,4	392,4	5467,2	80.020	210.030
Istiklal (/merkez)	2190	3.511.775	33,8	618,1	2174,5	34.010	103.520
Istiklal (Serdivan)	14.000	8.037.225	77,2	1414,6	2807,84	32.050	26.660
Sirinevler	3800	1.864.000	17,9	328,1	1002,68	11.450	9520
Hızırtepe	18.000	4.664.000	44,8	821,0	3607,68	41.900	34.860
Pabuccular	4500	257.727	2,5	45,4	3106,13	35.460	29.500
Semerciler	8500	3.731.000	35,8	656,8	2321,8	26.500	22.050
Yeni cami	3600	not use natural gas			1841,08	25.180	44.120
Akıncılar	4000	not use natural gas			3730,59	42.590	35.430
TOTAL	97.590	29.849.960	306	5606,8	34025,08	426.820	615.310

This particular quarter is the place where natural gas usage is highest. From high emission ratio to low, Cumhuriyet Quarter comes next in this list. Since it has been detected that in Akıncılar and Yenicami Quarters, natural gas usage is very low, natural gas originated emissions are ignored for these quarters (Figs. 6, 7).

In figures 8 and 9 show that Kemal Paşa and Maltepe Quarters as the places where coal originated SO_2 emission amounts are highest, while Kemal Paşa Quarter is indicated as the location with highest amounts of PM, Maltepe Quarter is the region with highest amounts of SO_2 (Figs. 8, 9).

Since the maps have been shaped as thematic maps, all the changes and updates that will be made on data base can monitored and make guery. The information screen on thematic maps give information such as ID number, quarter, street name, total number of houses, number of surveyed houses, central heating-combi boiler-stove usage ratio in flats and detached houses, coal consumption ratio, $SO_{2,}$ and PM values. In addition to visualized form of emission distribution, the analysis and queried that will be made with the information on his database enable both the sustainability of research and the planning stage of air quality, planning in forming decision support system.

4. DISCUSSION

We have observed that in the city of Adapazarı the factors giving rise to air pollution are dense manufacturing industry, increase in the traffic in and around the city, and the use of low-quality coal in lieu of natural gas. Although this problem, measurements of pollutants have been just in two certain selected points in the city and the status of current pollutants and their distribution are based only on these measurements. So, a good emission inventory is necessary and important. As there are no standards to compare inventory data, in this study the most densely polluted regions are detected according to the differences among regions. These are the regions where coal consumption is highest in particular.

The goal of this study was to create a model of pollutants originating from heating, to exhibit the present condition of air quality as a guide for eventual policy decisions.

In this study in order we have prepared emission inventory and mapped of emission distribution and also taken into consideration the error margin in the sampling formula. While SO_2 and PM emission inventories from quarters of Adapazarı district are accounted for by domestic heating, these pollutants in the Sakarya region have total emission for industry, heating, transportation.

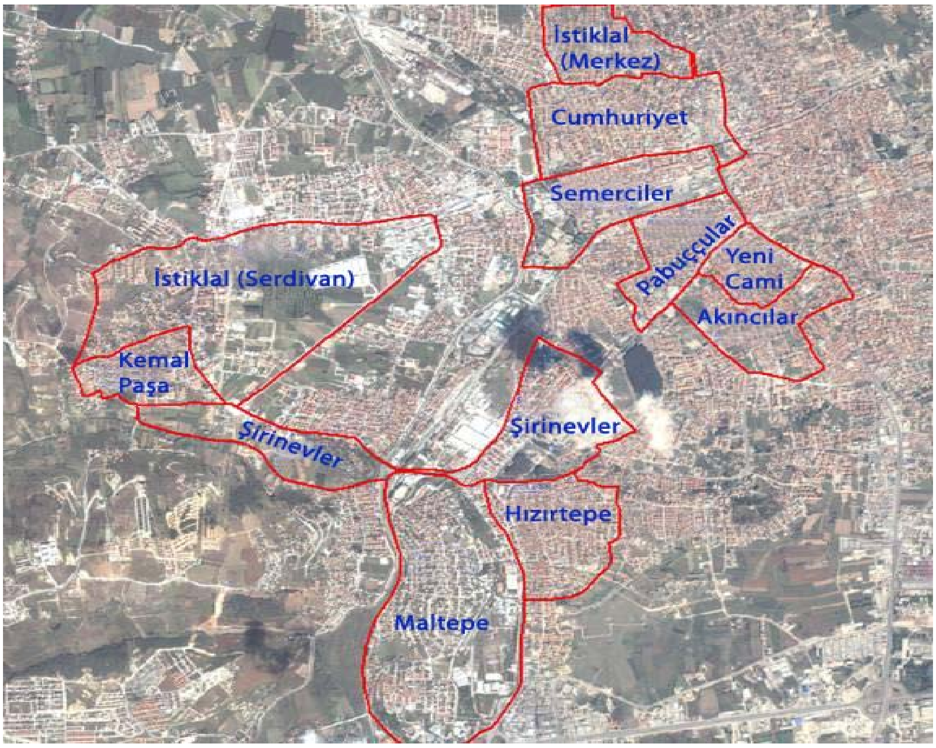

Figure 5. Real borders for 11 quarters

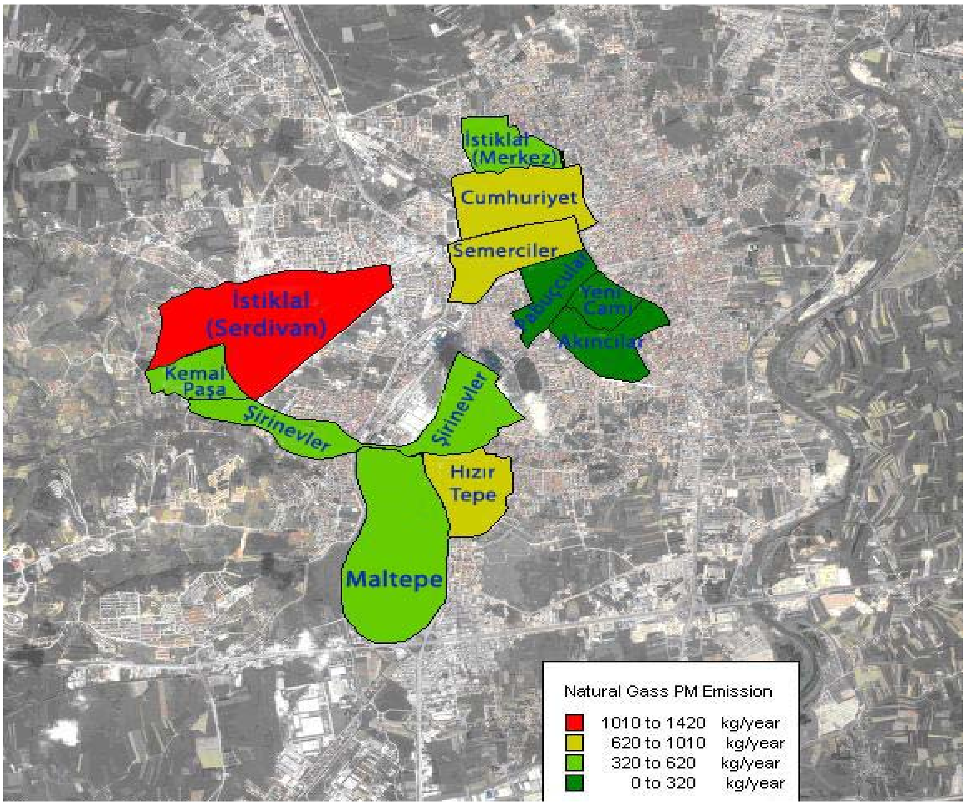

Figure 6. PM emission distribution for natural gas in 11 quarter of Adapazari city(Year of 2007)

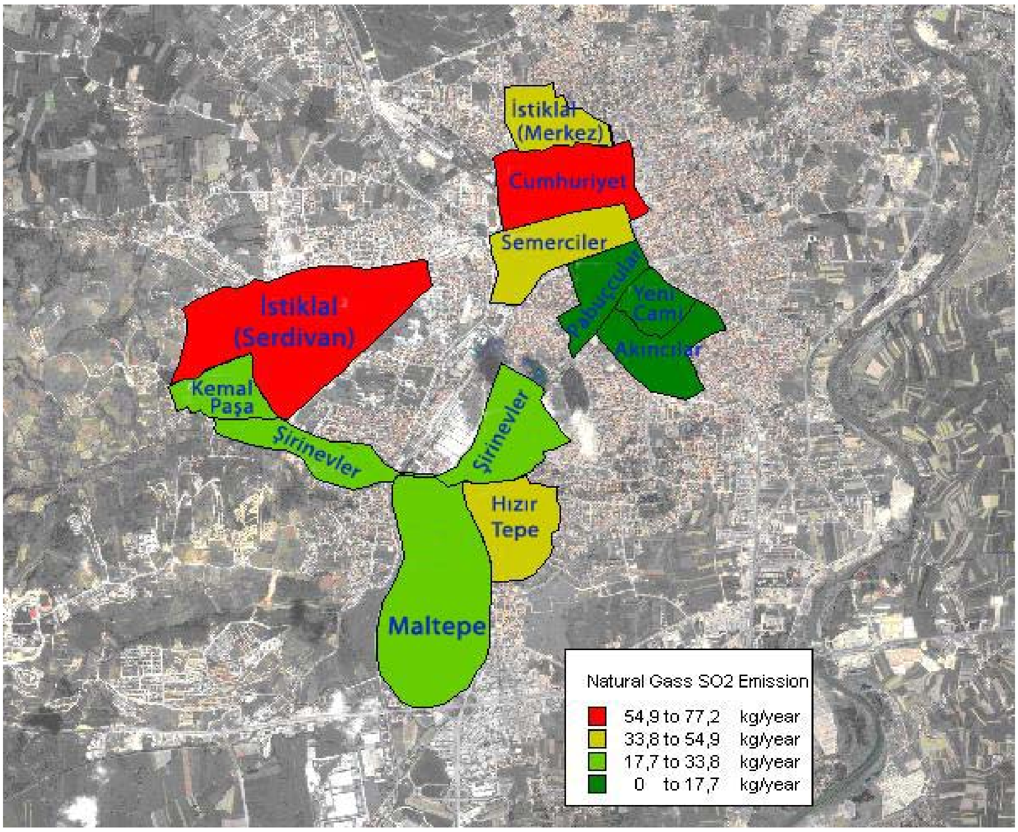

Figure 7. SO_2 emission distribution for natural gas in 11 quarter of Adapazari city (Year of 2007)

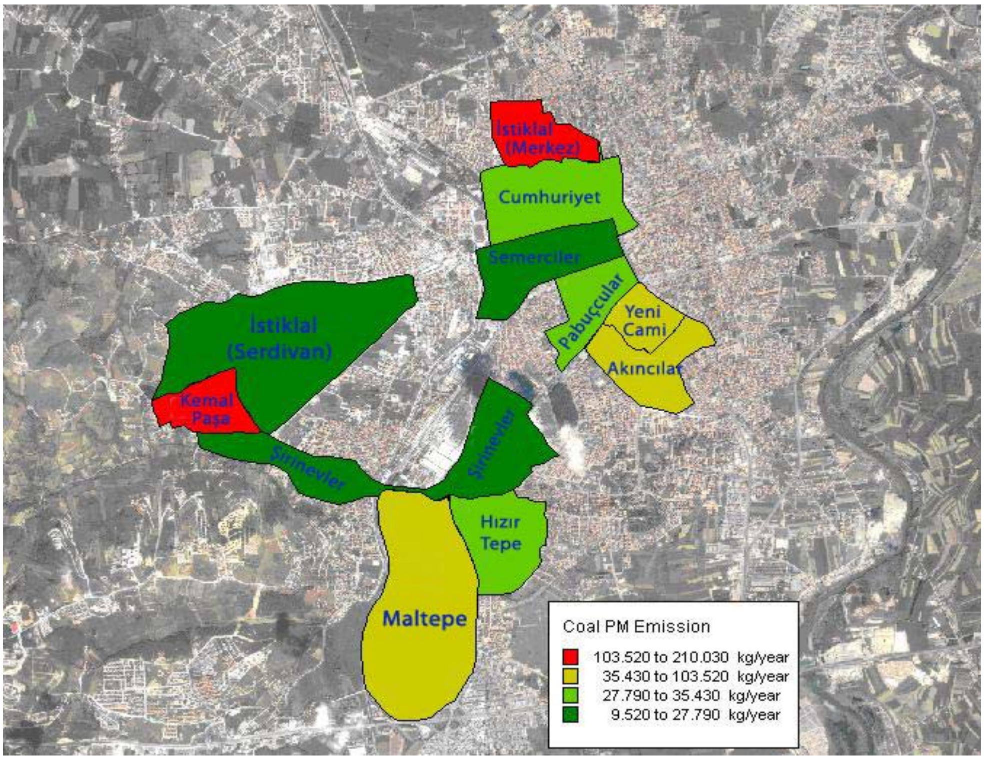

Figure 8. Coal PM emission distribution for coal in 11 quarter of Adapazari city (Year of 2007)

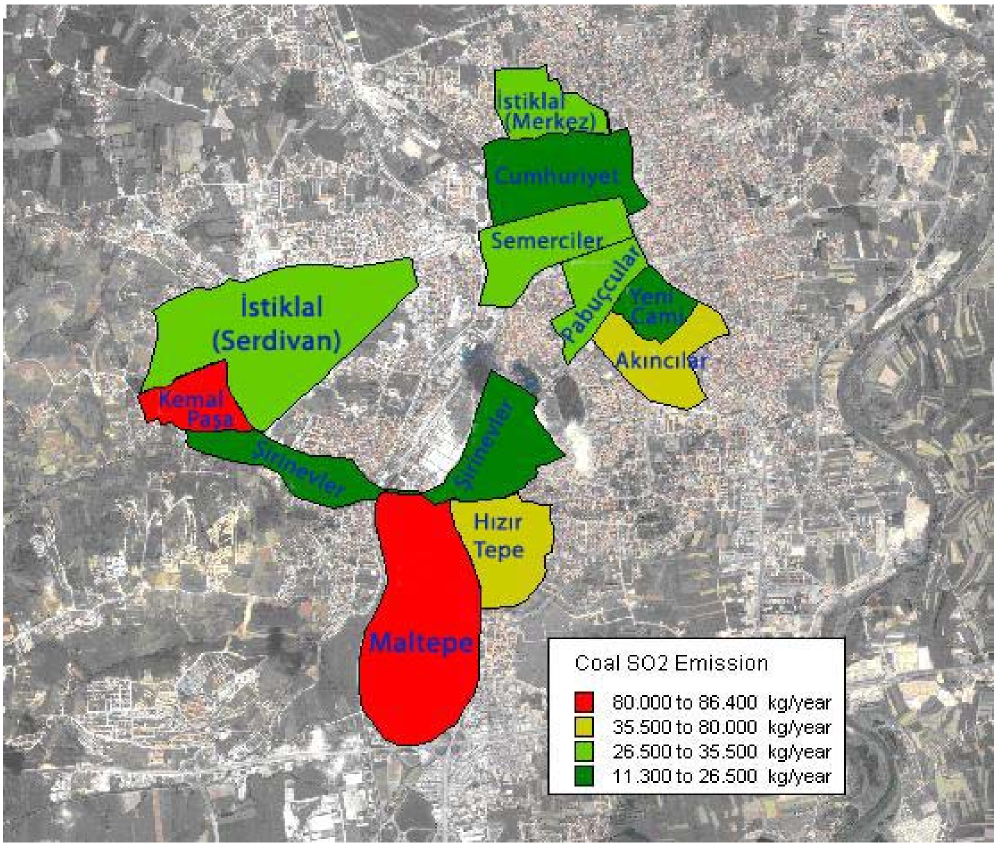

Figure 9. Coal SO_2 emission distribution for coal in 11 quarter of Adapazari city (Year of 2007)

It is not possible to estimate the origin of pollutant concentrations from point measurements performed in stations or to find out which source is more effective. However inventory calculations enables us to predict the concentration amounts released from certain sources, such as domestic heating, and thus take precautions for emission reduction. In the literature also, studies that show emission distribution maps performed by point measurements whose positions are given by the GIS, total emissions from air pollutants are indicated. Nevertheless it is still not possible to point out which one amongst them is the most effective. While analyzing emissions originating from domestic heating, studies in the literature indicate that registered measurement data of fuel type and amount were use.

This method may not always indicate exact actual use. Instead, in our study we used a more reliable method that of face-to-face survey to determine the fuel type, the quantity and the combustion method used. This approach is expected to increase the accuracy of the estimates.

It is known that in Turkey 34% of energy consumption takes place in houses and 80% of this energy is consumed in buildings for heating purposes, and that this energy is obtained by fossil fuels (World Bank, 2011). In order to curb the increasing air pollution reliable inventory data and visualization of for analysis are required. Reliable and comprehensive data will enable local administrations to see the main sources and level of pollutants, and to track the progress. This is especially important because air pollution control is costly and public in large must be convinced. In short, correct assessment of air pollution and its factors are the necessary steps for an effective control strategy.

In certain literature studies, time dependent changes of concentrations have been emphasized (Ferreira et al. 2000, Daylan & Incecik, 2002). Since our study is the first of its kind for Adapazarı, time dependent changes are not available, and the present data can serve as a reference for future studies. The data obtained through measurement can be compared with general emission standards. But there are no standards to compare inventory data so in this study the most densely polluted regions are detected according to the differences among regions. These are the regions where coal consumption is highest in particular.

In the study the error margin of sampling is calculated as 0.06. For each quarter of the city where a study was conducted, sampling errors are calculated by determining P and Q values separately. For instance, in Cumhuriyet Quarter sampling error is 0.1. The number and location of houses to be surveyed have been randomly selected from the total amount of houses in the Adapazarı Municipality. Actually the total number of houses should be measured before sampling. However in this study the exact formula has been used to measure sampling error margin. We believe that when the streets and number of houses to be included in the sampling are determined with a formula, the sampling error should be even smaller.

The obtained results were turned into visual form via GIS so that they could be queried. The fact that GIS reflects data with a minimum error margin enables application of plans on air quality most accurately. GIS technique has a capacity to support the development of spatial air pollution models, select monitoring station and support the development spatial decision support system (Rahmatizadeh et al., 2004). Conducting studies related to air pollution sources and distribution with a GIS approach lightens emission projection of city in the future and planning air pollution.

New EU regulations require monitoring and assessment of air quality by modeling and information to the public in large cities with more than 250.000 inhabitants (EU Council, 1996). Within this context, by obtaining emission inventories of cities, dispersion models of current air pollution can be practiced and pollution distribution levels within city can be analyzed better. Using high amounts of coal is increased of SO_2 and PM emissions in high populated regions. Higher rates of SO_2 and PM than natural gas using ones are shown that how the fuel type selection on effects to the air quality in coal using districts. Creating air pollution maps for the city is important in city planning in high polluted areas. By detecting the areas with high emission values, current situation analysis and air quality planning will be improved. Moreover, it will be helpful in taking decisions to prevent its exposure, determine its effects on human health, its socioeconomic influences and the precautions to take at the last stage. This study covering central Adapazarı will enable to classify air pollution according to its sources and pose a sample model for other regions. The uniqueness of this project is related to the fact that it is a vanguard study for Sakarya and a model for future studies concerning other cities for air quality control.

5. CONCLUSION and SUGGESTIONS for FURTHER STUDIES

Air pollution is still one of the major problems damaging human health and the natural environment especially in developing countries. Monitoring and showing the pollutants originating from heating, which is one of the sources of air pollution is absolutely necessary in surveying and structuring air quality standards, analyzing and planning the consumed fuels and heating techniques.

In the first part of this study the current situation in Adapazarı was analyzed by obtaining a pollution of the city, where the most polluted parts came into evidence. These datas were collected through fixed station measurements. In the second stage of the study we classified the houses in Adapazarı with respect to their heating system by survey study and prepared emission inventories. The survey study increases to accurate of results. Finally in the third stage, these data were mapped via GIS. Since the visualization and analysis of data reveal that particularly in quarters where coal consumption is high, the emission is also much higher, this can become an indication for pollution control policy.

As a conclusion in this study it surfaces that in city of Sakarya, the region with highest SO_2 and PM values is Adapazarı. This particular district's heating originated emission inventories have been formed and shown on the map. According to obtained data, distribution of SO_2 and PM emissions and natural gas originated emissions are relatively less than coal originated emissions. Besides, preparation of emission inventories and classification of the emissions with these data -one of the methods used in the study gives better results than classification with only measurement data. Because, it is impossible that identify of emissions resources as separately with total emission measurements. Total emission is also important but especially identification of heating sourced emissions is important in strategy determination about fuel type and fuel technologies. Therefore the emission inventory is very important for air quality studies. Creating of some projects and solutions will be possible with emission inventory for air pollution control and improving of air quality

A follow-up study of this study will be an air quality model for the city of Sakarya. Such studies are vital steps of the decision support system which is a professional support medium for politicians and decision makers engaged in air quality planning. Due to its outcomes this study is supportive of authorized institutions in giving scientific and technical information on required precautions to take against pollution caused by domestic-origin heating and also can be used in further modeling and projections. Furthermore, by using GIS, emission concentration distributions can be shown, analyzed and updated and future solutions of these problems can be sustainable. This study will use as first step for Sakarya province air quality studies. Besides the methodology is effective strategy for air quality and management.

According to the obtained results of this particular study it is an absolute necessity to take precautions for reducing emissions. To reduce heating originated emission coal consumption should be minimized in domestic-origin heating. In areas where the highest pollution is detected in city emission control techniques should be practiced. In order to eliminate pollution consumed fuels should be checked carefully, the use of clean heating technology and clean energy alternatives should be evaluated.

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