7TH ATMOSPHERIC SCIENCES SYMPOSIUM

28-30 APRIL 2015
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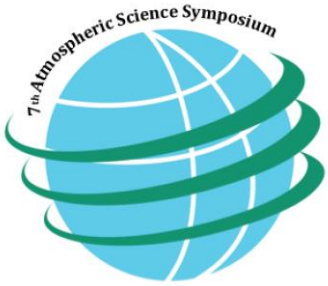

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Spatial Variation of PM10 in Turkey

Hakan Erdun[1], Ali Öztürk[2*], Özkan Çapraz[3] , Hüseyin Toros[4], Sükrü Dursun[5], Ali Deniz[3]

[1] Turkish Airlines Inc. Aviation Academy, Atatürk Airport Gate B, Yeşilköy, ISTANBUL, herdun@thy.com

[2] Istanbul Technical University, Chemical & Metallurgical Engineering Faculty, Department of Chemical Engineering, Maslak, Istanbul, Turkey, kmali@itu.edu.tr

[3] Marmara Clean Air Centre, Istanbul, Turkey, ozzqa@hotmail.com

[4] Istanbul Technical University, Faculty of Aeronautics and Astronautics, Department of Meteorology, Maslak, Istanbul, Turkey, toros@itu.edu.tr, denizali@itu.edu.tr

[5] Selcuk University, Engineering Faculty, Konya, Turkey, sdursun@selcuk.edu.tr

Abstract

Air pollution is a major environmental problem in the developing countries of the world with rapid growth of population, industrial activities, and traffic density. Turkey faces facing air pollution problems with all of them. This study describes analysis of particulate matter concentrations of the cities in Turkey. Hourly PM_{10} concentrations were used to calculate the seasonal and yearly spatial variation patterns of air pollutants in Turkey based on the data of 118 stations between the periods of 2008-2012. Spatial and seasonal variations of PM_{10} concentrations are fairly high over Turkey. In south eastern sites of Turkey, high concentration occurs in spring and summer, which could be attributed to long-range Saharan dust transportation and the transport of dust by southerly winds from the desert regions of Mesopotamia. A significant seasonal variation of PM_{10} concentrations observed in some cities in different regions is characterized by high concentrations in winter and low in summer due to the emissions added by domestic heating systems in winter months. There is a significant improvement from 1990 towards 2012 and PM_{10} value decreases by 74% in the provinces between the average of 2011 and 2012 and between the average of 2008 and 2009.

Keywords: Urbanization, Air quality, PM_{10}, Statistical analysis, Turkey

1. Introduction

Particulate matter is an important air quality indicator due to its physical and chemical properties depending on sources. Particulate matter with diameter less than 10μm (PM_{10}) is one of the primary air pollutants that adversely affect human respiration system. Larger particles could be seen as smoke or dust and settle out quickly human's upper respiration system, but the tiniest particles can be suspended in the air and remain for longer periods of time and travel long distances with atmospheric circulation. Therefore, the tiniest particles are the most harmful to human health, (U.S. E.P.A., 2004). Anthropogenic particular matter usually concentrated urban areas due to industrial process, motor vehicles, and heating. Particulate matter can be also transported from long distances. Industry and technology made human life lots easier but it's impacts on human health, well-being and the environment, has been widely attracted the attention of the world usually after 1970's (Pope et al., 1995; Donaldson et al., 2001; Aunan and Pan, 2004; Lu et al., 2006; Wang et al., 2007). Protecting air quality is a promoted policy among the governments in order to protect the atmosphere from pollutants. Air quality

standards are determined by many organization like EPA (Environmental Protection Agency), WHO (World Health Organization), the European Union Air Quality Framework and Daughter Directives, World Bank, etc.

Particulate matter is a primary air pollution problem in Turkey and several studies on PM_{10} pollution of certain settlement centres have been conducted so far (Onder and Dursun, 2005; Karaca et al., 2009; Im et al., 2010; Koçak et al., 2011; Köne and Büke, 2011; Unal et al., 2011, Toros et al., 2013). According to existing ambient air quality statistics in Turkey, urban air quality is quite poor in some cities where poor-quality fossil fuels is widely used for heating and in industrial activities and the annual concentrations of PM_{10} are below the national, WHO and EU (European Union) standards are exceeded in general (Özden et al., 2008). Like many other developing countries, Turkey, as a newly industrialized country, is severely affected by air pollution due to the increasing amount of heavy industries, prevalent usage of low-quality coal, high sulphur content local lignite, petroleum, wood and dried dung consumption in the households (Zaim, 1997). Air pollution caused by the exhaust gases from motor vehicles is also one of the most important pollution sources contributing to air pollution particularly in city centres in Turkey (Kanakidou et al., 2010; Koçak et al., 2011). Air quality considerably deteriorates in the central locations of the cities due to the large traffic volumes and congestion with the usage of old vehicle technology with no emission control equipment (Köne and Büke; 2011). Besides the local sources, the long-range transport of anthropogenic emissions from Europe (Kindap et al., 2006, Karaca and Camci, 2009) and natural emissions from North Africa and Middle East also severely affects the air quality of Turkey (Kubilay et al., 1999, Koçak et al., 2007, Koçak et al., 2009, Ercelebi and Toros, 2009).

The European Air Quality Directive set a 24 hour-limit value for PM_{10} of 50 $\mu g/m^3$ and the annual average should not exceed 40 $\mu g\ m^{-3}$ and a maximum number of exceedances of daily limit of 35 times per year (Council Directive 99/30/EC). EU member states have to report the occurrences of exceeding the limit values, and their possible reasons according to Council Directive (96/62/EC) on ambient air quality assessment and management. Turkey is an EU candidate country and adopted the Daughter Directive into the Air Quality regulation in June 2008. Currently having 112 air quality stations, air quality monitoring network is gradually expanded and estimated to reach 200 stations in 2014 in Turkey (IPA, 2010 and EU Directive, 2008).

The Ministry of Environment and Urbanization (MOEU) and the Ministry of Health (MOH) are responsible for decision-making related to protection of atmospheric pollution control in Turkey. Generally, the MOEU has been operating the national air quality monitoring network from the stations located throughout in all provinces in Turkey. However, some municipalities also conduct air quality measurements. The air quality control regulation is subjected to significant revisions by the MOEU to make it compatible with the EC directives (MOEU, 2013).

There are great requirements for better characterization of spatial, seasonal and long-term variations in PM10 in Turkey. The aim of this study has been to assess the air quality of Turkey and extract a general picture of PM10 distribution of the provinces in Turkey for the period of 2008-2012. For this purpose, available PM_{10} data of the all Turkish provinces has been obtained from National Air Quality Monitoring Network and evaluated accordingly.

2. Study Area, Data and Methodology

Turkey is located at the both of Europe and Asia, and covers an area of 814.578 km^2 as the second biggest country in Europe both in population and area cover and the 17^{th} largest country regarding to its population in the world. Turkey is subdivided into 81 provinces and into 7 geographic regions (figure 4). 77% of Turkey's

population live in urban areas. Turkey's geographic regions are shown in Figure 3. There are air quality monitoring stations in all provinces in Turkey and the number of stations is increasing rapidly. The spatial and temporal variabilities of particulate matter can be seriously effected by local sources, as well as meteorological and topographic conditions (Unal et all., 2011). Domestic sources and long range transportation are the factors which cause high particulate matter concentartion levels in Turkey.

PM_{10} concentrations continuously collected on the filter and hourly average recorded by the technique of automatic beta radiation attenuation according to EC Directive 2008/30/EC (EC Directive, 2008). In this study, the data during the years between 2008-2012 were studied statistical anayisis. Data of the 118 stations have been obtained from the Ministry of Environment and Urbanism database. The spatial distribution of the air quality stations is given in Figure 1. There is more than one air quality station in some cities that has been representing the arithmetic mean for these cities.

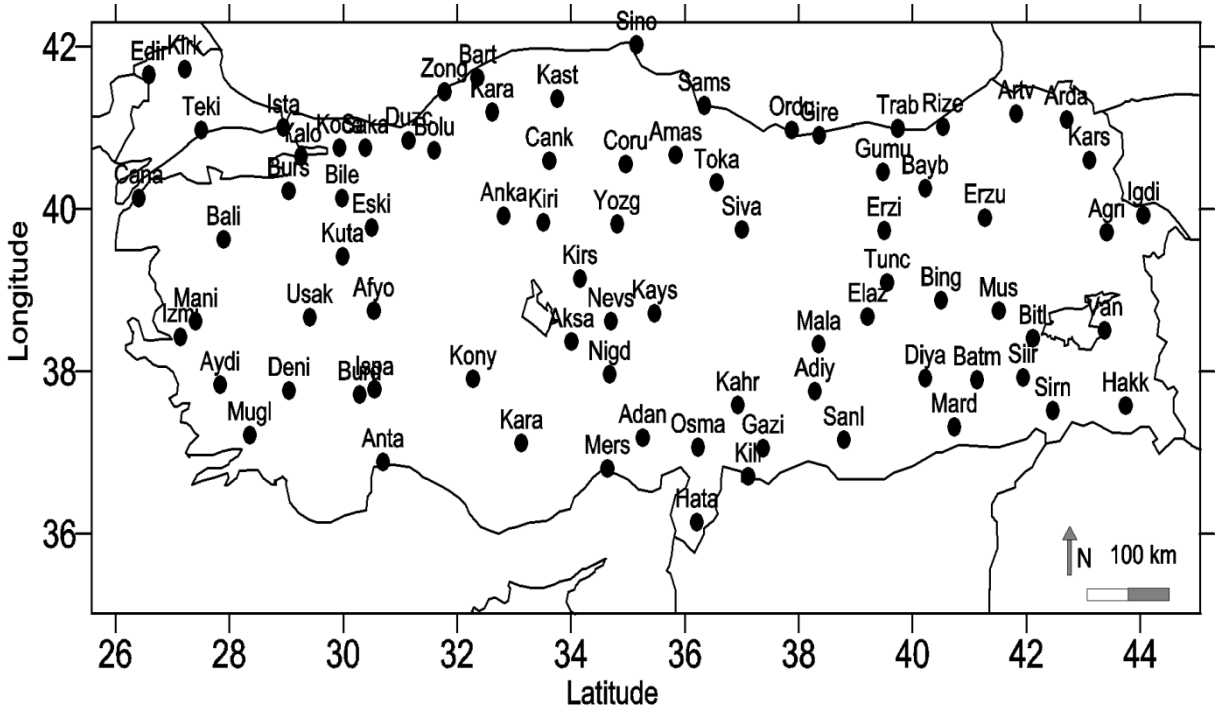

Figure 1. *Spatial distribution of the air quality data collected stations*

3. Results and Discussion

The data analysis is based on the 24-h averages of PM_{10} concentrations. In Turkey, PM_{10} concentrations show a seasonal dependence with high concentrations in winter and autumn and lower concentrations in summer and spring. Due to the emissions added by poor quality coal burning in winter season for domestic heating, and winter concentrations especially tend to be higher in some parts of Turkey. Besides, urbanization, industrialization and number of motor vehicles have increased rapidly in recent years, causing increased levels of air pollutants.

The population of cities in Turkey has increased during the last 50 years in Turkey (Figure 3a). Energy generation has also increased depending on increased needs (Figure 3b). Transportation and industrial activities are important and continue throughout the year generally in big cities. Pollution due to fuels for heating purposes continues for seven months, covering the months of October to April most of the cities in Turkey.

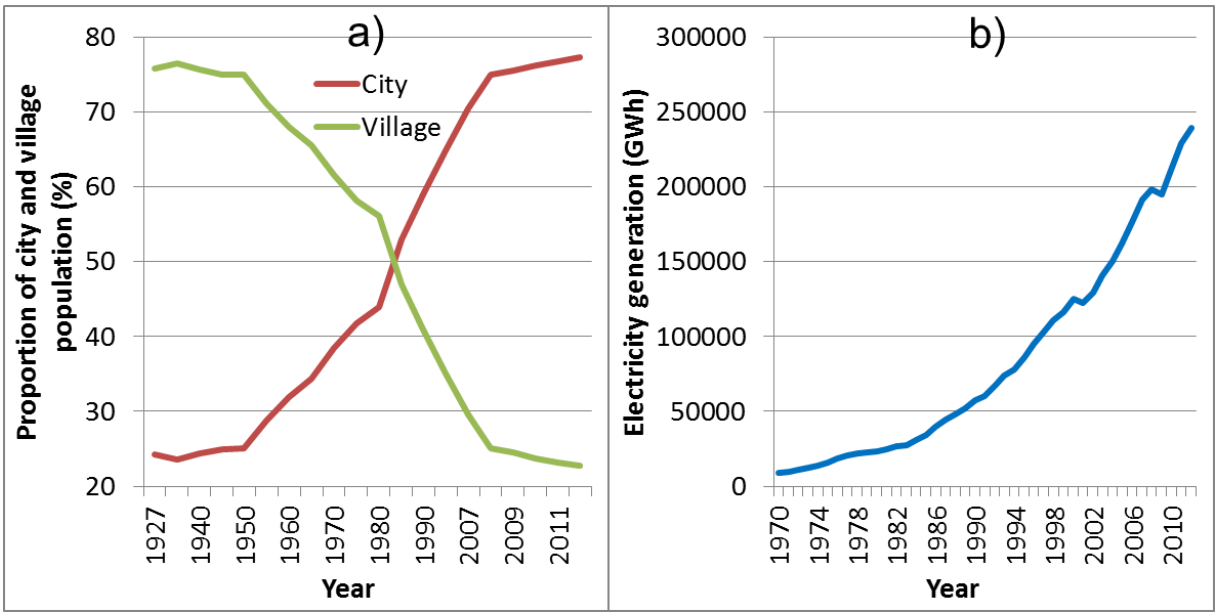

Figure 3. *The proportion of city and village population (a) and electricity generation (GWh) in Turkey*.

Expect Amasya and Çorum, the top ten provinces with the highest level of yearly PM_{10} levels are located in South-Eastern and Eastern Anatolia. According to the results of particulate matter measurements, the top ten most polluted cities are, Batman (120 µg/m^3), Iğdır (112 µg/m^3), Siirt (109 µg/m^3), Amasya (108 µg/m^3), Van (105 µg/m^3), Hakkari (104 µg/m^3), Osmaniye (104 µg/m^3), Çorum (93 µg/m^3), Gaziantep (92 µg/m^3), and Kahramanmaraş (92 µg/m^3), respectively. Even though the domestic heating is reduced with the higher temperatures, high PM_{10} concentrations continue to occur in South-eastern and Eastern Anatolian provinces like Batman, Siirt, Van, Hakkari and Osmaniye, in spring and summer. Since located close to Syro-Arabian desert, they are under the influence of natural particulate matter emissions transported from the desert. Dust clouds coming out of Syria covers Southeastern Anatolia Region on certain days of the year. These dust clouds usually coming from the south of the region influence the provinces for one or two days. On the other hand, local sand and dust storms appear to increase significantly during 2008-2012 in Turkey and dust storms are seen to extend into Central Anatolia Region as seen in Figure 4 (Dündar et al., 2013). The majority of observations of the sand and dust storms occurred in Southeastern Anatolia during 2008-2012 (Dündar et al., 2013). The distribution of the average sand and dust storm events during 2008-2012 is given in Figure 4. The number of dust events experienced in the spring season is more than the other seasons. Summer, winter and fall follow spring, respectively (Dündar et al., 2013).

Figure 4. *Distribution of the average sand and dust storm events during 2008-2012 (adapted from Dündar et al., 2013).*

Batman, the city with the highest annual concentrations of PM_{10}, is located at South-eastern Anatolia. The city is situated on a plain and surrounded by mountains. Batman has the largest oil field in Turkey and has a petroleum refinery which is contributing to air pollution problem in the city. Relying heavily on coal usage for heating, Batman suffers from poor air quality during winter season (October – March). Its geographical location and weak prevailing winds contribute to inversion conditions, which, in turn, lead to air pollutants accumulating and stagnating in the air (THEP, 2010). In addition to local sources, particulate matter (PM) concentration is significantly enhanced by further contributions of wind-blown dust from the Syro-Arabian desert.

The lowest annual average PM_{10} concentrations occurred in Giresun (21 $\mu g/m^3$), Adıyaman (29 $\mu g/m^3$), Artvin (33 $\mu g/m^3$), Çanakkale (35 $\mu g/m^3$) and Sinop (37 $\mu g/m^3$), respectively. Except Adıyaman, the other cities are having a coastline. ?? Bu şehirlerde rüzgar hızı Yüksek mi?

Annual averages of PM_{10} were 118, 103 and 77 $\mu g/m^3$ for İstanbul, Ankara and İzmir respectively in 1990 (Elbir et al., 2000). Air pollution level decreased during last two decades and the PM_{10} concentrations were 53, 78 and 47 $\mu g/m^3$ for this three biggest metropolitan cities of Turkey. There is a significant improvement of air quality from 1990 towards 2012. As seen Table 1 lasts column (Inc / dec) PM_{10} value is decrease 74% provinces between the average of 2012 and 2011 and between the average of 2009 and 2008. The most polluted city is Batman, 120 $\mu g/m^3$, and less polluted city is Giresun, 21 $\mu g/m^3$, in yearly average values. The averages of all provinces are 69, 90, 63, 54, 70, 91, 50, 28, 138 and 76 in yearly, winter, spring, summer, autumn, 2008, 2009, 2010, 2011 and 2012, sequentially.

Table 1. *Annual and seasonal of PM_{10} values in Turkey (city names, abbreviation name of cities, population, longitude, latitude, altitude, NS= number of station in the cities, DAD=daily available data, 95%, 75%, average, 75% and 5% values). (Ave: Average,Min: Minimum, Max: Maximum; Inc / dec: average(2012;2011)-average(2009;2008))*

No	Provinces	Population	Longitude	Latitude	Altitude	NS	DAD	Annual					Winter					Spring					Summer					Aut		
								95%	75%	Average	25%	5%	95%	75%	Average	25%	5%	95%	75%	Average	25%	5%	95%	75%	Average	25%	5%	95%	75%	
1	Adana (Adan)	2085225	35,26	37,19	98	4	1661	101	62	54	37	21	102	62	52	32	19	107	57	52	34	21	91	62	57	46	37	102	68	55
2	Adiyaman (Adiy)	590935	38,28	37,76	669	1	1158	78	35	29	14	4	86	36	33	14	8	62	27	24	13	5	53	40	31	18	14	78	41	29
3	Afyon (Afyo)	697559	30,54	38,75	1025	1	1451	112	71	64	48	32	118	79	68	50	28	116	66	62	42	29	85	67	63	53	45	118	79	65
4	Agri (Agri)	542022	43,41	39,72	1632	1	1213	148	92	77	52	31	153	97	80	48	29	118	79	68	45	29	181	95	85	59	49	136	92	77
5	Aksaray (Aksa)	377505	34,01	38,37	941	1	1603	212	105	85	44	28	244	166	121	67	41	180	79	70	38	26	115	65	59	39	30	204	111	87
6	Amasya (Amas)	334786	35,84	40,67	373	1	1404	260	135	108	59	33	348	202	160	92	58	195	120	90	55	8	96	67	59	48	32	247	154	11
7	Ankara (Anka)	4771716	32,82	39,92	963	7	1220	155	87	68	37	24	170	97	74	40	21	114	63	53	34	22	128	69	59	35	28	180	121	89
8	Antalya (Anta)	1978333	30,70	36,89	40	1	1638	138	73	63	39	24	181	118	86	45	26	96	61	51	33	21	79	61	52	42	29	126	72	60
9	Ardahan (Arda)	105454	42,70	41,11	1810	1	1484	198	89	72	33	18	251	154	116	60	28	130	73	58	33	17	80	50	42	25	16	149	77	61
10	Artvin (Artv)	164759	41,82	41,18	628	1	1404	64	40	33	21	12	63	42	35	22	12	64	40	31	18	11	56	37	31	22	16	73	40	34
11	Aydin (Aydi)	989862	27,84	37,84	57	1	1603	166	87	75	49	33	211	135	110	73	47	107	71	61	45	29	80	67	56	46	31	141	85	71
12	Balikesir (Bali)	1152323	27,90	39,63	139	1	1514	198	85	73	40	25	271	156	108	42	22	138	89	73	48	35	75	58	49	39	27	187	83	68
13	Bartin (Bart)	187758	32,36	41,62	32	1	1192	138	86	66	39	26	176	129	100	64	43	108	78	64	47	32	55	45	37	30	22	124	85	65
14	Batman (Batm)	510200	41,13	37,90	530	1	1353	258	150	120	71	40	276	174	131	72	42	241	112	96	57	33	187	129	108	79	51	277	180	14
15	Bayburt (Bayb)	74412	40,22	40,26	1568	1	1572	131	73	57	30	10	155	95	70	40	13	107	61	50	29	11	73	45	36	20	7	144	87	70
16	Bilecik (Bile)	225381	29,98	40,14	539	1	1651	93	62	51	36	22	102	73	58	39	25	90	60	50	35	22	71	52	43	32	21	93	65	53
17	Bingol (Bing)	255170	40,50	38,88	1140	1	1399	121	56	46	22	12	131	67	54	28	16	161	51	49	19	10	106	52	42	20	12	88	50	39
18	Bitlis (Bitl)	328767	42,11	38,41	1579	1	1239	177	98	80	45	16	155	102	89	65	42	224	89	75	32	11	237	106	87	43	16	136	90	70
19	Bolu (Bolu)	271208	31,60	40,73	740	1	1546	248	102	85	41	8	334	196	136	59	36	209	111	86	48	27	79	60	45	34	9	229	90	70
20	Burdur (Burd)	258868	30,29	37,72	965	1	1575	185	99	81	49	32	241	150	110	59	33	138	81	67	45	30	95	70	59	45	32	169	108	86
21	Bursa (Burs)	2605495	29,04	40,23	96	1	895	149	89	71	42	24	176	119	85	42	21	136	80	67	44	29	100	74	61	49	31	157	89	69
22	Canakkale (Cana)	490397	26,41	40,14	9	2	1550	85	46	35	16	7	113	62	46	20	11	79	47	36	18	11	55	41	27	12	3	68	36	27
23	Cankiri (Cank)	179067	33,62	40,60	721	1	1539	147	89	68	36	20	186	121	96	62	36	128	73	57	30	19	84	58	45	28	17	136	99	73
24	Corum (Coru)	535405	34,96	40,56	818	1	1589	220	113	93	53	33	276	167	125	67	36	176	95	82	50	32	105	75	63	46	35	270	132	10
25	Denizli (Deni)	931823	29,05	37,77	402	2	1740	195	103	87	53	31	283	165	127	68	34	138	88	75	50	31	98	78	64	51	32	169	98	82
26	Diyarbakir (Diya)	1528958	40,22	37,92	670	1	1147	165	98	82	51	34	175	116	93	59	41	184	82	74	42	29	126	84	71	49	33	152	104	86
27	Duzce (Duzc)	338188	31,15	40,85	137	1	1617	256	102	89	45	28	340	201	139	57	25	157	97	75	45	29	71	59	51	43	30	257	115	95
28	Edirne (Edir)	390428	26,59	41,66	108	1	1562	144	87	71	44	30	168	113	89	57	35	102	76	63	47	33	80	60	51	39	28	168	102	78
29	Elazig (Elaz)	552646	39,21	38,68	1071	1	1538	159	83	67	34	21	181	106	85	45	24	156	76	64	34	22	99	58	50	28	18	148	86	66
30	Erzincan (Erzi)	224949	39,50	39,74	1193	1	1614	164	76	62	29	15	195	108	82	38	18	130	56	51	25	13	82	52	42	24	14	165	101	72
31	Erzurum (Erzu)	769085	41,27	39,90	1950	1	1646	171	78	66	34	19	266	129	99	46	21	157	76	61	29	18	104	61	51	32	19	107	68	55
32	Eskisehir (Eski)	764584	30,50	39,78	800	1	1506	82	50	40	25	14	84	50	38	21	10	79	48	40	25	15	62	46	38	29	15	100	56	45
33	Gaziantep (Gazi)	1700763	37,37	37,06	854	1	1593	202	120	92	49	23	243	170	136	89	53	163	95	77	43	22	93	66	55	40	21	203	135	10
34	Giresun (Gire)	419256	38,36	40,91	1	1	1438	44	27	21	10	5	49	29	22	12	5	54	30	25	16	6	34	26	18	10	5	39	22	16
35	Gumushane (Gumu)	129618	39,48	40,46	1180	1	1646	123	74	57	33	21	145	91	70	41	25	115	70	55	30	20	75	49	42	30	21	128	84	61
36	Hakkari (Hakk)	251302	43,74	37,58	1724	1	853	235	123	104	56	29	398	139	122	60	37	231	137	100	48	26	171	109	92	60	44	145	113	85
37	Hatay (Hata)	1480571	36,21	36,15	104	2	1687	175	82	71	39	27	218	137	102	58	27	118	61	56	34	24	80	63	52	38	28	161	91	72
39	İgdir (İgdi)	184418	44,05	39,93	865	1	1495	342	132	112	45	25	474	303	210	101	50	164	82	69	36	22	111	76	60	39	24	302	142	11
40	İsparta (İspa)	448298	30,55	37,78	1022	1	1650	278	104	88	34	16	400	201	151	59	32	162	77	63	33	17	80	54	42	25	16	263	114	91
41	İstanbul (İsta)	13255690	28,95	41,01	40	10	1815	103	64	52	34	23	116	76	59	35	23	98	67	55	38	28	74	54	45	35	25	104	60	50
42	İzmir (İzmi)	3948848	27,14	38,43	11	8	1805	101	59	51	36	25	128	82	63	39	25	85	58	49	35	24	70	51	44	36	28	100	58	50
43	Kahramanmaras (Kahr)	1044816	36,93	37,59	560	2	1788	208	116	92	53	32	259	167	127	69	38	175	87	77	42	26	141	79	69	48	32	174	127	97
44	Karabuk (Kara)	227610	32,62	41,20	182	1	1625	201	106	84	44	25	286	165	123	62	33	157	96	75	40	22	86	67	53	38	24	170	109	81
45	Karaman (Kara)	232633	33,13	37,12	1021	1	1376	196	114	90	50	27	224	138	98	43	25	158	89	73	45	26	143	107	91	63	39	207	136	10
46	Kars (Kars)	301766	43,10	40,61	1758	1	1383	154	81	65	34	19	213	112	94	58	38	167	79	66	35	19	83	50	41	26	17	120	69	55
47	Kastamonu (Kast)	361222	33,76	41,37	796	1	1548	105	56	44	24	15	151	88	65	33	19	86	50	40	22	14	75	48	37	21	16	76	45	37

48	Kayseri (Kays)	1234651	35,47	38,72	1052	3	1812	171	88	70	37	24	229	132	100	56	31	116	63	53	32	23	86	56	46	30	22	185	109	84
49	Kilis (Kili)	123135	37,11	36,71	645	1	1719	171	83	74	45	27	190	91	79	41	24	168	75	69	41	29	126	77	71	54	42	180	94	76
50	Kirikkale (Kiri)	276647	33,51	39,84	750	1	1316	158	88	71	43	24	173	108	85	50	28	128	73	59	37	18	86	64	51	39	7	195	111	88
51	Kirklareli (Kirk)	332791	27,22	41,73	200	1	1429	101	56	49	33	20	140	79	62	36	20	81	52	45	33	22	60	44	39	32	23	113	61	51
52	Kirsehir (Kirs)	221876	34,16	39,15	974	1	1435	111	68	54	34	18	136	83	63	34	14	92	61	52	34	20	94	60	51	37	25	105	69	51
53	Kocaeli (Koca)	1560138	29,94	40,76	6	3	1797	154	85	70	43	29	174	119	86	47	29	150	91	74	48	34	88	63	54	42	30	138	78	63
54	Konya (Kony)	2013845	32,28	37,91	1032	2	1728	195	89	75	38	23	293	155	117	51	26	132	71	57	34	19	91	58	49	34	23	172	89	73
55	Kutahya (Kuta)	590496	29,99	39,42	962	1	1650	226	106	88	50	31	289	145	109	48	28	187	110	90	56	34	94	72	61	49	35	226	118	92
56	Malatya (Mala)	740643	38,35	38,34	981	1	1565	148	83	63	35	6	162	100	68	13	6	125	68	54	30	6	93	60	51	37	13	155	108	77
57	Manisa (Mani)	1379484	27,41	38,62	61	1	1318	196	93	81	49	34	249	147	109	53	34	110	75	65	45	33	90	70	61	50	40	181	100	82
58	Mardin (Mard)	744606	40,73	37,32	1083	1	1395	200	103	81	40	14	189	106	82	44	16	243	95	82	34	25	174	97	79	44	14	177	111	81
38	Mersin (Mers)	1647899	34,64	36,81	10	1	1611	145	77	68	46	29	179	107	83	51	30	139	75	68	42	27	94	65	60	48	38	114	75	61
59	Mugla (Mugl)	817503	28,36	37,22	640	2	1759	128	80	67	46	28	148	102	80	51	33	115	75	63	42	27	89	70	60	48	37	126	79	64
60	Mus (Mus)	406886	41,51	38,75	1312	1	1245	204	112	83	35	14	270	129	103	46	23	164	82	64	27	10	172	107	79	36	16	171	127	86
61	Nevsehir (Nevs)	282337	34,70	38,62	1259	1	1504	128	69	58	34	20	172	88	67	32	12	103	60	51	32	22	89	55	50	35	23	124	82	64
62	Nigde (Nigd)	337931	34,68	37,97	1211	1	1669	136	78	61	35	12	131	73	60	34	22	110	70	56	34	23	110	73	56	38	9	167	106	76
63	Ordu (Ordu)	719183	37,88	40,98	3	1	1383	114	69	58	38	24	150	101	82	56	35	96	66	57	43	32	57	46	40	30	20	91	62	52
64	Osmaniye (Osma)	479221	36,23	37,07	120	1	1359	226	126	104	64	42	260	175	140	94	49	180	106	91	58	41	143	94	83	62	47	226	126	10
65	Rize (Rize)	319637	40,53	41,02	5	1	1395	102	47	39	20	13	127	72	51	25	15	108	56	43	22	14	42	29	24	17	12	85	43	38
66	Sakarya (Saka)	872872	30,39	40,76	23	1	1517	168	84	69	39	18	199	109	80	38	14	138	87	70	45	19	78	61	48	30	20	194	95	77
67	Samsun (Sams)	1252693	36,34	41,28	54	2	1758	79	54	46	34	25	86	60	50	35	25	92	59	50	34	25	58	48	41	33	24	75	54	45
68	Sanliurfa (Sanl)	1663371	38,79	37,16	549	1	1382	177	94	79	45	30	235	126	107	67	42	187	72	67	35	24	116	71	62	40	30	152	90	77
69	Siirt (Siir)	300695	41,94	37,93	894	1	1208	218	130	109	69	44	243	170	129	82	53	239	123	102	56	37	170	110	103	79	57	169	120	10
70	Sinop (Sino)	202740	35,15	42,03	22	1	1088	74	45	37	24	16	82	58	45	30	19	67	43	36	25	16	46	33	28	19	15	66	43	34
71	Sirnak (Sirn)	430109	42,46	37,52	1391	1	1141	182	84	68	31	17	129	87	68	36	23	248	82	72	26	13	185	95	74	36	21	129	63	55
72	Sivas (Siva)	642224	37,00	39,75	1285	1	1504	155	78	64	35	23	193	118	90	50	30	131	66	57	33	23	81	49	42	28	20	140	84	65
73	Tekirdag (Teki)	798109	27,51	40,98	41	1	1133	148	92	75	50	34	163	111	89	62	44	149	91	77	51	36	86	61	54	41	30	142	89	70
74	Tokat (Toka)	617802	36,56	40,33	601	1	1541	122	58	46	21	11	161	88	68	35	14	106	47	40	20	11	48	34	27	18	12	113	67	47
75	Trabzon (Trab)	763714	39,74	41,00	50	2	1754	151	76	63	36	19	197	122	94	56	39	105	63	54	38	23	136	52	51	30	20	113	68	51
76	Tunceli (Tunc)	76699	39,55	39,10	980	1	1015	93	56	45	28	12	79	52	45	32	21	85	46	37	19	8	105	65	51	32	14	98	65	50
77	Usak (Usak)	338019	29,41	38,67	917	1	1691	135	90	72	49	34	156	118	94	63	37	117	86	69	47	34	81	64	55	46	33	112	86	68
78	Van (Van)	1035418	43,37	38,51	1688	1	1547	220	138	105	59	26	222	149	108	53	27	226	132	100	49	20	229	137	111	69	23	189	135	10
79	Yalova (Yalo)	476096	29,26	40,65	5	1	1605	84	52	42	26	13	92	58	45	26	15	93	60	49	33	20	65	44	35	23	12	84	50	39
80	Yozgat (Yozg)	203741	34,81	39,82	1288	1	1598	117	75	60	39	24	121	86	62	34	21	128	74	62	39	25	87	60	52	40	30	121	80	64
81	Zonguldak (Zong)	619703	31,78	41,45	10	1	1536	160	102	79	48	33	197	148	113	76	51	142	106	86	64	37	76	56	48	39	28	133	88	72
	Average							**159**	**85**	**69**	**40**	**23**	**194**	**117**	**90**	**49**	**28**	**137**	**75**	**63**	**37**	**23**	**98**	**65**	**54**	**38**	**25**	**149**	**89**	**70**

The distribution of annual PM_{10} values for all provinces is shown in Figure 3, Southeastern Region of Turkey is more polluted and middle region of Black Sea is the less polluted.

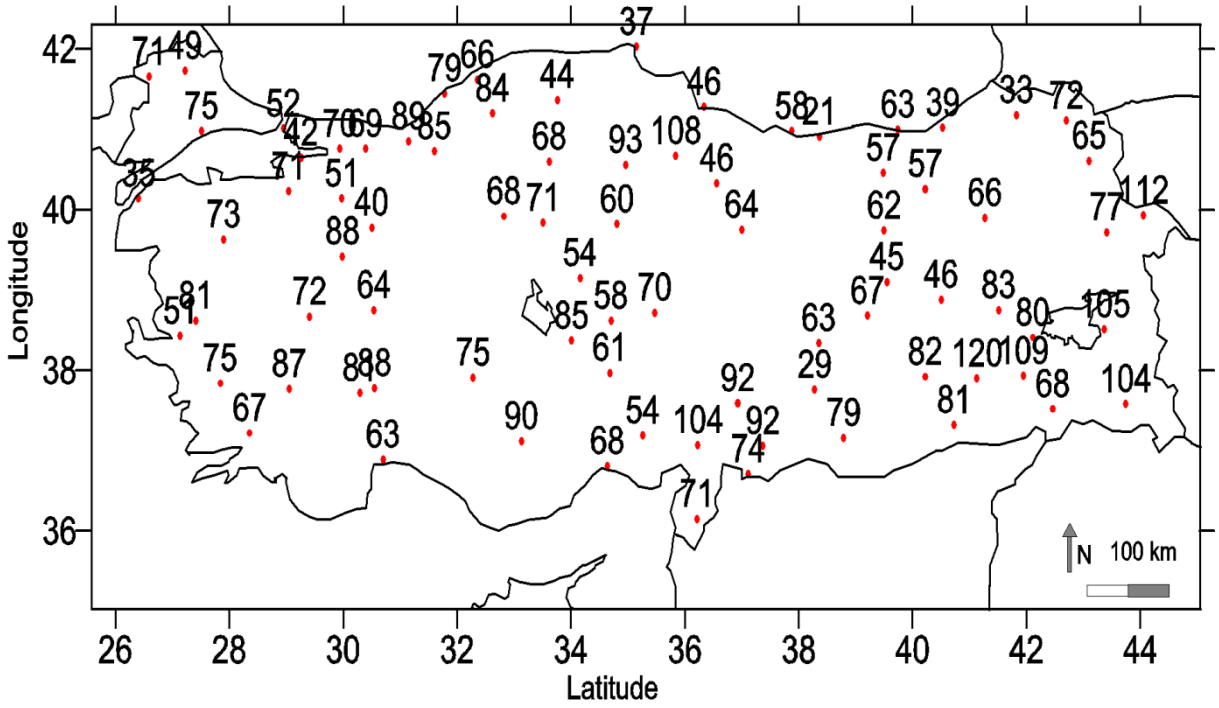

Figure 5. *Spatial distribution of the PM10 in yearly average*

As seen Figure 4, southeastern region of Turkey more polluted and middle Black sea region is cleanest in winter season.

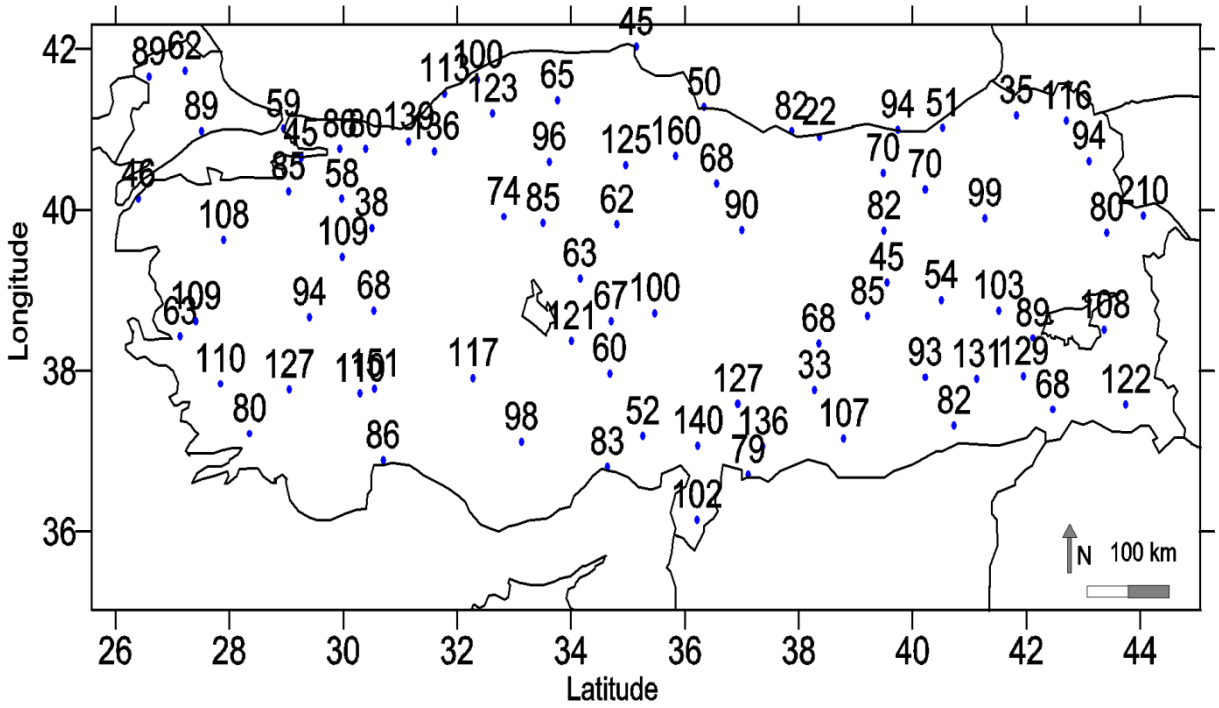

Figure 6*. Spatial distribution of the PM10 in winter average.*

As seen in Figure 7 and Figure 8, southeastern region of Turkey is more polluted by PM_{10} and middle Black sea region is the cleanest region in spring and summer seasons. Highest PM_{10} concentrations in spring and summer occur in southeastern provinces of Turkey, which is attributed to the local dust storms, dust transportation from desert regions of Mesopotamia and the transportation of Saharan dust. According to number of seasonal cyclones and cyclone trajectories, Sahara is the source region of particulate matter pollution for Turkey in spring (Kindap et al., 2010). In addition to these factors, Southeastern Region of Turkey is surrounded by Southeastern Toros Mountains located in the north of the region. This topographic structure of the region may be involved in the deposition of high concentrations of dust.

Siirt (102 µg/m^3), Hakkari (100 µg/m^3), Van (100 µg/m^3), Batman (96 µg/m^3) and Osmaniye (91 µg/m^3) are the top five most polluted cities in spring in Turkey, respectively. They are located in Eastern and South-Eastern Anatolia. Similarly, Van (111 µg/m^3), Batman (108 µg/m^3), Siirt (103 µg/m^3), Hakkari (92 µg/m^3) and Karaman (91 µg/m^3) are the cities having the highest concentration of particulate matter in summer in Turkey, respectively. Besides Karaman, these provinces are located in Eastern and South-Eastern Anatolia.

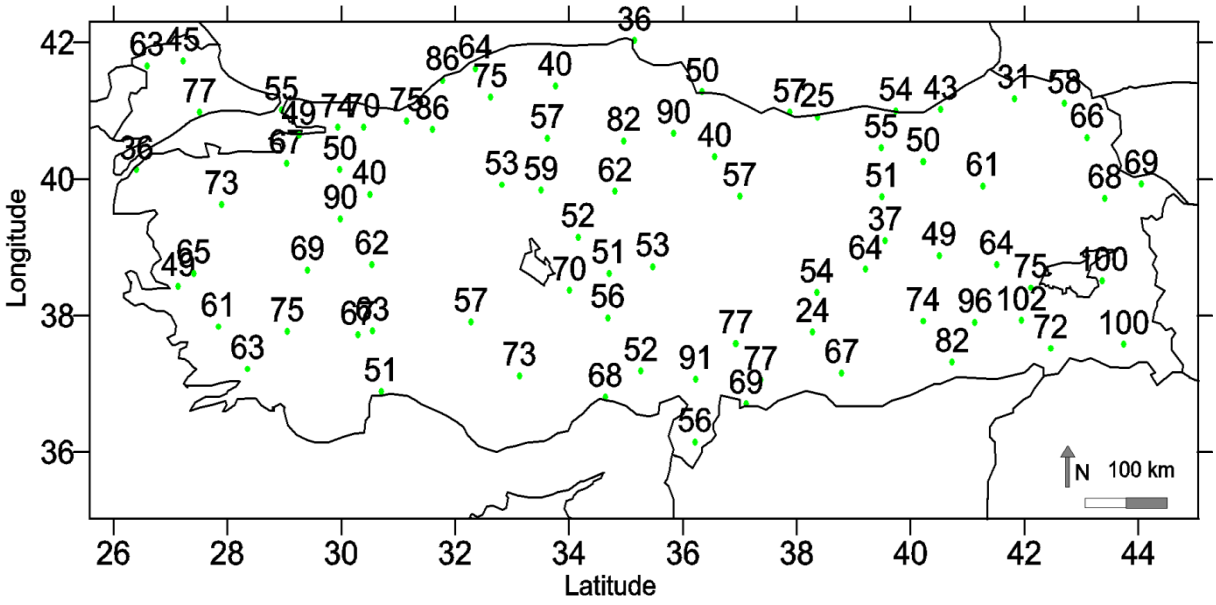

Figure 7. Spatial distribution of the PM10 in spring average.

Adıyaman (24 µg/m^3), Giresun (25 µg/m^3), Artvin (31 µg/m^3), Sinop (36 µg/m^3) and Çanakkale (36 µg/m^3) are the cities having the lowest concentration of particulate matter in spring in Turkey, respectively. Except Adıyaman which is located in South-Eastern Anatolia, all the provinces are having a coastline. Giresun, Artvin and Sinop are located in the Black Sea Region of Turkey which receives the greatest amount of precipitation and is the only region of Turkey that receives high precipitation throughout the year.

Similar to spring, the lowest particulate matter concentrations occur in Giresun (18 µg/m^3), Rize (24 µg/m^3), Tokat (27 µg/m^3), Çanakkale (27 µg/m^3) and Sinop (28 µg/m^3) in summer. Except Çanakkale, all the provinces are located in the Black Sea Region of Turkey.

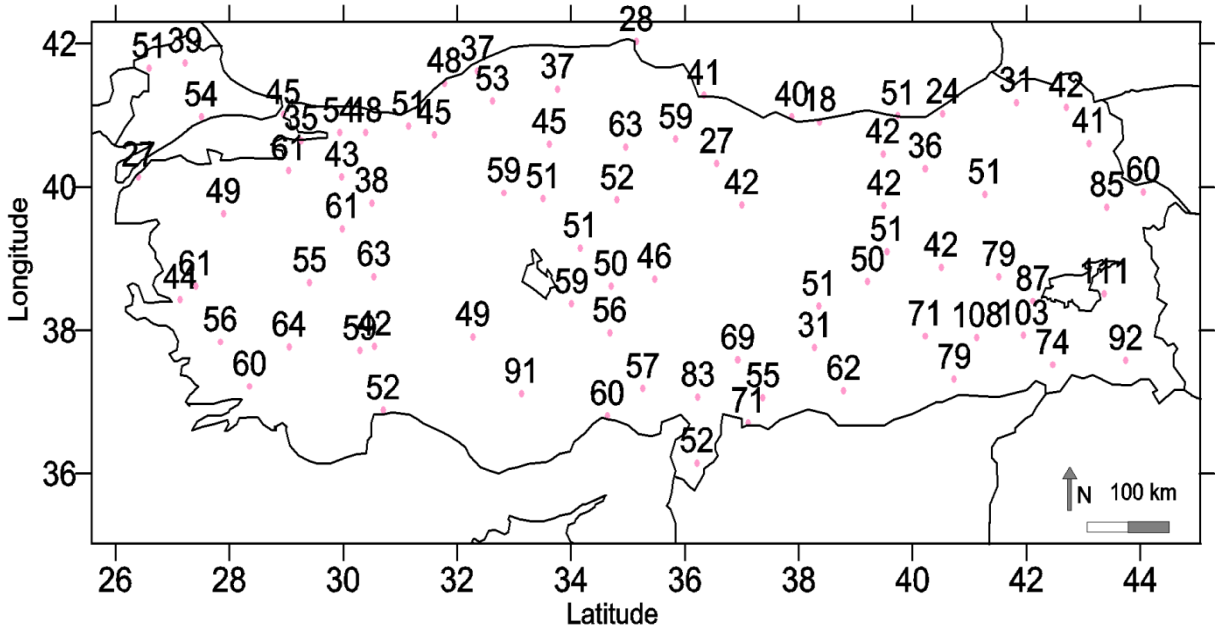

Figure 8. Spatial distribution of the PM10 in summer average.

As seen Figure 9, southeastern region of Turkey more polluted and middle Black sea region is cleanest autumn.

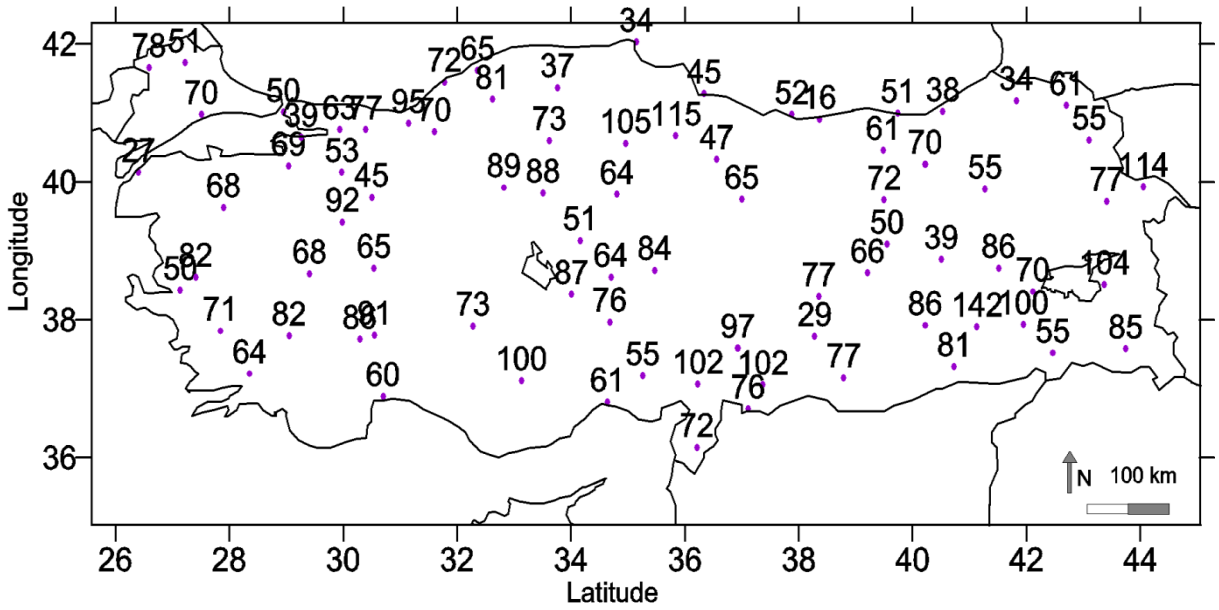

Figure 9. *Spatial distribution of the PM10 in autumn average.*

4. Conclusion

Air quality level is a key parameter in providing sustainable circumstances for future of cities.

As the centres of Europe and Asia, economic growth, industrialization, urbanization, social dynamics, historical, touristic and cultural land areas, Turkey has a growing population in a sustainable way. To know quality of air is important for the well-planned, densely populated areas. To accomplish sustainable and healthy development in urban areas, the following must include:

- More studies must be done to reduce emission from vehicle like engine improvement and energy efficiency systems in engine.

- Increasing transportation network and subway systems.
- Public transportation should be encouraged.
- During trip more than one in a vehicle should be encouraged.
- Insulation in buildings should be made.
- Using less and saving energy systems should be encouraged.
- Greater utilization of renewable energy resources should.
- To protect the atmosphere control measures for pollutants emissions are required.
- Meteorological conditions should get to benefit from the positive direction in new cities embodiments.

To decrease air pollution in all over the cities government started to precaution by education, TV spot, household heating system is converted to natural gas. To know air quality of cities to study variation is enough, it is also need more study on physical and chemical type of air pollution. The result will be help to improve standard and air pollution emergency measurement.

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