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Short-term and long-term exposure to particles and their consequences in Poldokhtar City (Iran)

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ABSTRACT

In Iran's biggest towns, deaths and hospitalizations from respiratory and cardiovascular diseases have a strong association with $PM_{2.5}$ pollution concentrations. The WHO recommends assessing the health impacts using the Air Quality and Health Evaluation approach (Air Q 2.2.3). Data of particulates on both clear, dusty days have been provided by the Meteorology Office for Lorestan. Results indicated that in terms of mean AQI, May (162.46), July (121.7), and April (110.23) are the most polluted months in Poldokhtar city in 2022. May (16 days), July (6 days), March (5 days), and April (4 days) are the most contaminated months of the total number of polluted days. The days having the highest amounts of pollution in terms of the daily mean AQI are May 17th (407), April 10th (402), May 24th (393), July 31st (351), and April 18th (341). The maps extracted from HYSPLIT showed that the origin of the dust entering the city of Poldokhtar is the arid and semi-arid regions of Saudi Arabia, Egypt, Kuwait, and Turkey. May shows the maximum amount of pollution in comparison to other months, as shown by the mean AQI of 162.46. Furthermore, with an AQI score of 407 on May 17, it is assumed to be the most polluted day of the year. Hospitalized people who had respiratory diseases were most severely impacted by the short-term adverse effects of fine dust inhalation.

1. Introduction

Asia is a significant contributor of particulate matter on a vast scale, mostly because of the rapid economic growth of developing nations like China and India, as well as extensive deserts[1]. WHO stated that human-related air pollution is responsible for 4–8 % of global annual[2]. Researchers have linked the consumption of air pollutants to an increase in chronic respiratory and pulmonary disorders, cancer, other negative health outcomes, and even death[3]. As a result, the increase in air pollution in metropolitan areas has become a major concern these past few years. Prior studies have shown that $PM_{2.5}$ and gaseous pollutants have a direct correlation with higher rates of hospitalizations and deaths caused by respiratory and cardiovascular ailments in the large cities of Iran[4,5]. The dimensions, concentration, content, toxicity, and ability of particles to transport hazardous compounds and components significantly influence the severity of negative health consequences linked to contact with airborne Particulate Matter (PM)[6]. Additionally, reports have compared the effects of air pollution on FeNO and pulmonary function in healthy kids on dusty or non-dusty days[7]. PM comes from not only human activities (such as domestic fireplaces, cars, and factories) but also natural resources (including biogenic emissions, dust, and ocean spray). The main sources of PM are anthropogenic, resulting from road traffic, the combustion process, transportation, power stations, heating plants, and industrial operations[8]. PM is categorized based on its dimension, which is directly correlated with how deep it may reach in the lungs; smaller particles may reach deeper[9]. $PM_{2.5}$

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refers to a type of air pollutant that is made up of tiny particles having a diameter of 2.5 mm or less that can move through the air. Researchers investigated how polluted air impacts human health in the short- and long-term[10]. These studies measured the increase in hospital admissions, visits to a doctor, asthma attacks, cardiovascular diseases, deaths, and years of life lost as a result of air pollution[11,12]. Numerous epidemiological studies have focused on the health impact of atmospheric PM over the past twenty years, worldwide[13]. A study by the World Health Organization revealed that a 10 µg increase in particle concentration can lead to a 1–3 % rise in death rates[14]. Recently, various studies have revealed a correlation between the health impacts and the immediate or long-lasting interaction with particle matter in local air[15–17].

This investigation attempted to assess the hazards associated with long- and short-term exposure to particle dust in Poldokhtar since the city is considered to be the most contaminated in regards to dust levels and no previous study has been done on the topic at issue.

2. Material and method

2.1. Study area

Poldokhtar is a town located in the southern province of Lorestan. It is located at coordinates 33°08′56″N - 47°42′59″E and comprises a region of 3615 km^2 (Fig. 1). The town is located near the foothills of Mount Male in the Zagros Mountain range, at a height that varies from 645 to 715 m above sea level. While summers in Poldokhtar are hot, winters are temperate and generally cold. However, Poldokhtar occasionally receives partial or complete snowfall every few years. Poldokhtar experiences six frost days annually, making it one of the cities in this province with the least rainfall. The average annual temperature and rainfall of Poldokhtar are 22.8^0 C and 372.6 millimeters, respectively. Thirty thousand people are around our study.

2.2. Health outcomes

The deputy head of the Management and Statistical Department of Poldokhtar Hospitals gave data to the investigation about the prevalence and raw death rates of heart and respiratory diseases in Poldokhtar. The death rates in Poldokhtar include a variety of causes of death and hospitalization. These consist of total causes of death in adults over 30 years, deaths resulting from ALRI[1] in kids aged 0–5 years, deaths caused by COPD[2] in adults over 30 years, deaths attributed to lung cancer in adults over 30 years, deaths resulting from IHD[3] in those aged 25 and older, hospitalizations for respiratory disorders, hospital admissions for cardiac conditions (including stroke), and population statistics.

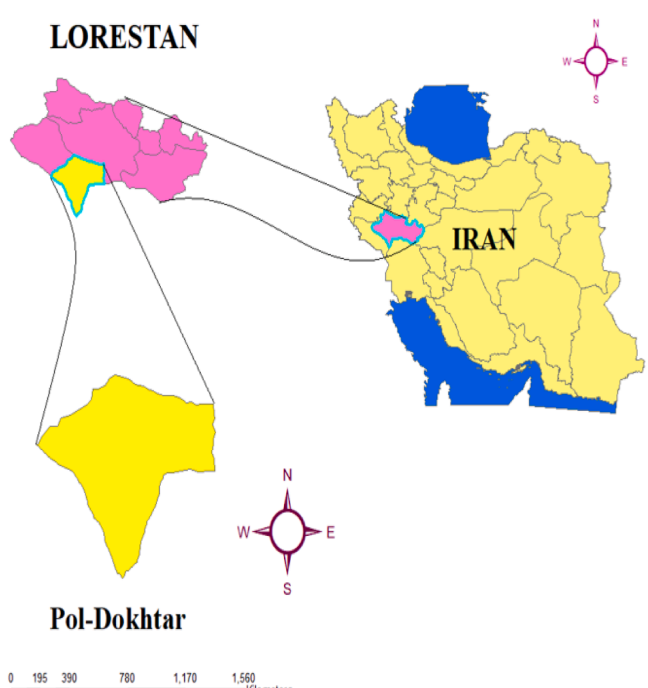

Fig. 1. Geographical location of Poldokhtar city.

2.3. Gathering and evaluation of air quality information

A monitoring station in Poldokhtar measures and records the levels of $PM_{2.5}$ particles. The hourly concentrations reported by the Environment Organization in 2022 were used to analyze by Air Q^+ model to quantify the health implications. The models used to assess health consequences are mainly statistical-epidemiological. They combine biological attributes, like baseline incidence, descriptive component, and relative risk, to present findings as death. The Air Q^+ model needs a 24-hour mean of $PM_{2.5}$ to assess their health consequences. To calculate this average in an Excel context, the data from days having at least 18 hours of data was used.

3. Result and discussion

3.1. $PM_{2.5}$ concentration

Table 1 shows the measured PM2.5 levels in Poldokhtar city. The findings from January demonstrated that there have been 20 days with good air quality, 5 days with moderate air, 3 days with unsafe air for vulnerable persons, and 1 day with extremely unsafe air (two days this month were also not reported). The minimum and maximum AQI reported for this month are on the 6th [14] and 25th (162) of January (Fig. 2). The 21st (104), 22nd (107), and 26th (141) were identified as unhealthy days for sensitive individuals, and the 25th (162) was reported as a completely unhealthy day. The principles of AQI for particles are as follows: 0–50 is satisfactory air quality, 51–100 is acceptable air quality (moderate), 101–150 exposure is dangerous for sensitive groups (children, elderly, etc.) 151–200 is dangerous for all groups and 200–300 is the air quality in the health alert stage. The average AQI of February was reported as moderate (50.71); The minimum and maximum AQI reported in this month were 15 (8th) and 224 (21st), respectively. This month, 21 days were identified to have clean air, 5 as possessing moderate air, 1 as being hazardous for individuals with sensitive respiratory systems, and 1 as being extremely unhealthy.

Table 1
Monthly level of $PM_{2.5}$.

Month	Min	Max	Mean	SD
January	14	162	48.75	37
February	15	224	50.71	52.25
March	29	183	94.22	38.5
April	27	402	110.23	93.75
May	57	407	162.46	87.5
Juan	33	159	75.88	31.5
July	61	351	121.7	72.5
August	71	220	90.74	37.25
September	29	92	53.43	15.75
October	41	92	59.25	12.75
November	13	42	23.07	7.25
December	7	38	19.64	7.75

[1] Acute Lower Respiratory Infections
[2] Chronic Obstructive Pulmonary Disease
[3] Ischemic Heart Disease

Fig. 2. Monthly levels of $PM_{2.5}$ and its comparison with AQI.

March 21st (102), 22nd (106), 23rd (149), and 26th (115) were reported as unhealthy days for sensitive people while the 12th (179), 13th (183), 14th (161), 15th (165), and 24th (162) were reported as completely unhealthy days. The average AQI in this month was 94.22(±38.5); The lowest and highest AQIs reported were 29 (17th) and 183 (13th). The average AQI reported in April was reported as unhealthy air condition (110.23); So, the concentration of AQI on the 8th, 9th, 10th, and 11th was 177, 183, 402, and 251 respectively. 7th [13], 12th (150), 13th (128), 14th (116), 15th (110), 26th (127), and 27th (148) were also reported as unhealthy air conditions for sensitive people. The average AQI reported in May was reported as completely unhealthy air condition (162.46); So the concentration of AQI in 17 days of this month was completely unhealthy; The days of this month when the air condition was reported as completely unhealthy included the 3rd (291), 6th (202), 7th (187), 8th (174), 12th (158), 17th (407), 18th (341), 19th (223), 23rd (165), 24th (393), 25th (151), 26th (167), 27th (171), 28th (172), 29th (169), and 30th (167). The 2nd (133), 4th (114), 5th (107), 9th (110), 11th (103), 21st (116), and 22nd (144) were also reported as days when the air condition was unhealthy for sensitive people. The average AQI in June was 75.88 (±31.5); Its minimum and maximum values were 33 (16th), and 159. 3 (26th) days of this month, the weather condition was reported as unhealthy for sensitive people, and only one day the

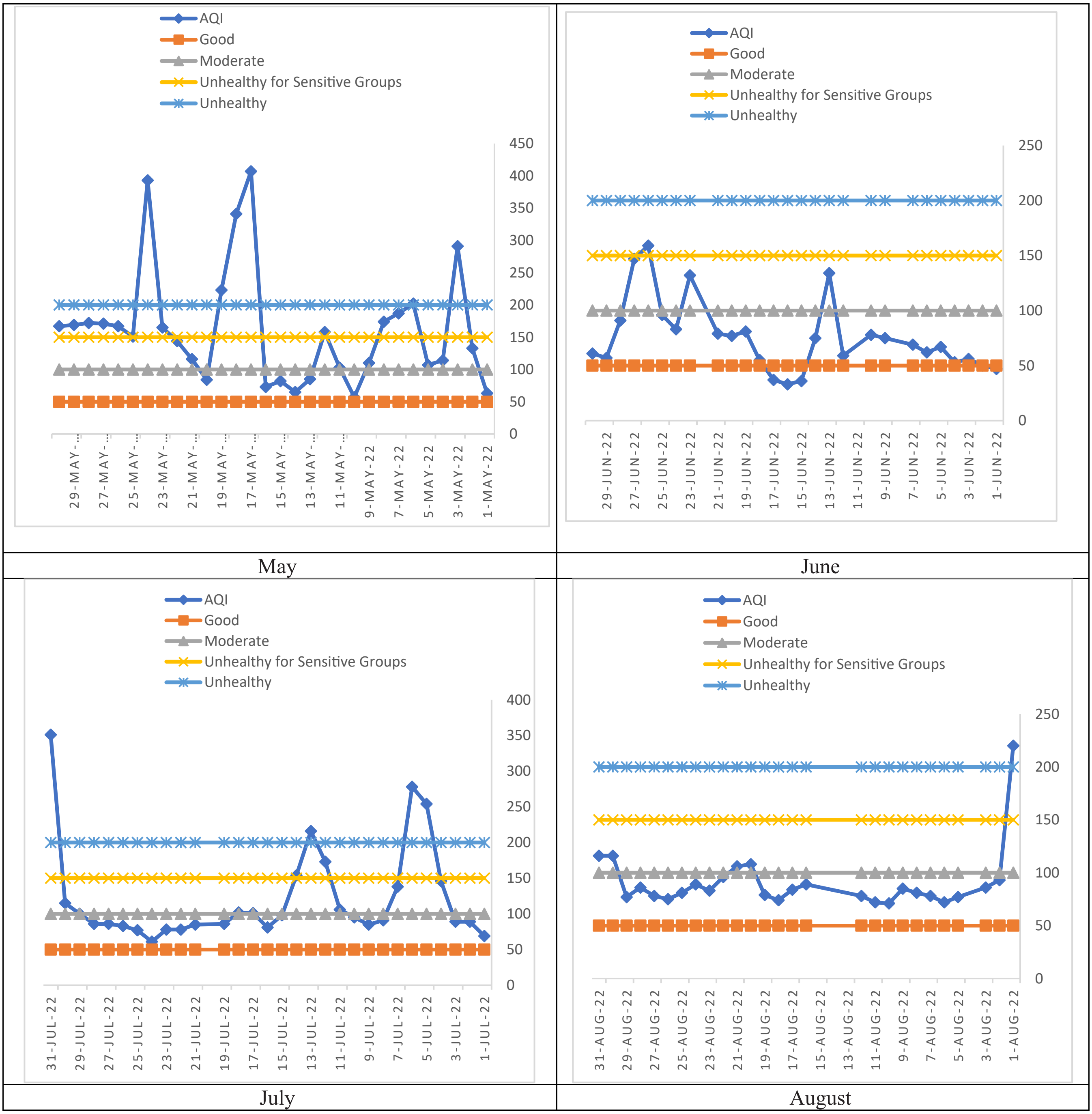

Fig. 2. (*continued*).

weather condition was reported as completely unhealthy. Of the other days of this month, 5 days were completely healthy, and the rest of those days were reported as moderate. July was also one of the most polluted months of 2022 in Poldokhtar city; so that the monthly average AQI was 121.7 (unhealthy air condition for sensitive people). For almost 6 days of this month, the air condition was completely unhealthy for everyone; AQI concentrations were 254, 278, 173, 216, and 351 on the 5th, 6th, 12th, 13th, 14th, and 31st days respectively. 4th (146), 7th (138), 11th (106), 17th (101), 18th (102), 29th (100), and 30th (115) were also reported as unhealthy days for sensitive people. The average AQI in August was reported as moderate (90.74); While the highest concentration reported in one day of this month belonged to the 1st (220). August 20th (108), 21st (106), 30th (116), and 31st (116) were considered as days when the weather conditions were reported as unhealthy for sensitive people; The rest of the days of this month were reported as moderate. The average September AQI was 53.43, which is considered moderate; for 12 days of this month, the air condition was clean, and the rest of the days were reported as moderate. The lowest and highest AQI reported in this month belonged to the 13th [29] and the 1st (92). In October, as in September, its weather condition was reported as moderate AQI (59.25). 6 days of this month were reported as good weather and the remaining days as moderate weather conditions. The lowest and highest concentrations reported this month were on the 11th [41] and 5th (92) respectively. November and December were the cleanest months of 2022 in Poldokhtar City; The average AQI in these months was 23.07(±7.25) and 19.64(7.75) respectively. The lowest AQI reported for November and December was 13 (21st) and 7 (25th), respectively, and the highest was 42 (9th) and 38 (6th), respectively.

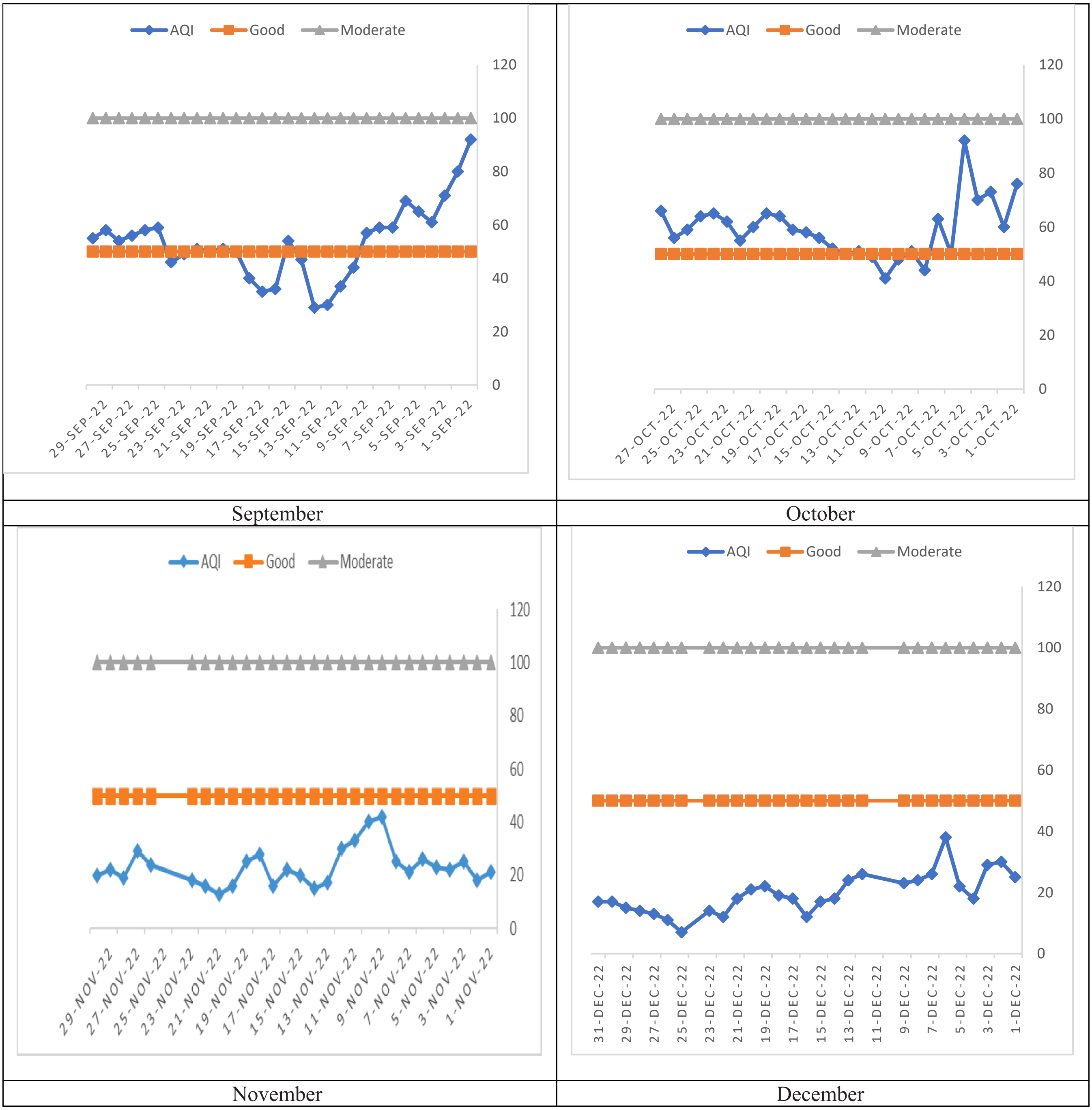

Fig. 2. (*continued*).

The $PM_{2.5}$ level mean for every season in Nikoonahad's research was greater than what the WHO suggests. Thus, in 2014 and 2015, the mean and highest $PM_{2.5}$ concentrations were about 5.6 and 88 times, respectively, over the WHO guideline of 30 μg/m^3 [18,19]. The highest findings surpassing the WHO requirements in 2014 were 24 times and the annual average was 3.35, respectively. Studies indicate summertime is when PM10 levels are highest, while winter is when levels are often lowest. The result matches with the PM10 levels measured in Ahvaz City, near the Ilam area, by Maleki et al. [20]. Significant amounts of particle scatter occur all year in the investigated region due to its dryness and windiness. City and company growth, especially in the petroleum and petrochemical sectors, has made the problem worse. Producing yearly mean PM2.5 levels of 103 μg/m3, 78 μg/m3, 90 μg/m3, 85 μg/m3, 102 μg/m3, and 385 μg/m3, respectively, have been detected in Yazd, Arak, Tehran, Tabriz, Shiraz, and Ahvaz [21–23].

3.2. *Origin of $PM_{2.5}$ particles*

As stated before, four days in January had unhealthy weather (from the 21st to the 25th); the 25th (162) got the highest AQI. Based on the maps obtained from the HYSPLIT program, the indicated dust originates in the Khuzestan region (Fig. 3). There are many rather small dust sources scattered throughout the Khuzestan region in southern Iran's Khuzestan County. Among the origins of these particles are seasonally saline lakes, field irrigation, abandoned rain-fed farming, and destroyed grassland[24]. The mean AQI for February was recorded as moderate, with a value of 50.71. This month, 21 days were regarded as having good air quality, 5 as having moderate air, 1 considered unhealthy for

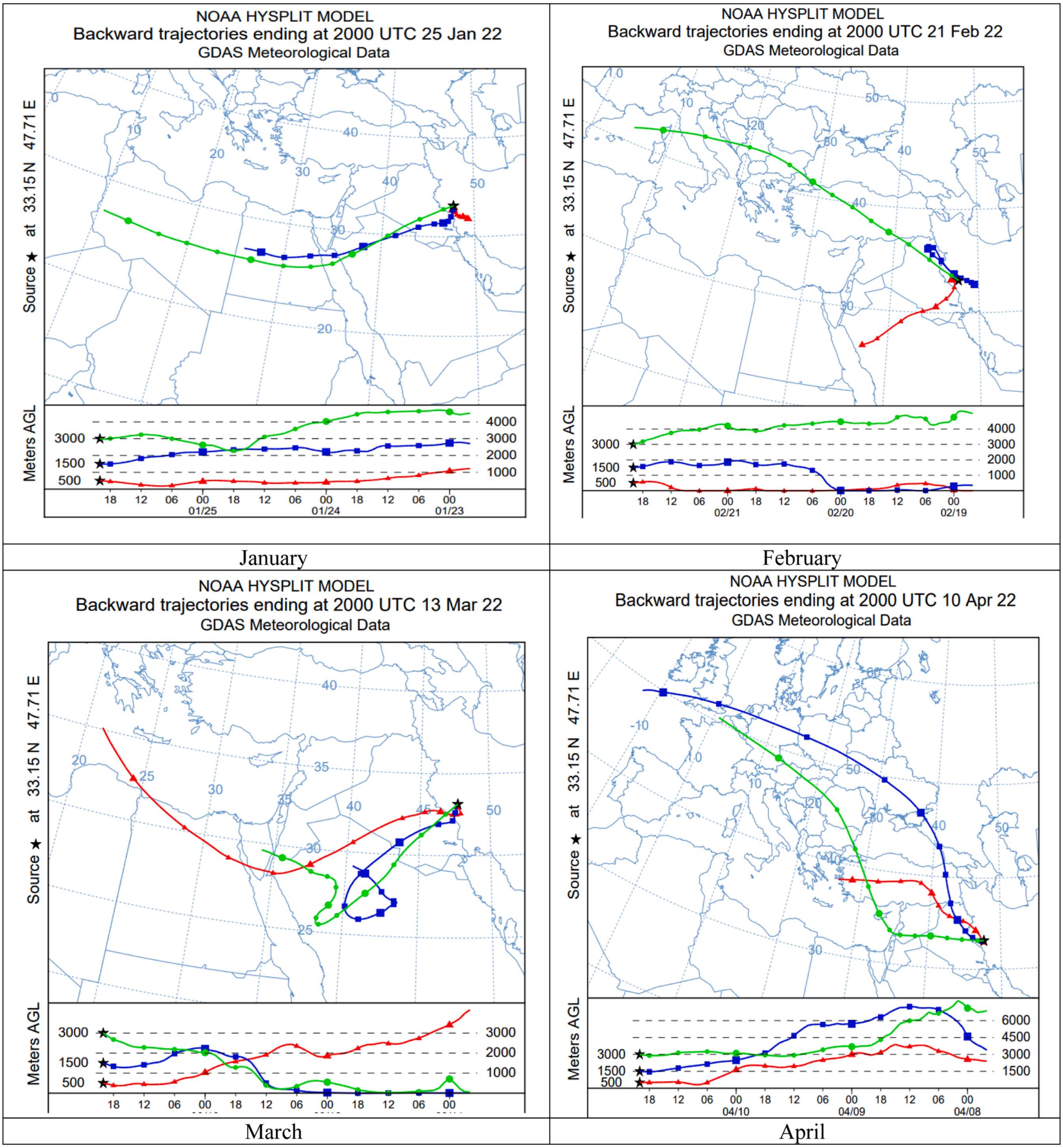

Fig. 3. The origin of monthly dust.

sensitive respiratory organs, and 1 as getting unhealthy. The mean AQI in August was recorded as moderate, with a score of 90.74. Nevertheless, the highest level of pollutants detected on a single day for this month was on the 1st, with a level of 220. According to the maps extracted from the HYSPLIT program, the origin of the dust in February and August was the Arabian desert. One of the four primary source areas indicated on the map generated by Boloorani et al. [25] was the Rub-Al-Khali desert in Saudi Arabia, which was already acknowledged by Salmabadi et al. [26].

In March, the level of particles exceeded the guidelines recommended by health organizations for a total of 9 days. The mean AQI for March was 94.22 with a standard deviation of 38.5. The minimum reported AQI was 29 on the 17th, however, the maximum reported AQI was 183 on the 13th. Since July was one of the most significantly polluted months in Poldokhtar City in 2022, the mean monthly AQI (unsafe air quality for sensitive individuals) was 121.7. For approximately six days this month, the air quality was consistently unsafe for the well-being of everybody. Based on the maps obtained by the

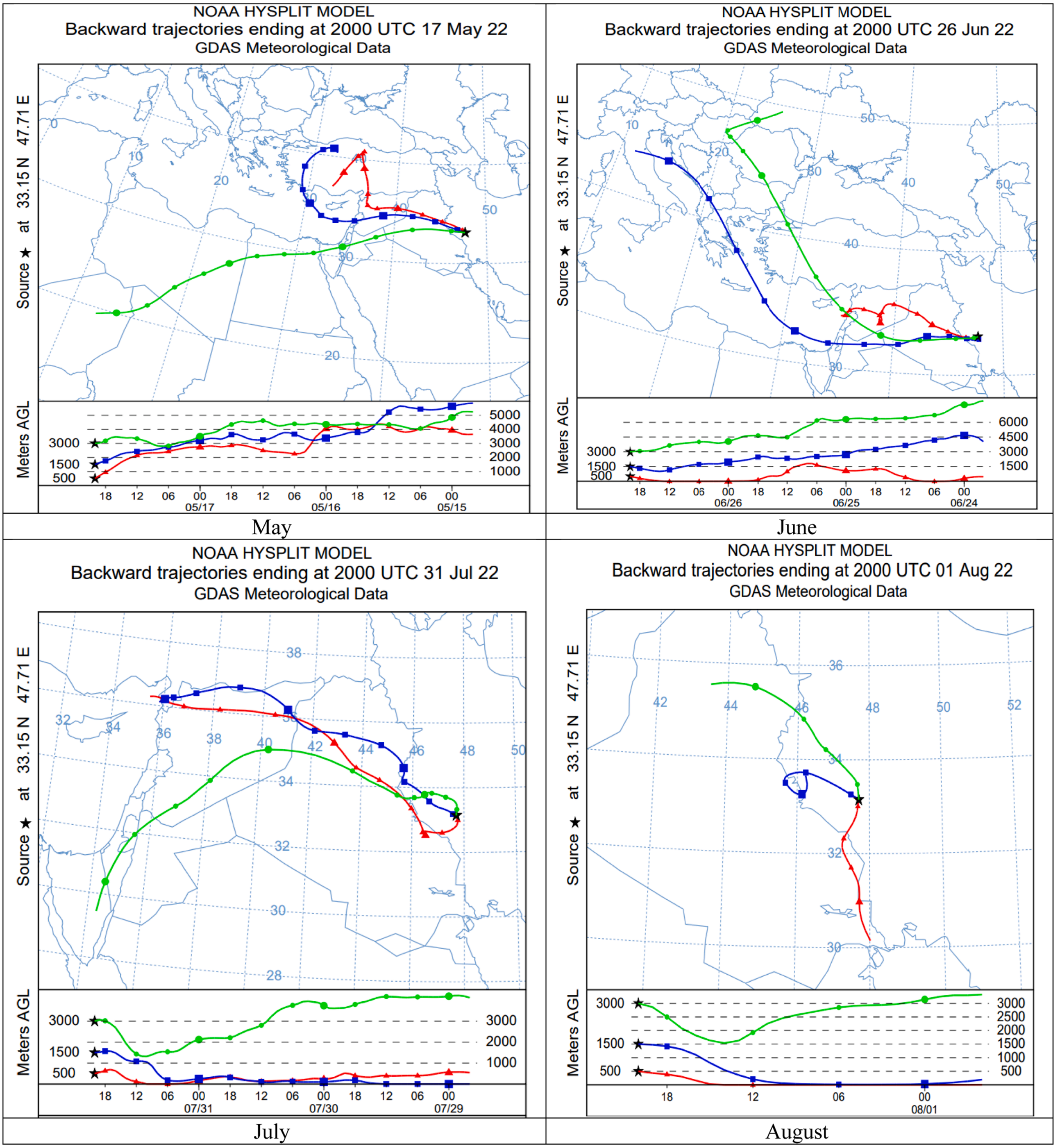

Fig. 3. (*continued*).

HYSPLIT apps, it can be concluded that the source of the particles in July and March was Egypt. The mean AQI for April was 110.23, which indicates unacceptable air quality. Therefore, the AQI levels for April 8–11 were 177, 183, 402, and 251, respectively. The mean AQI for May was determined as entirely unhealthy (162.46); hence, the AQI level for 17 days this month was deemed completely unhealthy. Turkey was the origin of the dust particles in April and May, according to the maps provided by the HYSPLIT applications.

June's mean AQI was 75.88 (±31.5); its lowest and highest readings were 33 (16th) and 159 (26th). During these days, the weather was considered harmful for sensitive individuals, and there was just one day that the weather was deemed unhealthy. HYSPLIT programs' maps indicate Kuwait was the origin of the fine dust in June. Located in southern Turkey, Syria, Iraq, northernmost Saudi Arabia, and Kuwait are the major origins of particles in Kermanshah, as reported to Akbary and Farahbakhshi [27]. Soleimani et al. [28] showed that by applying the technique of backward trajectory evaluation, it was found that a considerable quantity of dust originated from the Sahara, and throughout the southern rainfall season, particulates from northwestern parts of Africa pass over the eastern Persian Gulf to southern Iran [29].

according to Ashrafi et al., particles of Jordanian origins might have inadvertently mixed with dust from the southern Syrian Deserts [30]. According to Abdi et al. [31] and Sotoudeh et al. [32], the rivers Euphrates and Tigris are crucial for both Syria and Iraq, particularly in summertime when strong Shamal storms dominate the region. Cao et al.'s study [33]additionally indicates that dust is generated by the marshes that separate Iran and Iraq. Particulate matter from these origins may reach Iran at any time of year, but they are most active in summertime[34].

3.3. The health consequences of $PM_{2.5}$ exposure

In the present study, the health consequences of short-term and long-term exposure to $PM_{2.5}$ in Poldokhtar City were calculated. Hospitalization for cardiovascular and lung diseases, stroke fatalities, etc. were among the short-term outcomes. COPD, LC, and IHD were among the long-term health effects. The attribute proportion of hospital admissions (respiratory disease) due to short-term exposure to particles was 14.21 % (RR:1–1.040) (Table 2). According to the population of Poldokhtar city, 54 people were admitted to the hospital in 2022 due to exposure to 96.42 mg/kg of $PM_{2.5}$. Just one individual died because of short-term exposure to fine particulates, particularly from respiratory disease. The proportion of this attribute was 5.75 (RR: 1.0029–1.011). It is estimated that long-term exposure to dust particles caused 44.21 % of deaths (due to COPD). Less than 1 person died due to COPD in Poldokhtar city. According to the concentration of fine dust in 2022 in the study area, it is estimated that no deaths (due to LC) have occurred due to long-term exposure to $PM_{2.5}$. According to Hadei et al. [35], Ahvaz reported a yearly mean of AP of about 25 and an incidence of 23 instances of lung disease fatalities caused by $PM_{2.5}$. There are roughly 8 million reported cases of air pollution, each causing its own set of accompanying worries. There is a strong correlation between airborne pollution and death, based on an investigation in Tehran, Iran individuals' death rates are associated with ALRIs; Particularly, it might be directly related to air pollution[36]. According to an investigation conducted in 11 US towns, there is a 2.5 % increase (with a 95 % CI of 2–3.5) in hospitalizations for cardiovascular and lung disorders for every 10 μg m^{-3} rise in PM2.5 concentrations[37].

Based on the study region, short-term exposure to dust particulates was responsible for 7.11 % of hospitalizations (due to cardiovascular disease) in 2022 (RR:1.001–1.016). In the present study, it was determined that out of a population of 30,000, 9 persons were hospitalized this year. Based on an exposure concentration of 96.42 mg/kg, this leads to an admission to the hospital rate of 31 persons per 100,000 people. Chronic exposure to particulate matter has been associated with 56.09 % of adult deaths from IHD, according to the information. Based on the inhabitants of Poldokhtar City, four individuals probably suffered IHD as an outcome of long exposure to fine particulates. Chronic exposure to PM2.5 was associated with 338 ischemic mortality and approximately 660 IHD deaths, according to a study by Hadei et al.[38]. In comparison with stroke, which caused 47 deaths per 100,000, IHD caused 93 fatalities per 100,000 individuals. 51 deaths per 100,000 individuals was the mean annual mortality rate from IHD between 2011 and 2019, which was mainly brought on by long-term exposure to PM2.5. This mean is far less than what was identified in previous research. The mortality rate from IHD per 100,000 individuals in Tehran, Iran, during 2017 and 2018 occurred at 105, as reported in a study by Ansari and Ehrampoush;This was caused by polluted air[36]. Hadei et al. [35]employed the Air Q+ program for assessing ten towns in Iran to determine that the mean number of deaths from IHD caused by particulate matter was 84 per 100,000 people across all cities. Particles are responsible for 41.66 % of mortality related to breathing disorders. Tehran indicated an equivalent rate of 23.8 deaths caused by cardiovascular disease per 100,000 people in 2017–2018, even in cities with populations higher than our research's base. The research carried out between 2006 and 2017 in Tabriz, conducted by Barzegar et al., showed that long-term breathing in PM caused 24.5 % of the city's CVD-related deaths. The two primary risks associated with heart disease are exposure to air pollution from burning biomass and transportation[39]. Ya et al. detected an association between accidental daily deaths and PM2.5 (ER = 0.074 %) and PM10 (ER = 0.023 %) in their investigation. Studies on stratified revealed that summertime exposure to contaminants may be more common than wintertime exposure and that women and adults 65 years of old or older are most susceptible to air-polluted exposures. The incidence of daily fatalities from heart disease and non-accidental reasons increases due to rising concentrations of PM2.5 and PM10 particles,

Table 2
The health consequences of PM_{10} exposure.

Outcome		RR[a]	AP[b]	AC[c]	B+[C][d]	N+[C][e]
Short term	Hospital Admissions (Respiratory disease)	1–1.040	14.21 %	54	179.02	53.71
	Hospital Admissions (Cardiovascular disease)	1.001–1.016	7.11 %	9	31	9.3
	Mortality all causes	1.0044–1.008	5.14 %	8	27.93	8.38
	Mortality (Respiratory disease)	1.0029–1.011	5.75 %	1	2.81	0.84
	Mortality (Stroke)	1.0012–1.013	5.67 %	1	1.99	0.60
Long term	Mortality all (natural) causes (30+)	1.06–1.09	50.52 %	45	303.11	45.47
	COPD[f] (For adults)	-	44.21 %	1	3.54	0.53
	LC[g] (For adults)	-	33.25 %	0	2.49	0.37
	Mortality stroke (For adults)	-	67.94 %	4	24.22	3.63
	Mortality IHD[h] (For adults)	-	56.09 %	4	24.96	3.74

[a] Relative Risk
[b] Attributable Proportion
[c] Attributable Cases
[d] Estimated Change of incidence (per 100,000 population at risk) at a certain category of exposure
[e] Estimated number of cases attributable to a certain level of exposure
[f] Chronic Obstructive Pulmonary Disease
[g] Lung Cancer
[h] Ischemic Heart Disease

but not from respiratory disorders [40].

As a result of short-term exposure to $PM_{2.5}$ with an annual concentration of 96.42 mg/kg, less than one person died (due to a stroke) in Poldokhtar City; The attribute proportion associated with this was 5.67 (RR: 1.0012–1.013). It is anticipated that deaths from stroke due to exposure to the stated level is roughly 1.99 per 100,000 people. Based on the information, 67.94 % of adult stroke fatalities can be caused by prolonged exposure to dust particles. Four individuals in Poldokhtar City may have suffered strokes because of prolonged exposure to fine particles, based on the city's inhabitants. The research indicates approximately 5.14 % of deaths in the area may be caused by short-term exposure to $PM_{2.5}$, with an RR ranging from 1.008 to 1.0044. As a result of exposure to fine dust, 8 people from the population of Poldokhtar City died in 2022 (27.93 people per 100,000 people). Long-term exposure to $PM_{2.5}$ in the study area was responsible for 50.52 % (RR: 1.06–1.09) of deaths; In such a way that it accounted for 45 of all deaths. Exposure to an annual mean AQI of 76.71 resulted in 303.11 deaths per 100,000 population. Based on a Health Impact Assessment (HIA) conducted by the WHO, lung diseases led by airborne particulates were the cause of 1503 fatalities in Iran in 2012. Comparing the whole number of DALY to YLL, 42,301 years were determined, while 41,601 years had been anticipated for DALY. The long-term exposure to PM2.5 caused 415 instances of YLL, 9014 years of Disability-Adjusted Life Years (DALY), and 9014 years of deadly COPD incidents in total. Examples of YLL, DALY, and IHD related to PM2.5 have been reported from Iran in 388,334 years, 399,301 years, and 16.989 cases, respectively [41]. Based on the investigation done by Heli et al., between 2011 and 2019, 44–53 % of cases involving dust particles included people who were 18 years old or older and had an IHD diagnosis. Furthermore, 16–25 % of every incident that was recorded were strokes. There have been 25 deaths per 100,000 people in the northern Caribbean state of Colombia among kids below the age of four due to dust storms. It contributes to 12 % of the mortality associated with ALRI in the investigated region [42].

4. Conclusion

The source, level, and health impacts of PM2.5 in Poldokhtar City in 2022 were the primary goals of this research. May shows the maximum amount of pollution in comparison to other months, as shown by the mean AQI of 162.46. It additionally has the greatest number of days with high levels of pollution, totaling 16 days. Furthermore, with an AQI score of 407 on May 17, it is assumed to be the most polluted day of the year. The difference in the average number of polluted days seems to be due to the air temperature and rainfall, so that in summer when the air temperature is high and the rainfall is low, the number of dusty days is more than the wet season. Based on the maps obtained from the HYSPLIT program, Saudi Arabia is recognized as the primary cause of dust during January, February, and August. Egypt, on the other hand, is considered the primary origin of particles in March and July, while Turkey is responsible for dust emissions in April and May. Hospitalized people who had respiratory diseases were most severely impacted by the short-term adverse effects of fine dust inhalation.

CRediT authorship contribution statement

Ali Farhadi: Investigation. **Marzieh Bayat:** Methodology. **Narges Seihei:** Investigation. **Sara Namdaryan:** Investigation. **Masoumeh Sabzian:** Formal analysis. **Ayda Sepahvand:** Writing – original draft. **Mohammad Sabzehzari:** Investigation. **Arefeh Sepahvand:** Conceptualization. **Majid Farhadi:** Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. **Bahman Kamarehei:** Conceptualization. **Fatemeh Hayatolgheib:** Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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