Sustainability and Biodiversity Conservation

Modeling of SO_2 gas pollutant emission of Arak Refinery using AERMOD model

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Abstract

The pollution of metropolises and the environments around the industrial centers is considered one of the problems in developing countries. To control air pollution, new models were made for simulation and estimation of the amounts of air dopants. AEMOD is one of the commonest models which was confirmed by the EPA. This study aimed to model the dispersion pattern of gaseous pollutant SO_2 in Arak Refinery using the AERMOD model for periods of 1, 8, and 24 hours. This study was conducted with the information of 19 chimneys related to phase 1 of this industrial unit in 2014 and 2015. The results of this study showed that the concentration of SO_2 in this industrial unit is higher than the permissible limit of Iran and EPA standards in one hour. Also, according to the seasonal average of emissions, this pollutant has the highest concentration in winter.
Keywords: AERMOD, fuel refining industries, Modeling the distribution of pollutants, SO_2 pollutant

Introduction

One of the unpleasant consequences of industrialization is air pollution. Air is the most vital substance for human life; therefore the topic of air pollution is one of the most important topics in today's industrial world (Niroomand et all, 2012). The effects of air pollution include various respiratory and skin diseases, congenital defects, physical weakness and vision loss, damage to agricultural products and ecosystems, and climate change (WHO, 2010; Wallace et al., 2018). Oil refineries are among the major sources of air pollution, which have a significant contribution to the creation of photochemical smog, greenhouse gases, and dangerous secondary pollutants (Wakefield, 2007) The most abundant sulfur oxide in nature is sulfur dioxide, which is a colorless and non-flammable gas. This gas in concentrations close to 3ppm has a nasty and irritating smell (Dabiri, 2012). The main sources of SO_2 production include power plants and industrial boilers (Hashemi, 2004). In 1992, the International Agency for Research on Cancer, classified SO_2 as a carcinogen (Pesatori et all, 2006). SO_2 is formed from the oxidation of sulfur in fuels or during industrial processes that use sulfur-containing compounds (McGranahan and Murray, 2003). To meet regulatory objectives and minimize the acute health effects of air pollutants, it is important to understand how they are dispersed in the atmosphere (Masoumi, 2012). One of the problems that industries usually face in determining the number of pollutants is that it is not always possible to measure the number of pollutants at long distances due to topography and lack of equipment. In these cases, simulation software is used to estimate the number of pollutants in different areas, and finally, the simulation results will be compared with the measurement results in the available areas (Atabi et all, 2013). In 1991, the United States Environmental Protection Agency presented a model called the American Meteorological Society and Environmental Protection Regulatory Agency Model (AERMOD) (Gibson et all, 2013). AERMOD has two processors for inputting data into this model. Meteorological data processor (AERMET) and land surface feature data processor (AERMAP) integrate the complex features of the land surface using the digital elevation model (Mohan et all, 2011; Momeni et all, 2010). This model simulates different point, surface, and volume pollutant sources (EPA, 2004). Arak Refinery, located at km 20 of the Borujerd-Shazand highway, was launched with a nominal capacity of 150,000 barrels per day. This refinery is located at an altitude of 1800 meters above sea level. The dominant wind direction of the region is southwest and the climate of the region includes cold semi-humid and cold semi-dry. According to the natives of the region, the villages around the refinery with a distance of fewer than two kilometers, such as the village of Kazaz, are much more exposed to pollutants, and they believe that the high rate of abortion and cancer in these areas is closely related to this. It has pollutants. Studies have shown the adverse effect of refinery pollutants on the agricultural products of Shazand city in some areas (Hossein Abadi, 2012).

Material and methods

The information required for modeling with AERMOD includes meteorological information, information on emission sources, and land effects. The meteorological information used in this research includes three-hour information on parameters such as wind speed, wind direction, cloud cover, relative humidity, dry temperature, rainfall, saturation point, and air pressure in the period from January 2012 to November 2017, and this information from Meteorological department of Shazand city was obtained as an Excel file. Among other meteorological information required by this software are three surface parameters of the studied area, that is; Bowan's ratio and surface roughness length and albedo coefficient are according to the type of land use of the studied area, which is a Desert shrubland; They are determined automatically by the meteorological preprocessor (Table 1).

Table (1) surface parameters used

	albedo coefficient	Bowan's ratio	surface roughness length
Winter	0.45	6	0.15
Spring	0.30	3	0.30
Summer	0.28	4	0.3
Autumn	0.28	6	0.3

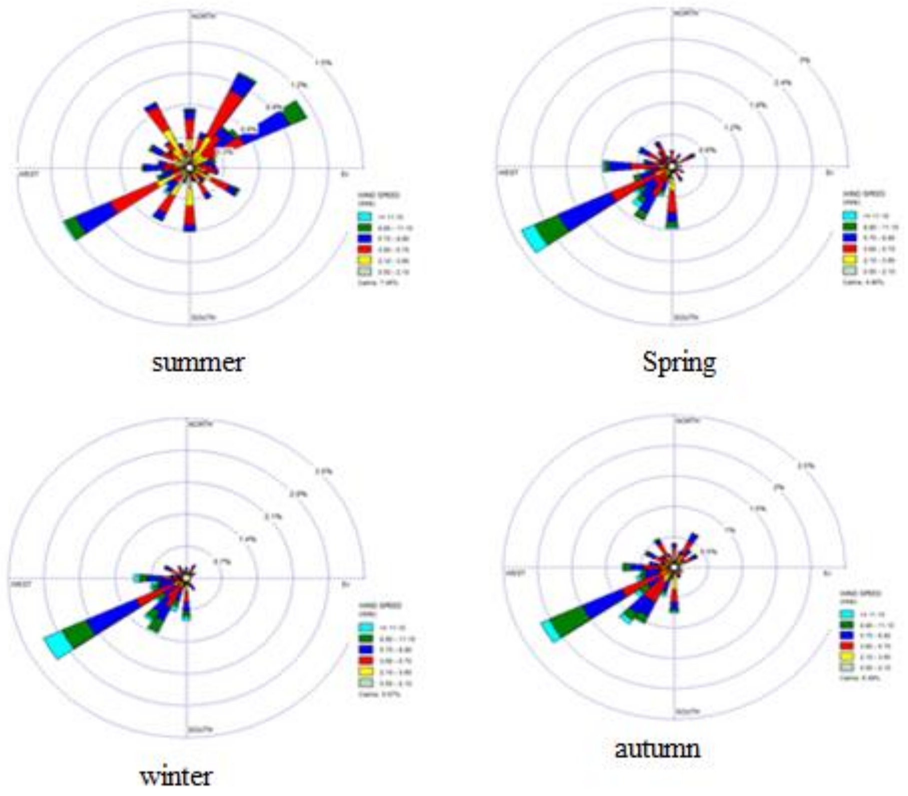

Figure 1. shows the regional wind rose. According to the climatic data of Shazand meteorological and wind rose, the dominant wind is in the southwest direction

Information on emission sources related to 19 chimneys of phase one of Arak Refinery for the years 2015 and 2016, which include; The geographical location of the chimneys, the height of each chimney, the speed of gas exit, and the temperature of the exit gas from each chimney, the internal diameter of the stack at the point of smoke exit and the emission rate of pollutants. This information was obtained from the mentioned refinery. You can see some of this information in table (2).

Table 2. Information on emission sources

chimney	Speed	temperature	Emission rate SO_2	Internal diameter m)(	m)(height
H101	9.737	416.862	830.19	4.65	49
H102	11.462	236.362	.049	1.72	12.5
H151	13.775	223.375	40.012	3.3	38
H301	13.425	378.375	0.761	2.73	49
BA	13.95	213.162	91.259	3.2	74
BB	13.437	222.775	82.195	3.2	74
BC	13.173	218.937	44.906	3.2	74
BD	13.912	218.612	19.196	3.2	74
BE	12.075	186.687	32.607	3.2	74
H630	9.037	410.175	0.012	1.52	23
H631	9.65	376.337	0.022	1.52	23
H632	8.5	357.425	0.020	1.52	23
H633	9.962	261.475	0.309	2.95	41
H701	13.987	231.687	0.746	4.05	49
H251	12.412	228.5	0.140	3.9	41
H201	12.15	266.975	0.092	1.4	34.7
H202	10.237	316	0.086	1.55	34.7
H255	9.862	273.387	0.083	1.4	36.7
IN901	7.087	315.462	222.038	2.02	66

The data related to the emission obtained with the ppm unit were available, but because the AERMOD software accepts the emission rate with the gram/second unit, therefore, the data were corrected using the following formulas.

1) $$\text{ppm} \times \frac{Mw}{22.4} = mg/m3$$

2) $$\frac{mg}{m3} \times \frac{273.15}{\text{Tg}} \times \frac{p}{760} = mg/Nm3$$

$$\frac{21-Reference\ oxygen}{21-Measured\ oxygen} \times \text{concentration (mg/Nm}^3 = \text{corrected concentration (mg/Nm}^3\text{)} \quad 3)$$

Mw: Molecular Weight(amu)

Tg: Chimney temperature(K)

p: ambient pressure*(atm)*

The reference oxygen for natural gas is 3%.

Finally, the emission rate with the unit of grams per second was obtained by calculating the flow rate with the scale of cubic meters per second and multiplying its values for each of the pollutant concentrations coming out of the chimney with the scale of micrograms per cubic meter. A map with NED/SRTM GeoTIFF format was also used to determine the topographic features of the region. Figure (2) shows the topography of the studied area.

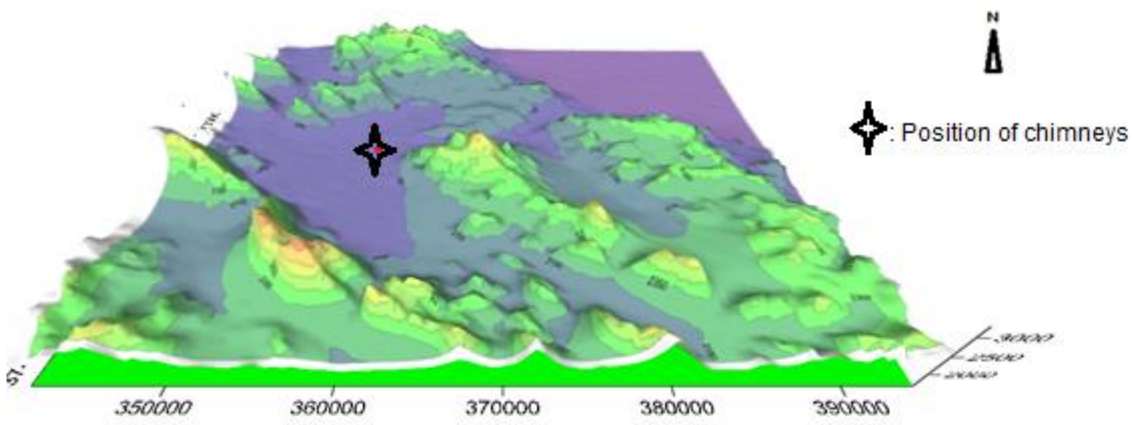

Figure 3. topographical situation of the area

Finally, by providing the required information, modeling of the distribution of SO_2 in Arak Refinery was done using the AERMOD model for maximum concentrations of 1, 8, and 24 hours for the four seasons of the year.

Results

Figures (3) to (5) show the emission of SO_2 pollutants with the highest concentration for each period. As can be seen from the graphs, the pollutants have spread in almost all directions of the source, but their main spread was in the direction of the dominant wind and also in the southeast of the sources. Here, as the period increases, the volume of pollutants decreases and most of the concentrations occur near the sources.

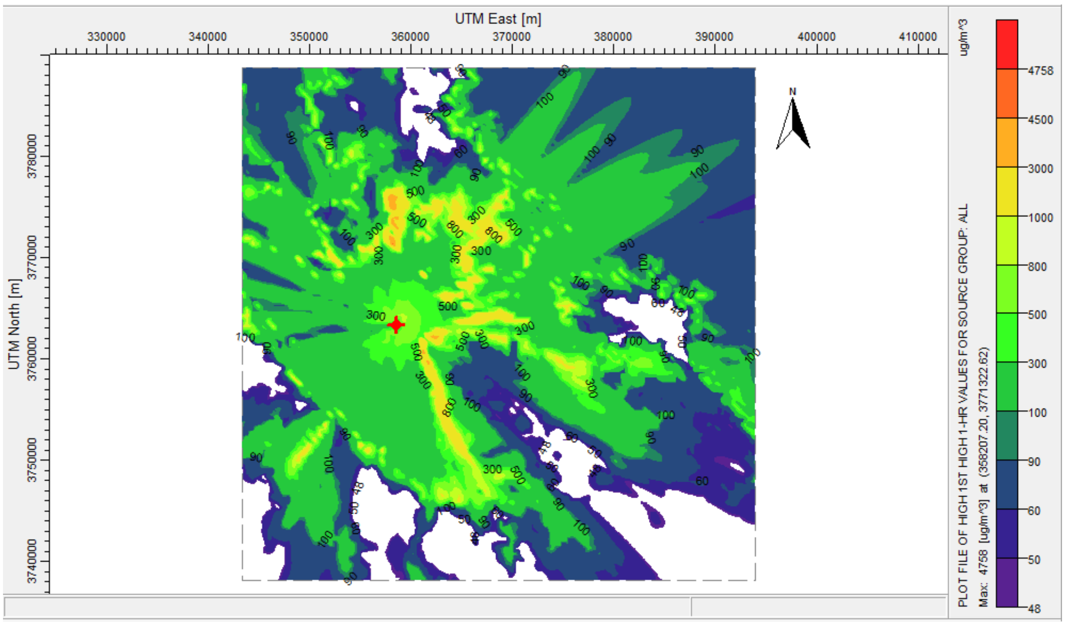

Figure 3. maximum one-hour concentration of SO_2

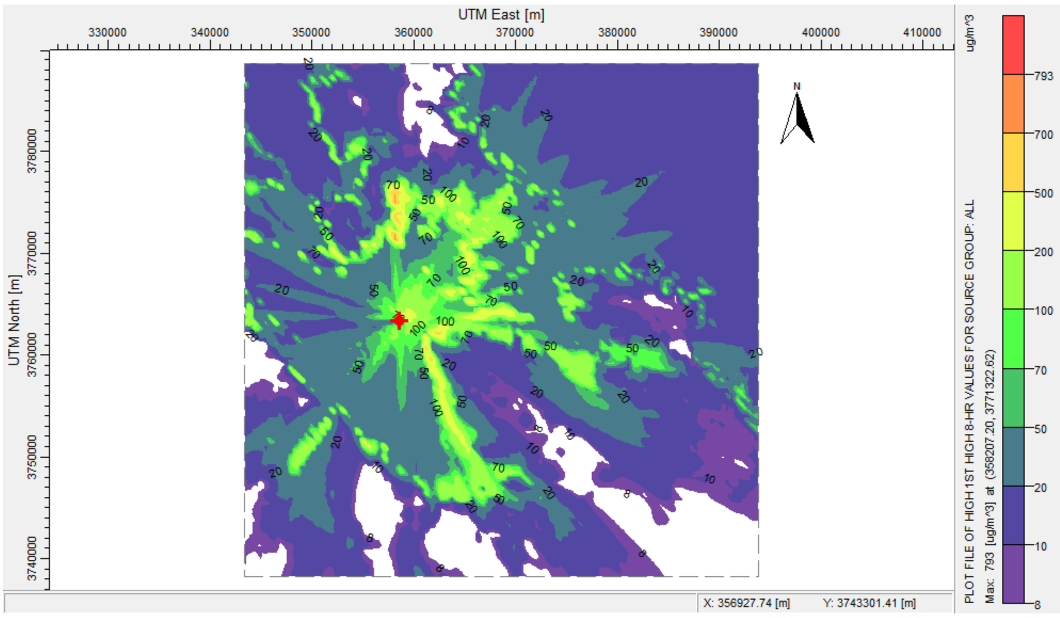

Figure 4. maximum eight-hour concentration of SO_2

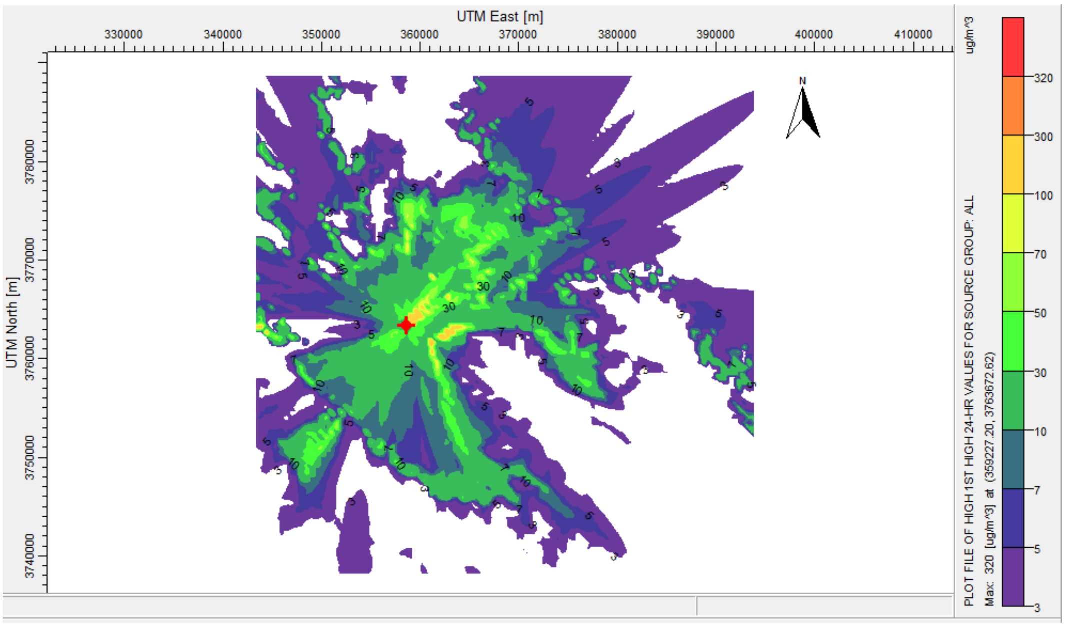

Figure 5. The maximum 24-hour concentration of SO_2

Figure (6) shows that the highest concentration is for the period of 1 and 8 hours and in winter. The highest 24-hour concentration occurred in autumn. The lowest concentrations are related to the spring season.

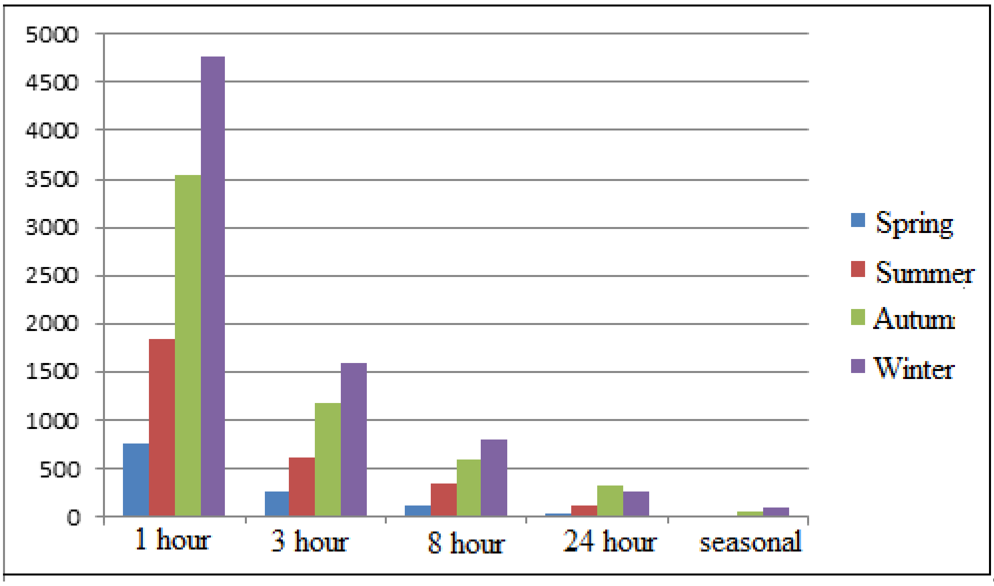

Figure 6. Comparison of maximum SO_2 concentrations in different seasons

According to Table (3), the amount of SO_2 in one hour is equal to 2721.546 micrograms per cubic meter, equivalent to 1040 ppb, which is much higher than the standards. But in 24-hour concentrations, it is lower than the permissible limit.

Table 3. comparison of maximum concentration of SO_2 with air quality standards in Iran and EPA

pollutant	Period	Iranian standard g/m³) µ(	Max concentration of Arak Refinery g/m³) µ(	EPA standard	
				primary	Secondary
SO_2	1 Hour 24 hours	196 395	2721.546 184.45	75 Ppb –	– –

Discussion

The SO_2 modeling of Arak Refinery shows that in hourly intervals, due to the complex topography and the presence of mountain ranges around the refinery, the maximum concentration is not definitely a function of the dominant wind and is also affected by local winds But in general, in cold seasons, it is more affected by dominant winds. In a way that the concentration of SO_2 that reaches Arak city is higher than the permissible limit and its environmental consequences cannot be ignored. According to the meteorological and topographical conditions of the region and the location of the chimneys, there are always concentrations of pollution in the refinery and its surroundings, which will undoubtedly affect the health of the employees. Also, near this refinery, there are villages such as Kazaz and Ali Abad, Jamal Abad, Gadhamgah, Bagh Bar Aftab, cities such as Mohajer and Shazand, and many agricultural lands where the pollutants of this refinery and other industries such as petrochemical and Arak thermal power plant can bring adverse effects on human societies, plants, and animals in these areas. Due to the high emission rate of pollutants, it is better to reduce the amount of production of the refinery to reduce its pollution load. It is suggested to use non-sulfur liquid fuel in boilers and heaters and gas purification in the sulfur recovery unit.

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