International Journal of Environmental Science and Technology (2022) 19:797–806
https://doi.org/10.1007/s13762-020-02914-7

ORIGINAL PAPER

High PM_{10} source regions and their influence on respiratory diseases in Canakkale, Turkey

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Received: 29 February 2020 / Revised: 7 August 2020 / Accepted: 31 August 2020 / Published online: 3 November 2020

Abstract
This study investigates the impacts of high PM_{10} concentrations on respiratory diseases in Canakkale, Turkey. Daily mean high-PM_{10} values (> 100 µg m^{-3}) and daily total numbers of chronic obstructive pulmonary disease (COPD) and pneumonia patients are selected for different sexes and age groups (children, adults, and elderly) during the period 2007–2017. Mainly five different source regions of high-PM_{10} concentration levels are found as a result of implementation of Ward's minimum clustering technique to HYSPLIT 72-h backward trajectory. From 104 days, 19.2% are categorized as internal sources and are positively linked to COPD in female—adult and elderly patients at lag2 and lag3. The other sources are exhibited as external sources and originated from Europe, Sahara, Mediterranean, and Russia regions with the 34.6%, 22.1%, 13.5%, and 10.6% percentages of all episodes, respectively. During Europe-originated high-PM_{10} days, anthropogenic pollutants mainly cause an increase in the numbers of the elderly female ($r = 0.55$) and adult male pneumonia patients ($r = 0.39$) at lag5. Additionally, accompanied by the interaction between Genoa cyclone and surface high over Caspian Sea, natural dust particles are transferred from Sahara to Canakkale by strong southwesterly winds. As a consequence, obvious increases are shown in hospital admissions based on adult female COPD patients at lag1 ($r = 0.50$) and lag4 ($r = 0.53$). While Mediterranean origin particulate matter triggering the numbers of COPD and pneumonia-related diseases at lag2 and lag3, the region is exposed to more pneumonia diseases 2 days after arriving of Russia origin harmful pollutants.

Keywords Respiratory diseases · PM_{10} · Cluster analysis · Synoptic conditions · Turkey

Introduction

Particulate matter (PM) is a solid or liquid substance that can be suspended in air for a long time. It can originate from anthropogenic (e.g., industrial processes, transportation, heating, construction, agriculture) or natural resources (e.g., sea salt and desert dust transport). PM is known as one of the most serious pollutants that adversely influence human health (e.g., Ghasemi et al. 2020). Studies showed that an obvious increment in PM triggers the risk of cardiovascular (Dastoorpoor et al. 2019; Momtazan et al. 2019), respiratory, and lung cancer diseases. For example, life expectancy of European Region reduces by approximately 1-year on average due to excessive PM values (WHO 2019). Owing to easily inhalation and accumulation in human body, PM_{10} adversely affect the respiratory systems (Analitis et al. 2006; Glorennec and Monroux 2007; Colais et al. 2009; Zanobetti and Schwartz 2009; Nastos et al. 2010; Parker et al. 2011; Canova et al. 2012; Carugno et al. 2018; Daryanoosh et al. 2018; Goudarzi et al. 2018; Idani et al. 2018; Effatpanah et al. 2020). From the studies, Medina-Ramón et al. (2006) examined the relationship between PM_{10} and respiratory diseases for the 36 U.S. cities. They found that 10 µg m^{-3} increase in PM_{10} values during warm season cause 1.47% (95% CI 0.93, 2.01) increase in COPD-related hospital admissions at lag1 and 0.84% (95% CI 0.50, 1.19) increase in pneumonia at lag0. Schindler et al. (2009) studied respiratory symptoms of adult individuals who exposed to PM_{10}

Editorial responsibility: Mohamed F. Yassin.

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in Switzerland. During the 11-year monitoring period, it was observed that decreasing in the PM_{10} amounts cause an improvement in respiratory symptoms of adult individuals. Mészáros et al. (2015) found for Australia that 10 µg m^{-3} increase in PM_{10} resulted in an increase of 4% in acute bronchitis/bronchiolitis admissions. In later studies, the negative impacts of PM_{10} concentration levels on different age and sex groups were also investigated in detail (e.g., Atkinson et al. 2001; Siddique et al. 2011; Hoek et al. 2012; Vandini et al. 2013; Vodonos et al. 2014; Jo et al. 2017). Both the protection of health-related diseases and increase in the air quality standards, standard limit values for PM_{10} were defined by the European Union (EU) and WHO (50 µg m^{-3} at 24-h average).

In terms of Turkey, PM_{10} concentrations are well above the EU and WHO standard limit values. Additionally, average PM_{10} values have increased by 8.4% in the last 15 years in the country (UCTEA Chamber of Environmental Engineers 2018). Despite its harmful effect on human health, limited studies investigating the role of PM_{10} on patients were done up till now. Latest European Environment Agency (EEA) report (2014) showed that 97.2% of the urban population in Turkey are estimated to be exposed to unhealthy levels of PM_{10}. Hapcioglu et al. (2006), by using 1586 patient records, found positive correlation between COPD in emergency department of Istanbul University Hospital and PM_{10} values for the period 1997–2001. Tecer et al. (2008) showed significant negative impacts of PM_{10} on asthma and allergic rhinitis in children (< 15-years) over Zonguldak city. Saygin et al. (2017) found strong correlation ($r = 0.59$, $p < 0.01$) between PM_{10} exposure and COPD and they found weak correlation ($r = 0.25$, $p > 0.05$) between PM_{10} and asthma in Isparta. Unlike previous studies, it was not investigated the role of high-PM_{10} values (> 100 µg m^{-3} on 24-h average), which were originated from different sources, on respiratory diseases in any parts of Turkey. To overcome this deficit, the goal of the current study is to improve our understanding the influences of high-PM_{10} concentrations originated from different sources on COPD and pneumonia diseases in Canakkale province of Turkey (Fig. 1).

In "Materials and methods" section, a description of the hospital, air quality and meteorological data and the methods used, are described. Results of the background atmospheric sources of high-PM_{10} values and their impacts on respiratory diseases are presented in "Results and discussion" section. The last part, fourth section, is devoted to the "Conclusion".

Materials and methods

Hospital, air quality, and meteorological data in Canakkale

Air pollution studies in Turkey often carried out in regions where intensive industrial activities take place. These studies carried out in industrial zones and residential areas where the pollutant sources are diverse and pollutant loads are high. They contribute to the determination of the current situation and help to produce solutions for improvement. However, in addition to local sources, due to long-distance atmospheric transport, it has been determined that the pollutants, which exhibit persistent properties or can be transformed into other species in the atmosphere, can be easily transported to the areas of hundreds kilometers away from their source and affect the receptors. Therefore, implementation of air quality management in rural areas is one of the most suitable methods for determining the effect of long-distance atmospheric transport, because in these areas industrial sector is not dense and there is no irregular urbanization. For this reason, Canakkale province (population 540,000), which is located in transition zone between Aegean- and Marmara-Regions and has the highest rural population ratio in Turkey. In our study, daily respiratory hospital admission numbers were obtained from the T.C. Mehmet Akif Ersoy Canakkale State

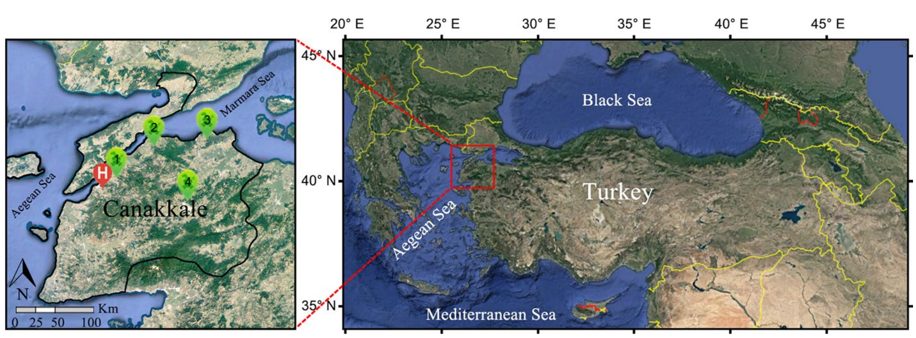

Fig. 1 The distribution of PM_{10} observations at 4 air quality stations (black numbers with green circles) in Canakkale. Numbers 1, 2, 3, and 4 mark the locations of Canakkale, Lapseki, Biga, and Can air quality stations, respectively. PM_{10} data of Canakkale (No: 1) are used in the study. H term represents the locations of Mehmet akif Ersoy Hospital in city center. The outset shows the location of Canakkale in Turkey

Hospital database for the period 2007–2017 (4018 days). Data were collected according to the International Classification of Diseases-Tenth Revision (ICD-10), which is a diagnostic-based grouping developed by the World Health Organization (WHO). Daily respiratory hospital admission numbers (ICD-10: J12-18 for pneumonia and ICD-10: J44 for COPD) were derived from the hospital database for each patient's age and gender. When patients are separated into their age groups, totally 21 children (0–14 years), 30,356 adult (15–64 years), and 73,519 elderly (≥ 65 years) people are influenced by COPD. Additionally, 3638 children, 10,364 adult, and 8503 elderly people negatively affected from pneumonia disease in the region. When compared to women, men are more exposed to these two diseases in the region (Table 1).

There are four Air Quality Monitoring Stations in Canakkale: Biga-Marmara Clean Air Center (MTHM), Can-MTHM, Lapseki-MTHM and Canakkale Center. We have chosen hourly PM_{10} values of Canakkale air quality station (Number 1 in Fig. 1) due to its closeness to Hospital. Firstly, hourly PM_{10} values were converted to daily averages and the period was chosen same as hospital data. Similar to the study published by Lee et al. (2011), we defined high-PM_{10} episode as above 100 µg m^{-3} at 24-h average. This value is 2 times higher than daily averaged concentration limit of PM_{10} (50 µg m^{-3}) set by the European Union's Air Quality Standard (EU AQS). "Episodic days" were determined by using the daily high-PM_{10} concentration data in the region, and their relationship between respiratory diseases was investigated.

Local meteorological factors (e.g., air temperature, wind speed and direction, relative humidity, precipitation, dew point temperature, average pressure, cloud cover and mixing layer) and/or large-scale circulation mechanisms play significant role in the variation of PM_{10} concentration values in the region. While generally high temperature values increase the concentration levels of PM, rainfall exhibits removal mechanism for suspended air pollutants. In this study, to find the impacts of air masses on high-PM_{10} values over Canakkale, we extracted synoptic composites for the selected episodes by using daily mean NCEP/NCAR (between 10 °W–70 °E and 20 °N–80 °N) sea level pressure (SLP) during the day of the extreme event.

Cluster and statistical analysis

Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model was employed in order to determine the origin of air masses (e.g., Yu et al. 2010; Goudarzi et al. 2019; Baltaci et al. 2020). In our study, 72-h backward trajectories of HYSPLIT trajectory analysis (GDAS $1° \times 1°$ high resolution data) were calculated for each episodic day to indicate the effect of the air mass sources on high-PM_{10} concentrations. Later, we applied Ward's minimum variance clustering technique and Euclidean distance to the each back trajectories. This method was chosen, because it was applied to investigate the source region of high-PM_{10} episodes for the other urban cities (e.g., Lee et al. 2011) and also this method was mainly applied to daily mean PM_{10} (Unal et al. 2011), precipitation and temperature (Ünal et al. 2003; Baltacı et al. 2017; Baltaci et al. 2020) values over the entire or the selected parts of Turkey. The longitudes and latitudes of the trajectories over 1-h intervals are used as clustering variables. The number of clusters is determined by assessing where noticeable increases in the distances between merged clusters occur. Computationally, trajectories are combined until the total variance of the individual trajectories about their cluster-mean starts to increase substantially (Stunder 1996).

As a consequence of the grouping high-PM_{10} cases, the roles of the intensive coarse particulate matters on COPD and pneumonia diseases were investigated for each different lags (from lag0 to lag6). Relationship between daily numbers of patients for different ages/sexes and the daily mean high-PM_{10} values for different source areas were investigated by using Pearson correlation coefficient and confidence intervals ($p < 0.01$).

Results and discussion

Monthly and seasonal variation of PM_{10} concentration

As a consequence of the analyzing 11-year period, 104 high-PM_{10} cases were found as episodic days from the selected period. Monthly and seasonal distribution of these high-PM_{10} episodes is shown in Fig. 2. The highest mean high-PM_{10} episode concentrations was found in winter (125 µg m^{-3}), and followed by spring (117 µg m^{-3}), summer (110 µg m^{-3}), and fall (105 µg m^{-3}) seasons, respectively (Fig. 2a). High-PM_{10} concentrations reached up to maximum levels during January (130 µg m^{-3}), December (125 µg m^{-3}) and February (122 µg m^{-3}) months and dropped to minimum levels in September and October (Fig. 2b). PM_{10} values decreased apart from winter and spring months, and the lowest values were observed in fall and summer months. Many previous studies showed that PM_{10} concentration is higher generally in winter (Vardoulakis and Kassomenos 2008; Kocak et al. 2011; Markasis et al. 2012; Baltaci et al. 2019; García et al. 2019; Sindosi et al. 2019). It is known that the region is under the influence of coal-fired and thermal power plants and thus, higher PM_{10} concentration values are observed in winter months. When the seasonal numbers of high-PM_{10} episodes are examined, 70% (73 days) of them

Table 1 Relationship between the numbers of the COPD/pneumonia patients and high-PM_{10} values for each five clusters and lags

Europe	COPD				Pneumonia			
	Female		Male		Female		Male	
	15–64	> 64	15–64	> 64	15–64	> 64	15–64	> 64
Lag0	−0.10	−0.03	−0.13	−0.01	−0.04	0.09	−0.08	0.09
Lag1	0.02	0.22	−0.12	0.13	0.25	−0.02	0.02	0.12
Lag2	−0.13	0.15	−0.23	−0.03	0.18	0.14	0.04	0.04
Lag3	−0.08	0.18	−0.05	−0.01	0.13	0.26	−0.13	0.08
Lag4	0.03	0.13	0.02	0.15	0.09	0.34	0.10	0.24
Lag5	0.03	0.22	0.15	0.09	0.24	*0.55*	**0.39**	0.31
Lag6	−0.20	−0.17	−0.19	−0.24	−0.12	−0.15	0.03	0.05
Sahara	15–64	> 64	15–64	> 64	15–64	> 64	15–64	> 64
Lag0	−0.27	0.15	−0.43	−0.06	0.14	−0.16	0.09	−0.27
Lag1	**0.50**	0.23	0.23	0.30	0.32	−0.24	0.24	0.06
Lag2	0.48	0.34	0.03	0.35	0.16	0.10	0.28	0.09
Lag3	0.17	0.30	−0.01	0.12	0.31	−0.14	0.29	−0.20
Lag4	**0.53**	0.04	−0.04	0.03	0.20	−0.39	0.38	−0.19
Lag5	−0.05	−0.31	0.04	−0.14	0.11	−0.07	−0.10	−0.06
Lag6	−0.09	0.08	−0.40	−0.38	−0.20	−0.14	0.07	−0.20
Local	15–64	> 64	15–64	> 64	15–64	> 64	15–64	> 64
Lag0	0.12	0.06	0.03	−0.05	−0.03	0.14	−0.20	−0.20
Lag1	**0.55**	0.08	0.23	0.19	−0.05	−0.23	−0.37	0.01
Lag2	**0.48**	**0.54**	0.37	0.40	−0.20	0.25	−0.10	−0.12
Lag3	**0.48**	**0.54**	0.37	0.40	−0.20	0.25	−0.10	−0.12
Lag4	−0.18	−0.04	−0.02	−0.06	−0.01	−0.13	−0.33	−0.08
Lag5	0.18	0.03	−0.11	−0.01	0.16	0.30	0.23	0.05
Lag6	0.01	−0.12	−0.01	−0.09	0.14	0.14	0.20	−0.01
Mediterranean	15–64	> 64	15–64	> 64	15–64	> 64	15–64	> 64
Lag0	−0.35	−0.56	−0.40	−0.36	−0.23	−0.37	−0.48	−0.20
Lag1	−0.47	−0.26	−0.33	−0.12	0.19	−0.21	−0.14	0.04
Lag2	0.45	**0.71**	0.54	*0.80*	**0.62**	−0.33	0.34	**0.61**
Lag3	0.42	*0.76*	*0.75*	*0.76*	0.21	−0.17	0.10	0.00
Lag4	0.02	0.08	*0.76*	0.16	−0.25	−0.27	−0.31	0.01
Lag5	0.38	0.06	0.29	0.38	0.35	0.33	−0.48	0.23
Lag6	0.55	−0.02	−0.03	−0.09	0.53	−0.33	−0.33	0.29
Russia	15–64	> 64	15–64	> 64	15–64	> 64	15–64	> 64
Lag0	−0.26	0.10	−0.05	0.05	0.10	0.44	0.19	−0.06
Lag1	0.83	0.32	0.57	0.35	**0.67**	*0.80*	**0.66**	**0.69**
Lag2	−0.26	0.11	0.01	−0.30	−0.23	0.37	−0.49	−0.36
Lag3	0.30	0.56	0.46	0.65	0.22	−0.08	0.01	−0.16
Lag4	**0.69**	0.36	0.04	0.17	−0.19	−0.27	−0.27	−0.17
Lag5	−0.46	−0.09	−0.41	−0.12	−0.05	−0.10	−0.07	−0.46
Lag6	0.03	−0.09	−0.33	−0.39	−0.25	−0.26	−0.34	−0.50

Male and female patients are analyzed for their adults and elderly people. Bold and italic numbers indicate the statistically significant correlations at the 0.95 and 0.99 confidence levels, respectively, according to Student's *t* test

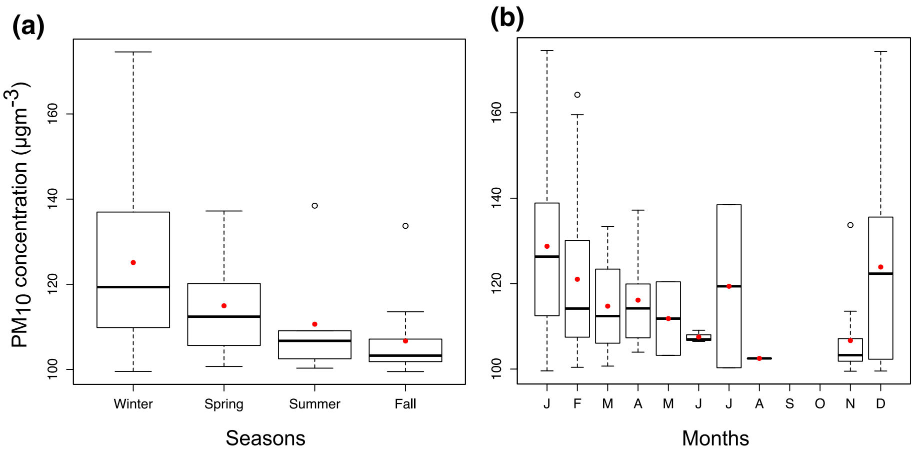

Fig. 2 **a** Seasonal and **b** monthly distribution of high-PM_{10} concentration values in the Canakkale district for the period 2007–2017. The boxes present the median, the first and third quartiles, while whiskers and dots present the minimum and maximum value and possible outliers, respectively. Red dots indicate the mean seasonal and monthly PM_{10} values, respectively

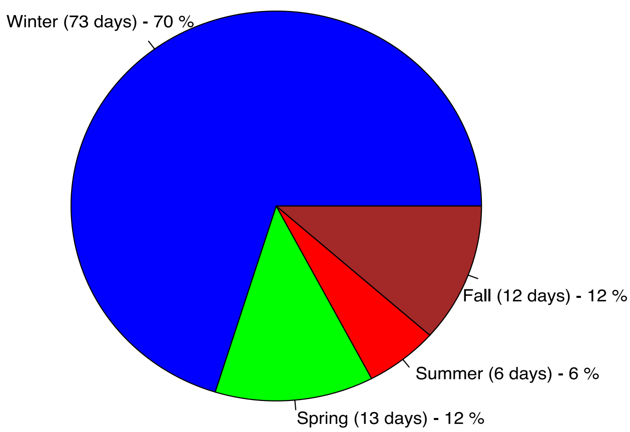

Fig. 3 Seasonal percentage frequencies of high-PM_{10} days in Canakkale during 2007–2017 period. Total numbers of high-PM_{10} cases for each season are shown in parenthesis

are found in winter, 12% (13 days) in spring, 12% (12 days) in fall and 6% (6 days) in summer (Fig. 3).

In Canakkale province, coal-fired power plants are considered to be the most important source of pollution for high-PM_{10} episodes. According to the 2017 data of Canakkale Provincial Directorate of Environment and Urbanization, Canakkale has a long heating period due to climatic characteristics and 109,000 tons of coal (domestic and import (Russia/Africa)) and 43,478,917 m^3 of natural gas, which has heating value of 8250 kcal/kg, have been used. In the industry, 3,200,000 tons of hard coal (Russia, South Africa), 95,000 tons of anthracite (Russia), 450,000 tons of petroleum coke (USA) and 139,307,267 m^3 of natural gas with a heating value of 8250 kcal/kg have been used. According to 2015 data of ICDAS (Steel, Energy, Shipbuilding and Transportation Industry Inc.), a total of 4,074,043 tons of coal is consumed (1,185,915 tons of coal per year in Degirmencik Thermal Power Plant and 2,888,128 tons of coal in Bekirli Thermal Power Plant) for power generation, which produces 463,660 tons of fly ash and 59,483 tons of slag annually. Coal extracted from the thermal power plant contains high amounts of pollutants. The amount of coal consumed by only 2 of the Thermal Power Plants in Canakkale is 38 times more than the coal used in domestic heating in the province. Coal usage in domestic heating and individual consumption causes an increase in PM_{10}, but it is considered that the biggest source of high-PM_{10} episodes are heavy industry and coal-fired power plants. While 3 coal-fired power plants were operational in Canakkale until December 2017, as of 2018, 4 thermal power plants with 3245 MW capacity have been operational in the province. Additionally, there are three organized industrial zones (Canakkale OIZ, Biga OIZ and Ezine OIZ) in the province. While Canakkale's industry is based on agriculture, sectors with environmental risks such as coal-fired power plants, iron and steel, cement industry and mining are among the most important factors that increases PM_{10} concentration levels due to the high air pollutant emission rates they bring. They significantly reduce the air quality of Canakkale province and threaten ecological balance and public health. Likewise, as stated in the environmental problems report issued by the Ministry of Environment and Urbanization in 2016, air pollution is the most important environmental problem in Canakkale and the source of this problem is coal-fired power plants.

Clustering results of high-PM_{10} values in Canakkale

In order to identify large-scale and near continental pollution sources that cause episodic PM_{10} days, we applied HYSPLIT 72-h backward trajectory model to the 104 cases at a height of 1000 m. As a result of the classification with Ward's Minimum Hierarchical Method, 5 different clusters were formed as: Europe, Sahara, Local, Mediterranean and Russia (Fig. 4). Result of cluster analysis show that 34.6% (36 days) of high-PM_{10} episodes originating from Europe, 22.1% (23 days) from Sahara, 19.2% (20 days) local, 13.5% from (14 days) Mediterranean and 10.6% (11 days) from Russia as the lowest.

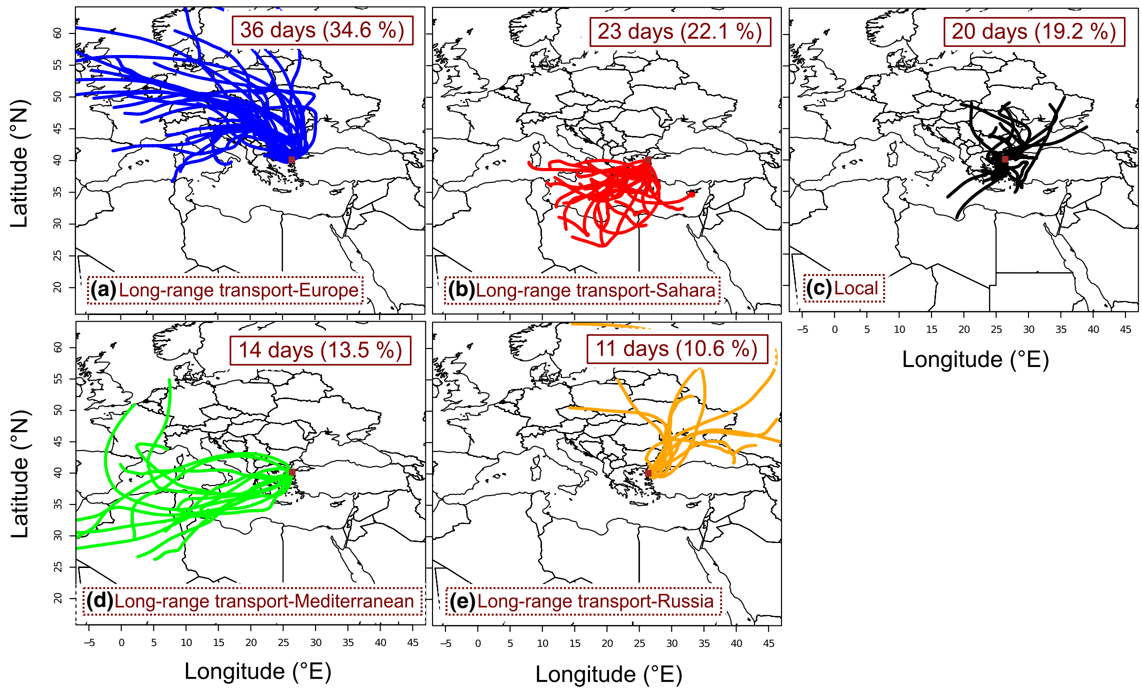

Fig. 4 Considering 72-h backward trajectories of extreme pollutant days, frequencies of high-PM_{10} concentration cases are grouped according to their **a** Europe, **b** Sahara, **c** Local, **d** Mediterranean, and **e** Russia source areas. Brown rectangle indicates the region of Canakkale

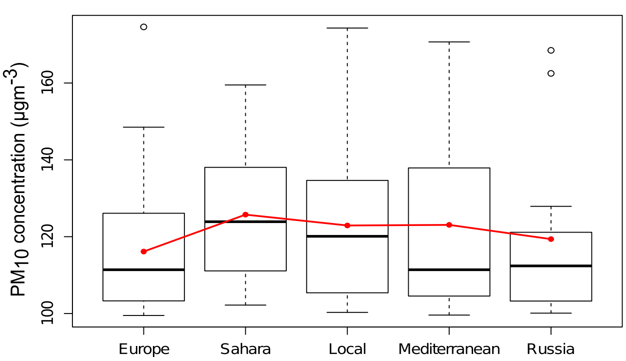

Fig. 5 High-PM_{10} concentration changes during internal (Local) and external origins sourced from Europe, Sahara, Mediterranean, and Russia. The boxes present the median, the first and third quartiles, while whiskers and dots present the minimum and maximum value and possible outliers, respectively. Red line indicates the mean PM_{10} values for each clustering type

When we divided high-PM_{10} variation according to its source areas, it was shown that natural dust particles originated from Sahara cause poorer air quality than the other external or internal sources with the mean 125 µg m^{-3} (Fig. 5). Anthropogenic pollutants caused Mediterranean and local sources play also critical role to have high-PM_{10} values in the region with the mean values of 123, and 121 µg m^{-3}, respectively.

We extracted seasonal and annual distributions of high-PM_{10} variations for each group to better understand the variations in episodic times. According to the main results, highest numbers of high-PM_{10} values in each group are shown during winter season (Fig. 6a). This condition can be explained by the loading of natural/anthropogenic particles and residential heating with thermal plants. When compared to the each group, region is more sensitive to the pollutants, which are coming from Europe, with 26 days. Dust particles sourced by Sahara appear to be of secondary importance in the region with 16 days. In this condition, suspended particles do not meet any barrier such as mountains and reach the region by moving through the Mediterranean Sea. We can see high dust loadings in spring months when proper synoptic conditions, dry and calm weather conditions are active in the region (not shown). In addition to these two external sources, internal sources also play significant role in having large numbers of episodic days (15 days). It is known that local emissions cause an increase in PM_{10} concentrations especially in winter (Kassomenos et al. 2014).

In spring, although frequencies of extensive PM_{10} loadings decreases, transferring of natural dust particles are more important for the region than the other source types (6 days). These results are consistent with previous studies on dust loadings in spring (e.g., Baltaci 2017; Koçak et al. 2007; Katragkou et al. 2009; Querol et al. 2009; Baltaci et al. 2019). During this season, the transport of Saharan dust into the Mediterranean Basin is thought to be due to intense baroclinic systems called Sharav cyclones (Meloni et al. 2007). Annual distribution of high-PM_{10} days indicated that

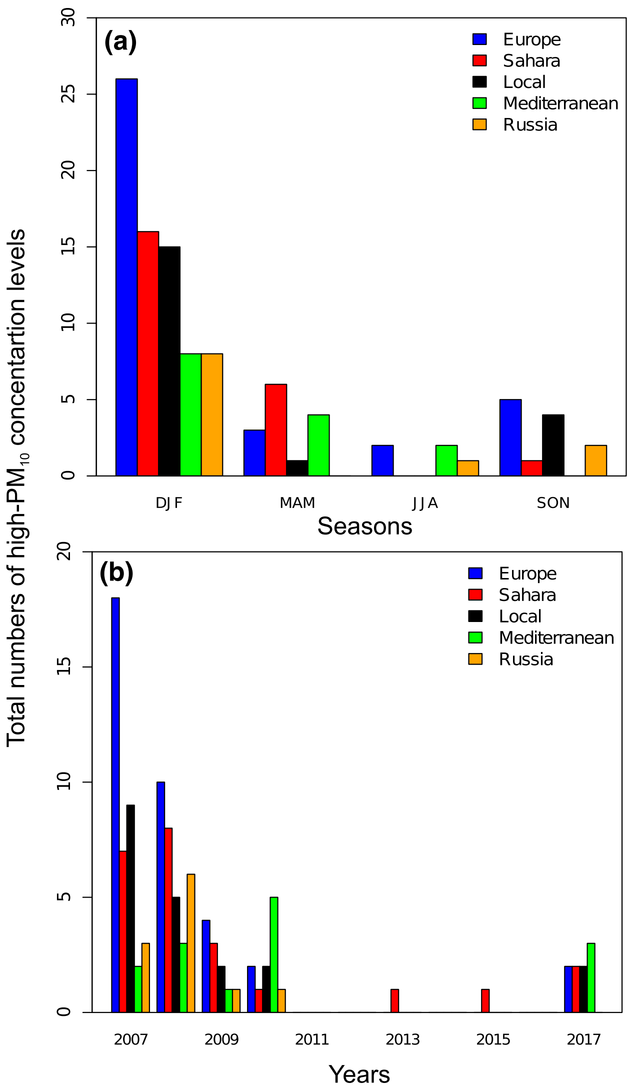

Fig. 6 Depending on the five types (local and long-range transports from Europe, Sahara, Mediterranean, and Russia), changes in the numbers of high-PM_{10} days in **a** each season, and **b** each year

extreme episodic years are shown as between 2007–2010 and 2017 years (Fig. 6b). As previously explained by Unal et al. (2012), 2007–2008 droughts were the worst in the last 50 years in the west parts of Turkey. Therefore, more dry and warm air with dust particles are transferred to the region with the aid of Sharav cyclones.

Synoptic conditions during episodic days

To improve our atmospheric understanding that cause high-PM_{10} cases, we extracted synoptic composites of extreme PM_{10} days. Hence, we took into account of the days occurring in four different clusters (Fig. 7). If the deep low-pressure center (LPC) is located over Iceland and high-pressure center is positioned over Central Anatolian Peninsula, northwesterly

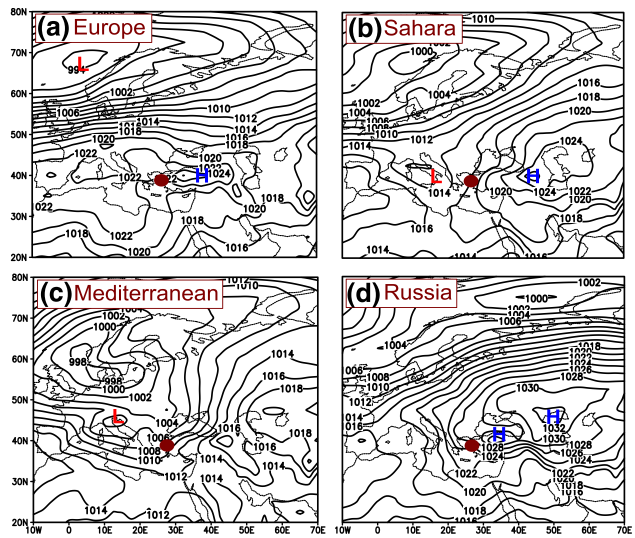

Fig. 7 Composite analysis of daily mean sea level pressure (hPa, contour) during the extreme pollutant event originated by **a** Europe, **b** Sahara, **c** Mediterranean, **d** Russia. H and L mark the high- and low-pressure centers, respectively. Brown rectangle indicates the region of Canakkale

winds bring anthropogenic originated PMs to Canakkale province (Fig. 7a). On the other side, the interaction between Genoa cyclone and surface high located over Caspian Sea resulted in dusty days in the region. This condition occurs, because strong pressure gradient force and associated with high southwesterly wind speeds bring natural suspended dust particles from Sahara in a very short time scale such as hours (Fig. 7b). We generally observe above-normal PM_{10} concentrations during these similar atmospheric conditions in the western of Turkey (Baltaci 2017; Baltaci et al. 2019, 2020). Natural dust loadings to Eastern Mediterranean Basin are frequently shown during spring months and numerous studies investigated the role of atmospheric conditions on the dust transport mechanism (e.g., Agacayak et al. 2015; Kabatas et al. 2018). If the cyclone moves to the north and is located over northern Italy, then southwesterly winds turn into the westerly wind patterns. Thus, the region is influenced winds in W–E direction. During this circulation pattern, we generally observe high-PM_{10} values in winter and spring months of the year (Fig. 7c). Although we have least frequent, Russia originated particles also cause air quality problems. During this type, owing to position of surface high over Black Sea with its 1028-hPa core, particles start moving from Russia by northerly winds (Fig. 7d).

Relationship between the number of patients and high-PM_{10} days

In this section of the study, we examined the relations between patients and high-PM_{10} concentration levels. For this reason, daily numbers of the COPD and pneumonia diseases were separated into different age groups (i.e., children, adult, and elderly) and sexes. Therewithal, variations of the PM_{10} levels from lag0 (current day) to lag6 days were considered in the analysis. At the end, the impacts of the different source areas of PMs, which causing air pollution, on the respiratory diseases were investigated for Canakkale province of Turkey. Due to the small numbers of the children patients, we eliminated this group to get better results in our study.

According to our main findings, high PM_{10} levels originated by Europe appear to cause especially pneumonia diseases in elderly female at lag5 ($r = 0.55$, $p < 0.01$) and adults in male at lag5 ($r = 0.39$, $p < 0.05$). This implies that if the PM values exceed its threshold level (> 100 μg m^{-3}), the elderly and adult patient numbers in female and male, respectively, are observed as increasing mode at lag5. This condition also indicates that anthropogenic origin PMs is more likely to cause pneumonia diseases than COPD.

During high-PM_{10} loadings from Sahara, we have observed significant increases in the numbers of adult female patients in COPD disease at lag1 and lag4. We can expect an increase in the number of female patients in hospital admissions, especially during severe dust transport events in spring months. Therefore, early warning alerts based on dust transport from Sahara should be followed in emergency services of the hospitals to take preventive precautions. During internal sources, the symptoms causing COPD diseases are more exposed to pollutants. As a result, female patients are at the risk within 3 days of the event occurred.

Mediterranean sourced PM loadings to the region distinctly threat COPD and pneumonia diseases when examined hospital admission records. During the active phase of Genoa cyclone in winter, high PMs in W-E direction are transferred to the region and cause an increase in the frequencies of the elderly female COPD patients at lag2 and lag3, and male COPD patients from lag2 to lag4. Additionally, adult female and elderly male pneumonia patients appear to be negatively affected during the next 2 days of the event. Although Russia originated pollutants are shown as least frequent in Canakkale (totally 11 days during 11-year period), their impacts on pneumonia diseases are very evident. We can expect an increase in the number of all patient groups on the day after the event occurs.

Conclusion

In this paper, we first extracted daily mean high-PM_{10} concentration levels in the Canakkale province of Turkey for the period 2007–2017. Later, high-PM_{10} days were grouped by applying Ward's minimum clustering techniques on HYSPLIT 72-h backward trajectory analysis. After analyzing seasonal and annual distribution of intense pollutant days and their contribution to high-PM_{10} levels for each cluster, synoptic mechanisms triggering these pollutant loadings to the region were investigated by using NCEP/NCAR reanalysis daily mean sea level pressure data. At the end, the relationship between respiratory diseases (i.e., COPD and pneumonia) and high-PM_{10} concentration levels were investigated by applying Pearson's correlation coefficient on each cluster, age groups, sexes, and lags. The main results are as follows:

- From the 11-year period, totally 104 days are recorded as high-PM_{10} episodes for the region. The intrusion of PMs to Canakkale is mostly shown in winter (70%), followed by spring, and fall months, respectively. Considering pathways of the pollutants, we have found different five groups originated by Europe, Sahara, Local, Mediterranean, and Russia. From these clusters, 19.2% of all episodic days are observed as internal sources. For the external sources, 34.6%, 22.1%, 13.5%, and 10.6% of all high-PM_{10} days are sourced from Europe, Sahara, Mediterranean, and Russia origins.
- It was found that while all internal/external sources are active in winter season, we observed highest frequencies of particle loadings during active Europe-originated air masses. On the other side, as a consequence of the location of surface low over Genoa and surface high over Caspian Sea, strong southwesterly flows bring natural dust particles to Canakkale especially in spring months.
- When investigated the role of pollutants on respiratory diseases, we have an obvious increases in the numbers of pneumonia diseases related to elderly female ($r = 0.55$, $p < 0.01$) and adult male ($r = 0.39$, $p < 0.05$) at lag5. On the other hand, Sahara originated dust particles cause an increase in the frequencies of adult female COPD patients at lag1 ($r = 0.50$, $p < 0.05$) and lag4 ($r = 0.53$, $p < 0.05$). In local sourced high PM concentration levels, it was shown obvious increment in female COPD patients from lag1 to lag3. Although we see small number of particles originating from Russia, this circulation mechanism causes abnormal increments in the numbers of pneumonia-related diseases at lag1.

Our findings inform and add to the current literature on the risk of PM_{10} as a health hazard and the prevention of respiratory diseases exacerbated by PM_{10} pollutants as well as expecting local policy makers to assist with the improvement of air quality.

Acknowledgements This study was financially supported by BAPKO with FEN-C-DRP-100719-0248 project number.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the Ethical Committee of Istanbul Gedik University (No. 71457743-202.03.02) and conducted using the data between January 1, 2007 and December 31, 2017 in Canakkale, Turkey.

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