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ASSESSMENT OF PM_{10} LIMIT EXCEEDANCES IN TURKISH CITIES

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Abstract

Turkey, as a European Union (EU) candidate country, is harmonising the air quality limits to meet EU standards. For this reason, PM_{10} limit value is being reducing in yearly intervals till 2019 when daily PM_{10} limit value of 50 µg/m^3 will be met.On the other hand, as the limit value decreases, the air quality of Turkish cities are being considered as polluted.

The aim of this paper is to present the PM_{10} exceedance events in Turkey between 2014 and 2016. The daily measured PM_{10} concentrations were obtained from National Air Quality Monitoring Network of Turkey. We calculated the number of exceedance events. Then, we created thematic maps to evaluate the PM_{10} exceedances both spatial and temporal.

There is an increasing trend in total number of cities where the PM_{10} threshold is exceeded. Moreover, there exist a decreasing trend in the number of cities in which no PM_{10} exceedance events occurred.It would be difficult for Turkey to meet EU PM_{10} standards in 2019 unless certain precautions are applied. At the end of the paper, there are some suggestions to reduce PM_{10} emissions and to meet threshold value.

***Key words**: air quality standard, geographical information systems, limit exceedance, PM_{10}, Turkey*

INTRODUCTION

Particulate matter (PM) is the subset of atmospheric aerosols. Solid and liquid particles with aerodynamic diameter less than 10 µm are called PM_{10}, in other words inhalable coarse particulates.

Particulates with aerodynamic diameter less than 2.5 µm and 0.1µm are classified as fine and ultra-fine particulates respectively. PM may contain sulphates, nitrates, elemental and organic carbon, polycyclic aromatic hydrocarbons, metals, soil or dust depending on the origin.

The sources of PM can be either natural or anthropogenic. Volcanoes, fires, dust storms and sea salt are natural sources. Combustion of fossil fuels and industrial emissions are main sources of anthropogenic PM (Anderson et al., 2012; Fuzzi et al., 2015; Kim et al., 2015).

Studies related with particulate matter are in the focus of scientist due to the adverse effects of PM on climate, air quality, ecosystem, visibility and human health. PM is related with premature human mortality, cardiovascular diseases, lung cancer and other respiratory diseases (Polichetti et al., 2009; Fuzzi et al., 2015). In order to visualise the spatial distribution of air pollution, Geographical Information System (GIS) is used as a tool for pollution mapping.Geographic Information Systems is a computer-based tool that analyses, stores, manipulates and visualizes geographic information on a map (GISGeography, 2017). Markakis et al., (2010) used GIS to visualise the spatial distribution of anthropogenic emission inventory of PM_{10} in Greece. Elbir (2004) developed a GIS based decision support system to estimate, visualise and analyse the air pollution level in İzmir, Turkey. Behera et al., (2011) used a GIS based emission inventory for PM_{10} dispersion modelling in Kanpur city, India.

Turkey is a European Union (EU) candidate country. In order to meet environmental quality standards of EU, Turkey has started to adjust environmental legislations. Therefore, in terms of air quality, Turkey is in transition period and limit values are being reduced gradually.

Daily PM_{10} limit values in Turkey among the years are represented in Table 1. EU daily limit value of 50 µg/m^3 will be entered in force at the beginning of 2019. According to the EU legislation 35 days exceedance is allowed for daily PM_{10} concentrations.

Table 1. Daily PM_{10} Limit Values in Turkey

Years	2010	2011	2012	2013	2014
PM_{10} ($\mu g/m^3$)	**260**	**220**	**180**	**140**	**100**
Years	2015	2016	2017	2018	2019
PM_{10} ($\mu g/m^3$)	**90**	**80**	**70**	**60**	**50**

In this study, we investigated the daily exceedances of PM_{10} concentrations in Turkish cities for the years of 2014, 2015 and 2016.
The aim of this study is to decide whether the Turkish cities satisfy air quality standards in terms of PM_{10}or not. Materials and Methods section describe data acquisition, data flow and how thematic maps are created. PM_{10} exceedance thematic maps are represented and discussed in Results and Discussions part. Several suggestions have been made to reduce PM_{10} emissions in Conclusion section.

MATERIALS AND METHODS

There exist 195 stationary and 4 mobile stations in National Air Quality Monitoring Network of Turkey (Figure 1). Hourly and daily measurements of air pollutants are accessible via web site of this network (http://www.havaizleme.gov.tr/). Daily average values of PM_{10} measurements have been downloaded for the years 2014, 2015 and 2016 from that web page as Microsoft Excel files.

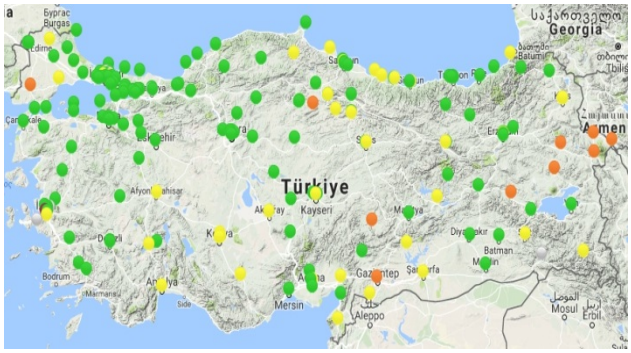

Figure 1.National Air Quality Monitoring Network of Turkey

As seen from Table 1, in Turkey, PM_{10} limits are 100, 90 and 80 $\mu g/m^3$ in 2014, 2015 and 2016 respectively. Both EU Legislation and Turkish Assessment and Management of Air Quality Regulation permit 35 days exceedance for daily PM_{10} limits. So as to calculate yearly exceedance number for cities following Excel formula in Equation 1 has been used.

=IF(COUNTIF(C2:C367;">80")-35>0; COUNTIF(C2:C367;">80")-35;0) (Eq.1)

Equation 1 assumes daily average PM_{10} measurements have been written on C2:C367 range. "80" is limit value for 2016 and "35" is allowable exceedance. This formula checks if there exist more exceedance than 35 days or not. If so, then formula calculates number of exceedance by subtracting allowable number otherwise it displays "0" which means upper limit is not exceeded.
Some cities have more than one air quality monitoring station. For these cities, average value of each station is calculated and single exceedance value is given.
After having calculating the data necessary to create thematic maps, MapInfo version 12 has been used as GIS software."Create Thematic Map" option is used from "Map" menu. We prepared 3 thematic maps for 2014, 2015 and 2016 that show number of exceedances in terms of PM_{10} pollutant.
To create thematic maps, we classified cities as severely polluted (red colour on map), highly polluted (orange), polluted (yellowish green), less polluted (light green) and no-exceedance (dark green).
In severely polluted cities, more than 100 daily exceedances occurred.

RESULTS AND DISCUSSIONS

The number of PM_{10} Exceedances in 2014, 2015 and 2016 in Turkey is shown in Table 2. Figure 2, 3 and 4 show PM_{10} limit exceedances for Turkish cities in 2014, 2015 and 2016 respectively. In 2014, there exist 5 cities that can be considered as severely and highly polluted in terms of PM_{10}.
Threshold value is exceeded 163 times in Siirt, 84 times in Muş, 82 times in Düzce and 70 times in Batman. There weren't any PM_{10} limit exceedance in 42 cities. Next year, the daily limit value of PM_{10} is reduced to 90 $\mu g/m^3$. There were 3 severely polluted cities. 199 times exceedance was occurred in Mus, followed by Siirt (126 times) and Batman (112 times) in 2015. 11 cities (Karaman, Manisa, Düzce, Muğla, Bursa, Hakkari, Kayseri, Iğdır, Afyonkarahisar, Kahramanmaraş and Bolu) were categorized as highly pollutedcities.

The number of cities with no-exceedance of PM_{10} limit was decreased to 26. In 2016, the daily limit value of PM_{10} is further reduced to 80 $\mu g/m^3$. 4 cities were fallen into severely polluted category.

These cities were Mus, Siirt, Kütahya and Manisa with 186, 157, 118 and 117 exceedance events respectively. The number of highly polluted cities (Düzce, Kayseri, Denizli, Karaman, Tekirdağ, Muğla, Gaziantep, Niğde, Erzincan, Afyonkarahisar, Batman, Bursa, Uşak, Iğdır, Ankara, Hakkari, Osmaniye and Kahramanmaraş) increased to 18.

In 2016, there were only 22 cities with no-exceedance events.

Table 2. Number of PM_{10} Exceedances in Turkey

	Number of Exceedances				Number of Exceedances				Number of Exceedances		
City	**2014**	**2015**	**2016**	**City**	**2014**	**2015**	**2016**	**City**	**2014**	**2015**	**2016**
Adana	1	12	3	Giresun	0	0	0	Samsun	3	13	21
Adıyaman	30	11	11	Gümüşhane	5	3	0	Siirt	163	126	157
Afyonkarahisar	39	65	72	Hakkâri	25	70	56	Sinop	0	16	44
Ağrı	0	15	26	Hatay	24	31	45	Sivas	0	9	35
Amasya	0	6	44	Isparta	36	20	20	Tekirdağ	9	36	86
Ankara	18	23	59	Mersin	0	23	8	Tokat	0	3	32
Antalya	6	0	4	İstanbul	6	13	8	Trabzon	0	6	11
Artvin	0	0	0	İzmir	2	2	3	Tunceli	0	0	0
Aydın	13	26	25	Kars	0	0	14	Şanlıurfa	0	0	0
Balıkesir	0	0	0	Kastamonu	0	0	12	Uşak	0	7	69
Bilecik	8	8	19	Kayseri	30	69	93	Van	0	0	0
Bingöl	0	0	0	Kırklareli	0	3	18	Yozgat	0	0	0
Bitlis	5	0	0	Kırşehir	0	0	0	Zonguldak	24	26	32
Bolu	47	50	0	Kocaeli	9	7	13	Aksaray	0	26	35
Burdur	0	13	25	Konya	5	7	15	Bayburt	0	0	0
Bursa	50	70	71	Kütahya	3	16	118	Karaman	45	94	92
Çanakkale	11	17	18	Malatya	0	0	0	Kırıkkale	0	0	0
Çankırı	0	0	1	Manisa	41	76	117	Batman	70	112	72
Çorum	0	2	49	Kahramanmaraş	21	52	51	Şırnak	0	0	0
Denizli	36	37	92	Mardin	0	39	40	Bartın	0	1	40
Diyarbakır	0	16	10	Muğla	44	71	85	Ardahan	0	0	0
Edirne	30	32	36	Muş	84	199	186	Iğdır	43	67	63
Elâzığ	0	0	0	Nevşehir	0	0	0	Yalova	0	0	18
Erzincan	0	27	74	Niğde	2	46	80	Karabük	36	28	18
Erzurum	0	0	31	Ordu	0	1	19	Kilis	0	0	0
Eskişehir	0	0	0	Rize	0	0	0	Osmaniye	28	34	55
Gaziantep	0	15	80	Sakarya	45	41	42	Düzce	82	72	94

As seen from Figures 2, 3 and 4, there is an increasing trend in total number of cities where the PM_{10} threshold is exceeded. Moreover, there exists a decreasing trend in the number of cities in which no PM_{10} exceedance events occurred.

In previous years, air quality was not considered as polluted due to the higher limits in Turkey.

However, after reduction in limit values, air quality is now being considered as polluted in most of the Turkish cities. It should be noted that daily PM_{10} limit is 70$\mu g/m^3$in 2017. There will be further reduction until 2019 when Turkey will meet EU limit value (50$\mu g/m^3$) for PM_{10}. Karaca (2012) used the PM_{10} data of year 2008 and geographical information system based interpolation technique to classify the air quality zones in Turkey.

4 hotspots were identified as a result of this study: the eastern part of the Black Sea region (Düzce, Zonguldak and neighbour cities), (ii) Kütahya, Afyon and Isparta area, (iii) Kahramanmaraş, Osmaniye and Hatay area, (vi) Easthern Anatolia (Muş, Bingöl, Erzurum, Iğdır).

Atmospheric PM_{10} levels of cities like Zonguldak, Kütahya and Kahramanmaraş were strongly influenced by coal based thermal power plant emissions.

In 2008, the natural gas usage as a fuel source for domestic heating was not available at Black

Sea region, Mediterranean Sea Region and Eastern Anatolia Region except few cities. At the beginning of 2017, there exist only 3 cities remaining (Artvin, Şırnak and Hakkari) which lack of natural gas distribution. However, the cities in Eastern Anatolia Region had natural gas quite recently. Shifting from coal to natural gas takes some time and that is why some cities have still high PM_{10} levels. On the other hand, Ministry of Energy and Natural Resources considers coal as a primary source for generating electricity.

Therefore, the number of coal based thermal power plants are increasing continuously in Turkey. Hence, PM_{10} levels are still high especially in cities with thermal power plants.

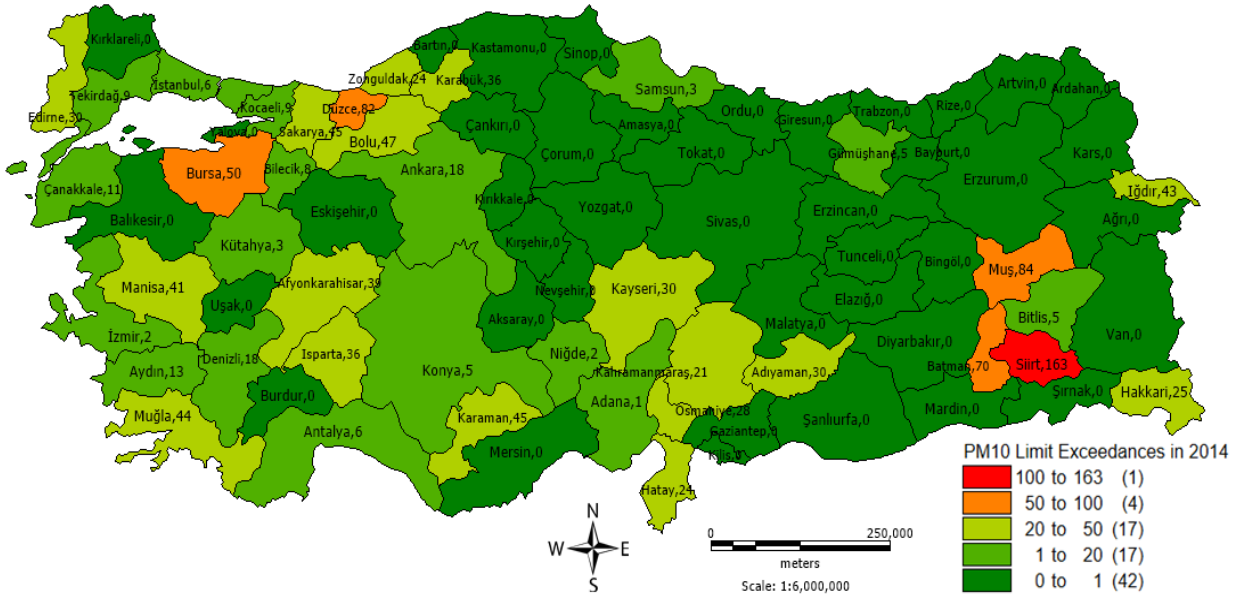

Figure 2. PM_{10} Limit Exceedances in 2014 (Limit: 100 µg/m^3)

Figure 3. PM_{10} Limit Exceedances in 2015 (Limit: 90µg/m^3)

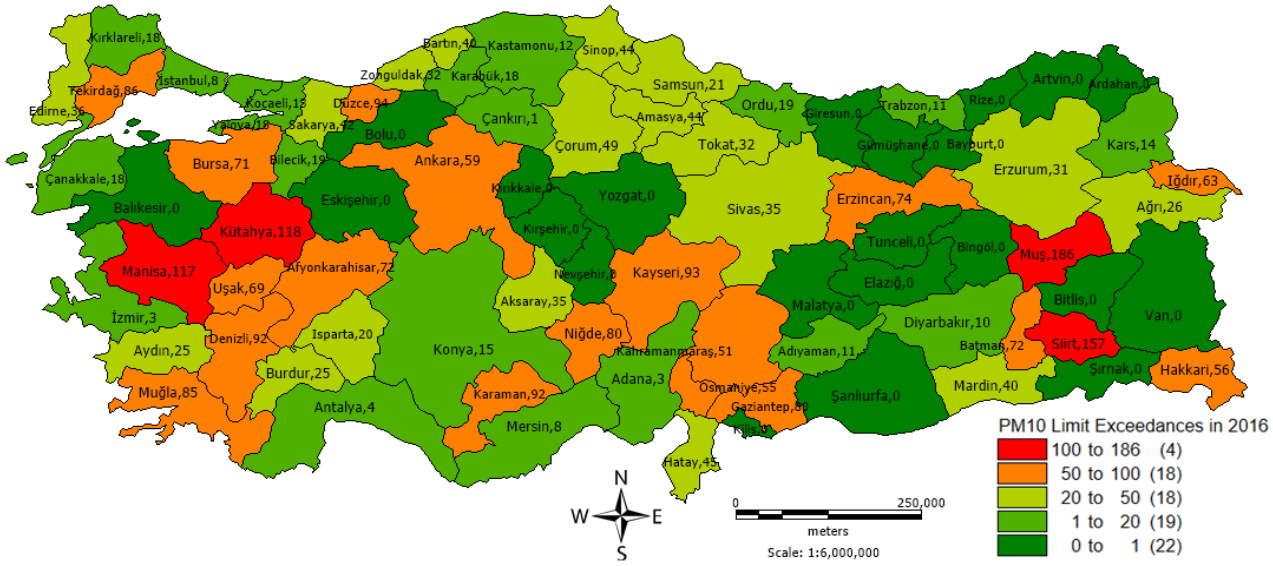

Figure 4. PM_{10} Limit Exceedances in 2016 (Limit: 80µg/m^3)

Exposure to PM_{10} concentrations in ambient atmosphere of Turkish cities causes health related issues. Tecer et al., (2008) investigated the relation between hospital admissions of children (younger than 15) for respiratory diseases and the levels of particulate pollution in Zonguldak, Turkey. The results of this study showed a significant relation between PM_{10} levels and hospital admissions due to asthma, allergic rhinitis, and upperand lower respiratory diseases.

In our study, we observed that Muş, Batman and Siirt can be considered as cities with poorest air quality which is similar to the study of Dolar and Saraç (2015). They examined the daily PM_{10}concentrations in 2014 in Southern Eastern and Eastern Anatolia Region.

They mentioned that highest PM_{10} concentrations were measured at Siirt, Iğdır, Muş, Batman, Hakkari, Adıyamanand Diyarbakır in 2014. They also stated that exceedance events were common both in summer and winter. The reason of high PM_{10} concentrations in summer days is dust transport from south. Saharan dust transport is one of the important sources of PM_{10} pollution in Turkey. Özdemir and Ertaş (2011) investigated two dust events during 2009 and 2010 period in Ankara, capitol city of Turkey. They stated that 566 µg/m^3 and 452 µg/m^3 PM_{10} concentrations were recorded at air quality monitoring stations in Ankara.

Özdemir and Ertaş (2011) also mentioned that air quality is heavily influenced by dust transport events, consequently health and economical hazards occurs.

Dust from Saharan Desert is not the only trans-boundary source of PM_{10} in Turkey. For example, Kindap et al., (2006) investigated the long range transport of PM_{10} to İstanbul, Turkey. They found that at certain times a quarter of PM_{10} concentration in İstanbul came from Eastern European countries. Therefore, in order to make an assessment about particulate matter levels of Turkish cities, long range transport from either Europa or Saharan Desert should be kept in mind. One of the limitations of this study is taking the average of exceedances if more than one station exists in a city. If there exist a station with high PM_{10} concentrations and the other stations have lower measurements, the air quality of that city may seem to be good. For example, Edirne Keşan has the poorest air quality. Özşahin et al., (2016) mentioned that poor quality of fuels and topographical structure of this site are the main reasons of this. However, air quality of central area of Edirne is much better than Edirne Keşan. Therefore, taking the averages of these two stations results less number of exceedances.

CONCLUSIONS

Turkey, as an EU candidate country, is trying to harmonise environmental regulations with EU. To meet the air quality standardspollutants levels have being reducing. In this study, the

daily exceedances of PM_{10} concentrations in Turkish cities for the years of 2014, 2015 and 2016 were evaluated. The numbers of exceedances were calculated using Microsoft Excel and data were transferred to GIS software MapInfo. Thematic maps crated to visualise the current levels of PM_{10} pollution. We found that, there is an increasing trend in the number of cities that exceed PM_{10} threshold levelover years. Turkey has been changing primary fuel from coal to natural gas for domestic heating.

Natural gas is much better fuel as compared to coal in terms of particulate matter emissions. On the other hand, Turkish Ministry of Energy and Natural Resources still considers coal as a primary source for generating electricity. Therefore, coal based thermal power plants continues to emit particulate matter to the atmosphere. Moreover, long range transport also affects air qualityin Turkey. As a result, it would be difficult for Turkey to meet EU PM_{10} standards in 2019 unless certain precautions are applied.

In order to meet EU air quality standards PM_{10} emissions must be reduced. Using coal for domestic heating is one of the main sources of PM_{10}. Shifting from coal to natural gas is an important solution and should be done quickly. Heat isolation of buildings keep temperature inside the building and less amount of fuel is required for domestic heating. Furthermore, renewable energy resources should be considered as an alternative for coal based thermal power plants. Diesel motor vehicles exhaust is another source of particulate matter. To reduce PM from vehicles, sustainable transport solutions should be developed.

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