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Modeling the distribution of pollutants caused by gas refinery flares with AERMOD software (South Pars Gas Complex Company)

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Abstract

In this research, data obtained from sources of pollution (stack and flares), and meteorological and physical information of stack and flares of South Pars Gas Complex Company were used in the AERMOD model and the results were analyzed in GIS software. The results showed that the amount of carbon monoxide in the autumn and winter seasons of 2020 and the summer of 2021 was higher than the standard range, and the amount of SO_2 in all seasons was above the standard range. Also, regarding the areas affected by pollutants in the studied years, it was observed that the amount of emissions and areas affected by pollution in 2020 was higher due to CO and SO_2 pollutants. In examining the radius of influence of CO in 2020, the highest amount was in the northern and eastern directions from polluting source. Also, for the radius of influence of NO_X in the year 2021, the maximum amount of pollutant emission was in the eastern region, which reached about 7.5 micrograms per cubic meter. In the study of the radius of influence of SO_2 in 2020, the emission rate of pollutant in all directions was about 3 micrograms per cubic meter and the same was recorded for SO_2 in the year 2021. We concluded that with the available data for air quality measurement models and tools, we could provide appropriate management solutions to control and reduce the effects of air pollutants in the studied refinery. In other words, air pollution distribution models are relatively easy to implement and very useful to monitor and investigate the spread and distribution of pollutants and assess their impact on air quality. These models also provide means for adoption of suitable air pollution prevention and reduction strategies towards reduction of flaring and better environmental protection.

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Introduction

Oil and natural gas are the world's largest primary sources of energy, and source emissions from these fuels can produce a lot of pollution and environmental concerns. Emissions at the production stage are of particular concern due to the proximity of local populations to large volumes of emissions (Dos Santos Cerqueira & et al, 2022).

Torches are utilized as components of installations within chemical and petrochemical refinery facilities to incinerate flammable gases through combustion (Aliyarpour, 2020). Torch-burning stands as a widely adopted solution for disposing of unwanted flammable gases that are not economically feasible to utilize (Asadollah Fardi et al., 2016). Despite being a form of air pollution control device, torches themselves serve as sources of pollutants such as nitrogen oxide, hydrogen sulfide, and sulfur dioxide (Mohammadzadeh et al., 2021). They are recognized as significant contributors to air pollution in oil and refinery facilities, emitting substantial quantities of harmful pollutants into the atmosphere. This issue has multifaceted impacts on the ecosystem and, in addition to greenhouse gas emissions, exerts diverse effects on the environment (Vahabpour et al., 2018).

In oil tanks, a certain amount of natural gas exists in a fluid solution form. This natural gas, referred to as associated gas or flare gas, is produced alongside oil extraction and essentially constitutes a byproduct of oil production. The predominant component of associated gas (approximately 70 to 80 percent) is methane, with smaller proportions of ethane, propane, and even heavier hydrocarbons. It often contains traces of carbon dioxide and sulfur-containing compounds. Despite its relatively high calorific value, the handling or utilization of this gas is typically neglected in oil fields. In many instances, this gas is flared at the production site due to safety concerns, excessive venting, impracticality, remote extraction sites, high transfer costs, and other reasons (World Bank, 2021). In oil and gas refineries, torches are employed to burn organic compounds in waste and undesirable gases during start-up, shutdown, maintenance, process interruptions, and other operational phases (Tanzania, 2018).

According to the latest data from the World Bank in 2021, over 140 billion cubic meters of gas are flared globally annually. The energy contained in this volume of gas is equivalent to approximately 2.5 million barrels of crude oil per day. To put this energy loss into perspective, it's noteworthy that the global daily average crude oil production in the same year was around 80 million barrels (World Bank, 2021).

Beyond resource wastage, the pollution resulting from flare gas combustion has profound and sometimes irreversible environmental consequences. Notably, it contributes to greenhouse gas emissions and severe air pollution in regions with significant oil production. The burning of these gases releases more than 400 million tons of CO_2 into the atmosphere each year, which is equivalent to the emissions from 77 million passenger cars. This volume of CO_2 accounts for 1.2% of total CO_2 emissions from primary hydrocarbon sources (Elvidge et al., 2017 & Farina et al., 2018).

Measuring pollutants from flaring is challenging as these pollutants disperse over large areas and are not confined to specific emission points (Zarandi et al., 2021). Therefore, conventional methods for measuring emissions from chimneys are unsuitable for estimating the pollutants produced by flares, making accurate assessments difficult (Tanzaziari, 2018).

To mitigate pollution effects, particularly in regions with multiple pollution sources, evaluating, modeling, and estimating pollutant concentrations and their impact on the environment over time are scientific and logical methods (Aliyarpour, 2020). Modeling the distribution of air pollutants involves predicting how one or more pollutant sources affect the environment (Momeni et al., 2011). Such models rely on mathematical and physical relationships based on scientific principles to determine pollutant concentrations at receptor points (Demirarslan et al., 2017). Furthermore, studying the behavior of pollutant emissions during dispersion helps ascertain complex time-dependent concentration patterns at various locations and distances from the emission source, providing valuable insights for industrial environment design and safety (Rahimi et al., 2021).

AERMOD stands out as one of the most widely used and powerful software for modeling the distribution and concentration of pollutants from diverse sources (Momeni et al., 2011). It operates as a steady-state air dispersion model, employing Gaussian dispersion theory to predict pollutant concentrations within the stable boundary layer horizontally (Motalebi Damuchali & Guo, 2020). Simulation with AERMOD considers two key parameters: pollutant transport and dispersion from surface, volume, and point sources, necessitating up-to-date data for accurate modeling (Iranian, 2020). AERMOD is frequently utilized by environmental agencies and organizations to investigate, manage, predict, and estimate pollutants in various regions (Dame et al., 2017).

The Assaluyeh region in Iran is the focus of many environmental science experts due to the concentration of oil and gas industries, and air pollution is one of the challenges facing this region. Therefore, efficient control and reduction of air pollutants more has been at the forefront of the programs of the relevant organizations. As the first step in achieving the above goal is to determine the emission rate and identify the distribution of pollutants in the region, this important issue has been addressed in the present study. Hence, the distribution of pollutants in the 9th refinery of Assaluyeh South Pars Gas Complex was selected for modeling using AERMOD software Accordingly, the purpose of this study was to determine the distribution of pollutants caused by torch burning in the 9th Refinery of South Pars Gas Complex of Assaluyeh, and the following two minor objectives were also examined:

- Determination of the most important range of cumulative effects due to the distribution of pollutants caused by the burning in the study site, and
- Determination of pollutants caused by the torch burning in the study site in different seasons.

Materials and Methods

Considering the importance of the study and the effects of pollution caused by the activities of refineries in the Assaluyeh region, the 9th refinery of the South Pars Gas Complex was selected. The required data for modeling the air pollutants of flue and flares included meteorological and physical information of chimneys and flares. With the data at hand, the model provides outputs. In the process the following is conducted:

1. Identification of the industry processes through literature review and studying of reports.
2. Determining the data required as input of the model.
3. Preparation of the required information including meteorological information, topography, and sources of pollution and validation of the results.

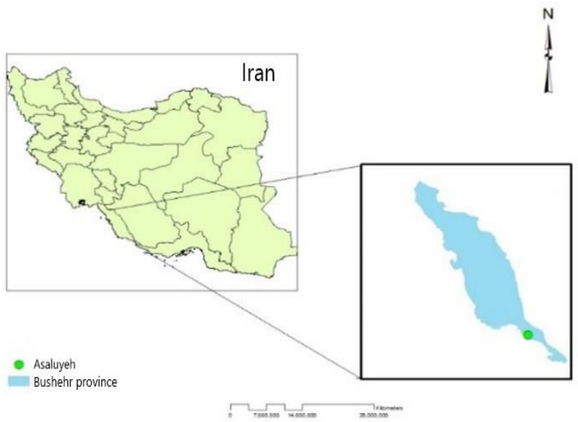


Figure 1. Location of the 9th Refinery of South Pars Gas Complex in Bushehr Province

The refinery in question is the ninth refinery of the South Pars Gas Complex which has been implemented in the 12th development plan. The Phase 12 of gas field is located in the southeast bloc of the South Pars gas field in the border line with Qatar with an area of about 206 square kilometers, with dry natural gas estimated at 21 trillion cubic feet. The offshore facility is located about 150 km from the coast, and the onshore facilities of this are located in the area of Tombak (65 km east of Assaluyeh). This phase with in-situ reserves equivalent to 600 billion cubic meters accounts for about 5% of the South Pars gas field's reserves. The natural gas produced in this phase is transported from the seabed to the refinery around Tombak located 15 km east of Kangan.

Modeling of air pollution distribution

Modeling of air pollutants is conducted through a mathematical formula estimating the effects of pollutants from one or more sources of emissions within a given range. The effective factors on displacement, dilution, and dispersion of pollutants can be divided into the following groups:

- Pollutant’s emission characteristics.
- Pollutant’s nature and characteristics.
- Meteorological parameters.
- Impacts on earth and human installations.

AERMOD is a comprehensive air pollution dispersion system consisting of three modules:

1. AERMET: This module processes surface meteorological data, altimetry, upper atmospheric data, and optionally, station measurements. AERMET calculates essential atmospheric parameters required for atmospheric diffusion equations, such as air turbulence, mixing height, friction velocity, Monin-Obukhov length, and surface thermal flux.
2. AERMAP: The primary purpose of this module is to establish a physical connection between surface terrain and the behavior of air pollutants. AERMAP uses digital elevation model (DEM) files as input data to preprocess information.
3. AERMOD: This module models the dispersion of atmospheric pollutants within a distance of less than 50 kilometers from emission sources in urban and rural industrial areas.

In general distribution models require three types of input data: meteorological data, topography of the study area, and the rate of pollutant emission. The overall structure of the AERMOD modeling system is shown in Figure 3:

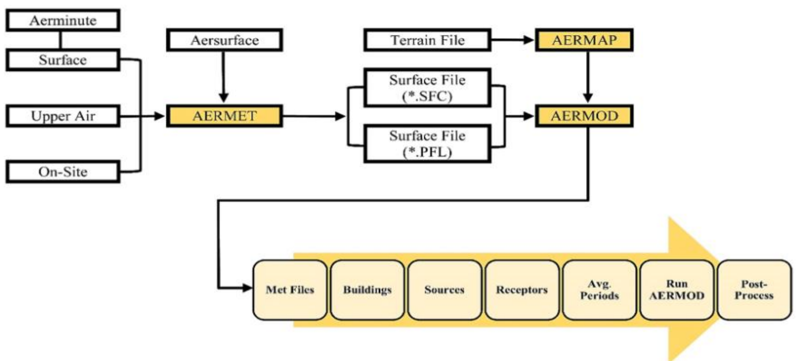


Figure 2. Overall structure of AERMOD software (Dos Santos Sarquira et al., 2018)

Input information to the model

Meteorological data: To use the AERMOD in modeling air pollutants from the 9th Refinery of South Pars Gas Complex, meteorological data from Assaluyeh station and the prevailing wind direction of the region were used.

Table 1. Specification of Assaluyeh Synoptic Station

Station Type	Latitude	Longitude	Established Year	Elevation above sea level
Asaluyeh Synoptic	49.16188	30.55619	1340	1248

To prepare the required meteorological data, weather data on the lower and upper synoptic station of the Assaluyeh area, which is the nearest station to the selected refinery was used with its characteristics being shown in Table 1.

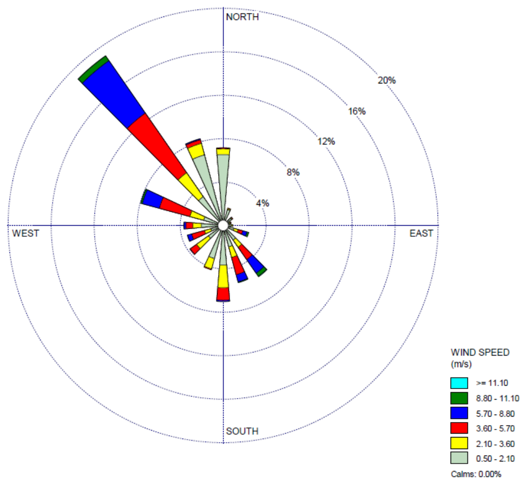


Figure 3. Windrose of Assaluyeh synoptic station in 2020

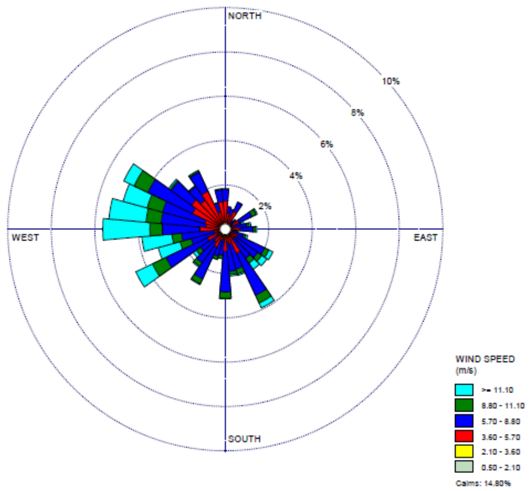


Figure 4. Windrose of Assalouyeh synoptic station in 2021

In the wind analysis for the year 2020, it was observed that 7% of the winds were calm, while the remaining 93% had both direction and speed. Among these winds, approximately 10% were coming from the northwest direction. Within this ten percent, around 8% fell within the speed range of 6 to 8 m/s in the northwest direction.

In the analysis of 1400 winds, it was noted that 14.8% of the winds were calm, and the remaining 85.2% had both direction and speed. Among these winds, about 8% were characterized by speeds ranging from 6 to 8 m/s, and they were blowing from the west direction.

The specifications of the exhaust from chimneys of the 9th refinery of South Pars Gas Complex Phase 12 were estimated, presented in Table 2.

Table 2. Required data for AERMOD modeling of the 9th Refinery of South Pars Gas Complex Phase 12

Flare/Chimney	Height (m)	Diameter (m)	Speed (m/s)		Temperature (Kelvin)	
			1399	1400	1399	1400
1	40	3.5	11.56	11.56	465	565
2	90	2.5	12.35	12.35	768	658
3	30	2.4	9.5	9.5	680.5	520.6
4	40	0.27	17.8	17	112.5	112.5

Figure 5. Location of the studied refinery

Research Results

The results of monitoring pollutants caused by flue and flares in the 9th refinery of South Pars Gas Complex Phase 12 are compared with the values of the existing standards and presented in figures 6, 7, and 8.

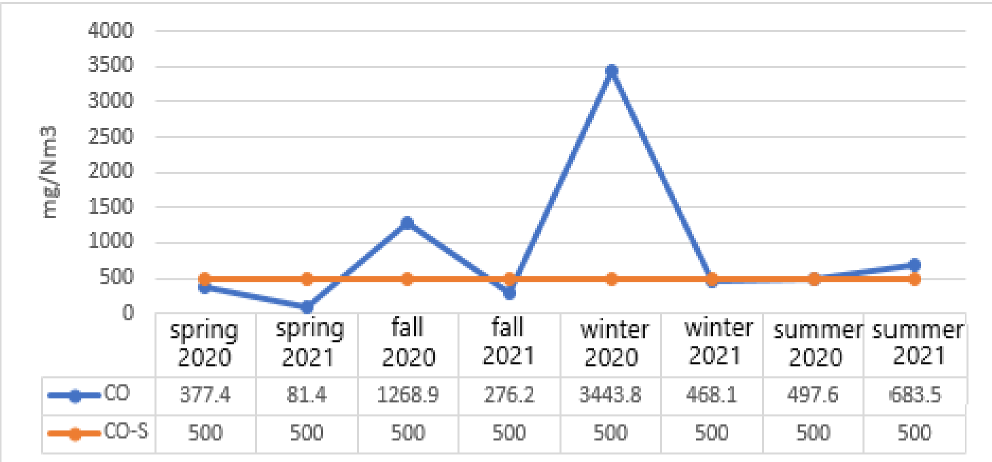


Figure 6. Comparison of seasonal carbon monoxide emissions in 2020 and 2021

Comparing the seasonal carbon monoxide emissions in 2020 and 2020 with standard values showed that the amount of carbon monoxide in autumn and winter of 2020 and summer 2021 was higher than the standard range.

In comparison of seasonal nitrogen oxide emissions in 2020 and 2021 with standard values, it was found that these values in all seasons were lower than the standard range.

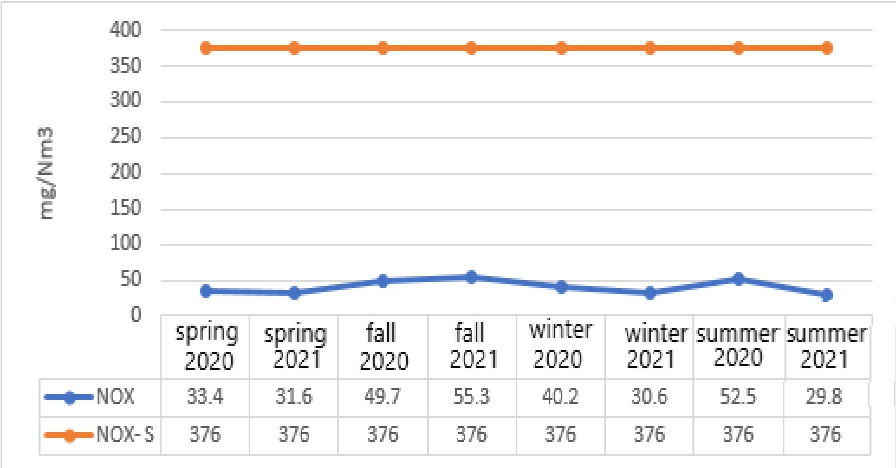


Figure 7. Seasonal emission of Nitrogen Oxide in 2020 and 2021

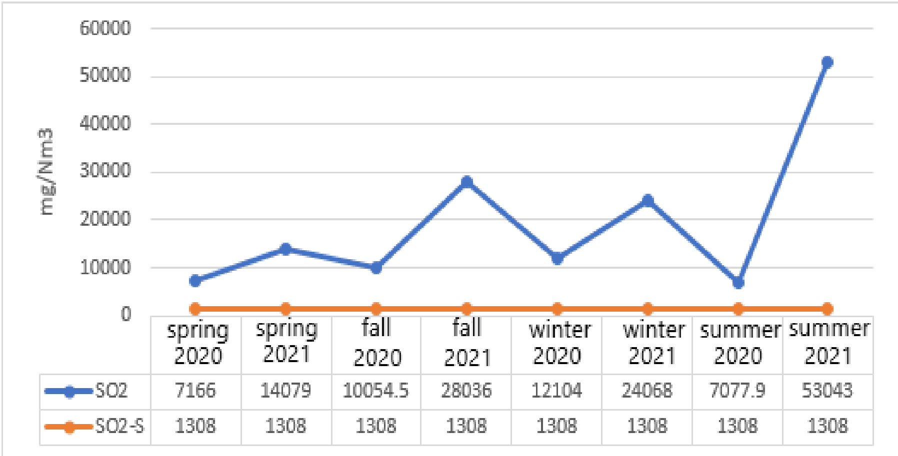


Figure 8. Comparison of seasonal emissions of Sulfur Dioxide in 2020 and 2020

In the comparison of the seasonal emissions of sulfur dioxide in 2020 and 2020 with standard values, it was found that the amount of sulfur dioxide pollutants in all seasons was higher than the standard range.

Results of CO Pollutant Modeling

According to the hourly and 8-hour carbon monoxide (CO) emissions standard, modeling the dispersion and dispersion of this pollutant is shown as a maximum hour and eight-hour in Figures, 9 to 14.

The maximum hourly concentration of carbon monoxide from the activities of the 9^{th} refinery of South Pars Gas Complex in 2020 and 2021 was 5.306 and 11.553 µg/m3, respectively, which is less than the standard hourly limit (40000 µg/ m3). Also, the maximum 8-hour concentration in the mentioned years was estimated to be 39.175 and 5.793 µg/m3, respectively, which is less than the standard 8-hour range (10000 µg/m3). The maximum annual concentration of this pollutant in 2020 and 2021 was between 2.28 and 8.481 µg/m, respectively.

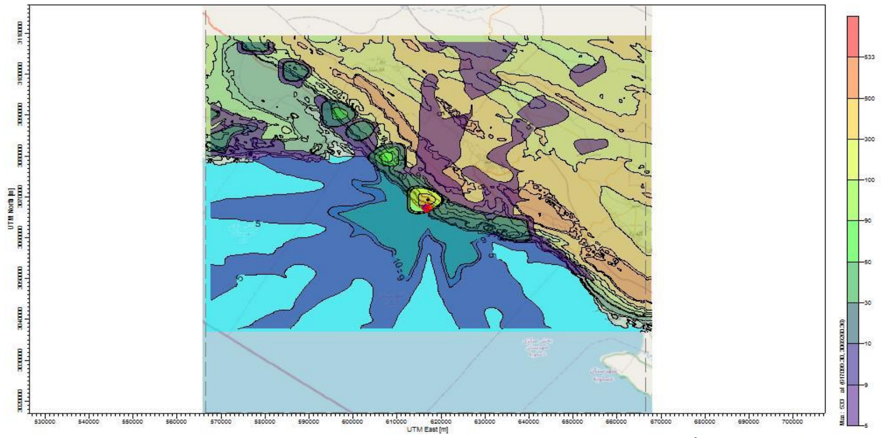


Figure 9. One-hour carbon monoxide emissions of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

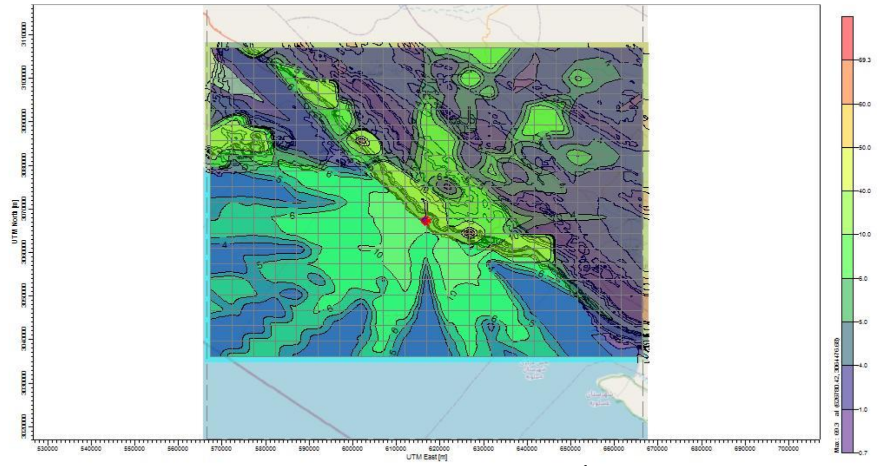


Figure 10. Carbon monoxide emissions of 9th refinery of South Pars Gas Complex, Phase 12 in 2021

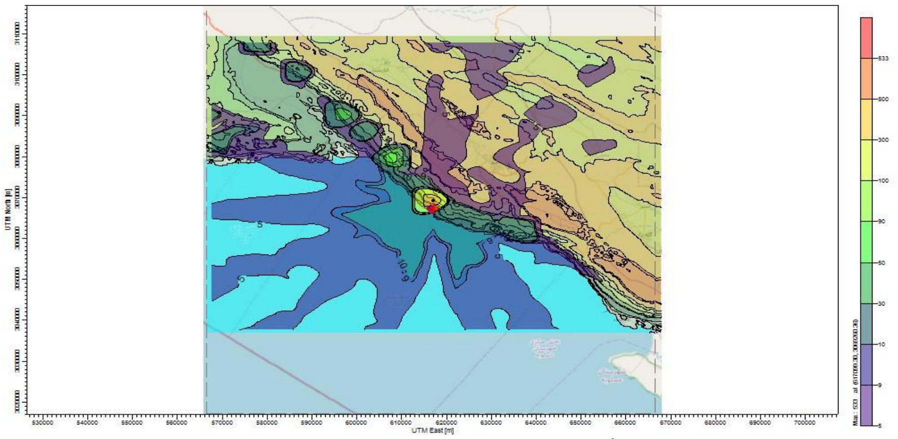


Figure 11. Emissions of 8-hour carbon monoxide in 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

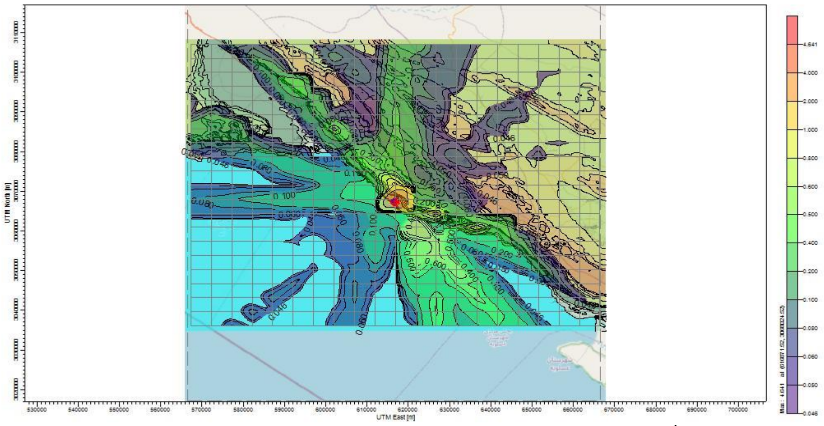


Figure 12. The 8-hour carbon monoxide emission of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2021

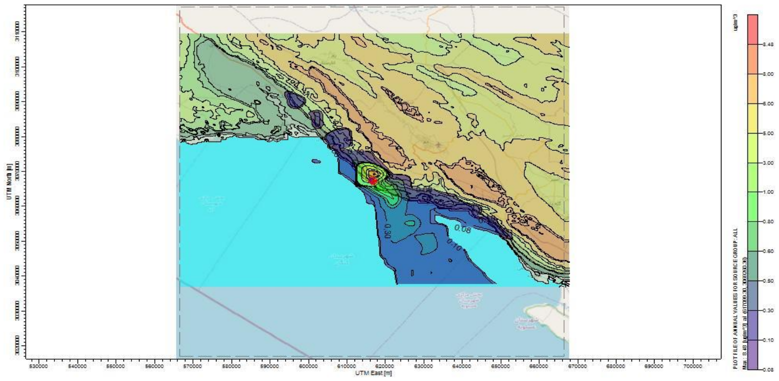


Figure 13. Annual carbon monoxide emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

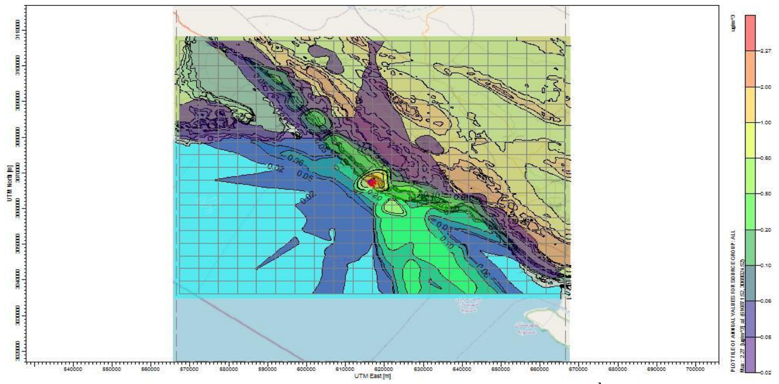


Figure 14. Annual carbon monoxide emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2021

Results of NOx Modeling

According to the hourly and annual standard of nitrogen oxide (NO_X), hourly and annual modeling of the distribution and dispersion of this pollutant is shown in Figures 15 to 18.

The maximum hourly concentration of nitrogen oxides caused by the 9th refinery of South Pars Gas Complex was 12.197 and 2.434µg/m3 respectively in 2020 and 2021 µg/m3 which is far from the hourly standard (200 µg/m3). The annual concentration of this pollutant was 8.809 and 9.785 µg/m3, respectively in the mentioned years, which is less than the standard annual limit (100 µg/m3).

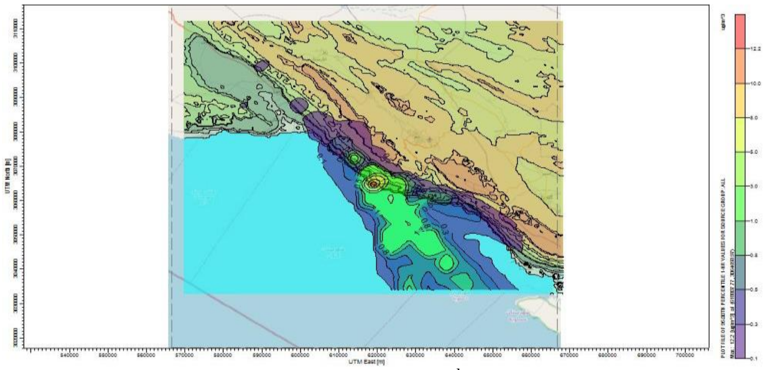


Figure 15. Nitrogen oxides emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

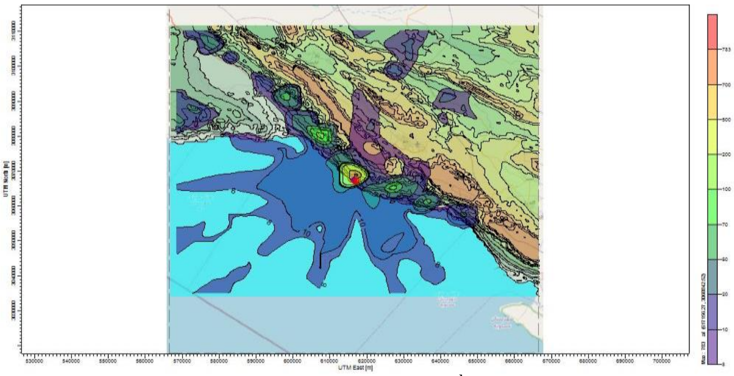


Figure 16. Nitrogen oxides emission of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2021

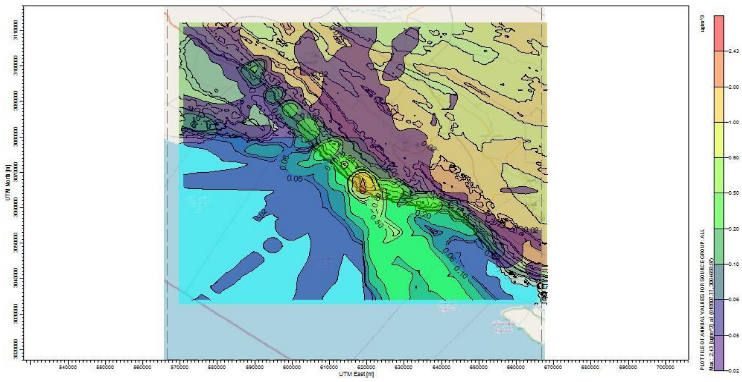


Figure 17. Annual nitrogen oxides emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

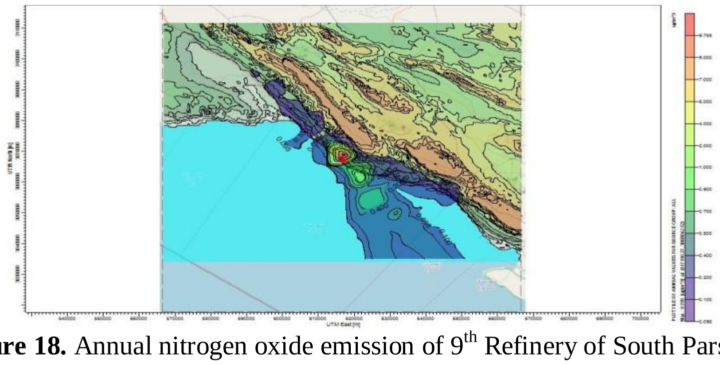


Figure 18. Annual nitrogen oxide emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2021

Results of SO2 Modeling

According to the hourly and annual standard of sulfur dioxide (SO2), the maximum and 24-hour modeling of the dispersion of this pollutant is shown in Figures 19 to 21.

The maximum hourly concentration of sulfur dioxide from the 9th refinery of South Pars Gas Complex in 2020 and 2021 was between 14.413 and 13.463 µg/m3, respectively, which is less than the hourly standard of this pollutant (196µg/ m3) and the maximum annual concentration in the mentioned years was between 2.947 and 2.782 µg/m3, respectively, which is less than the 24-hour standard of this pollutant (95 3 µg/m3).

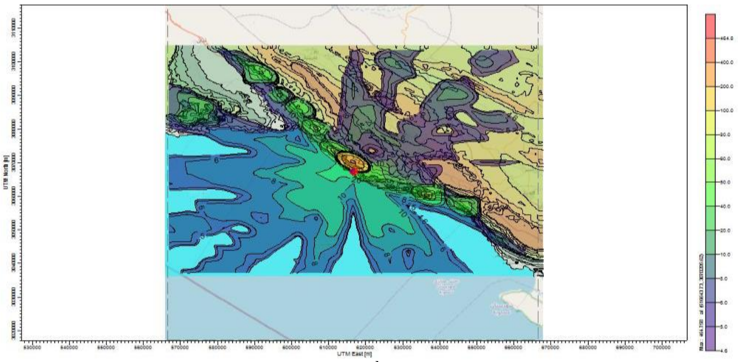


Figure 19. Sulfur dioxide emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

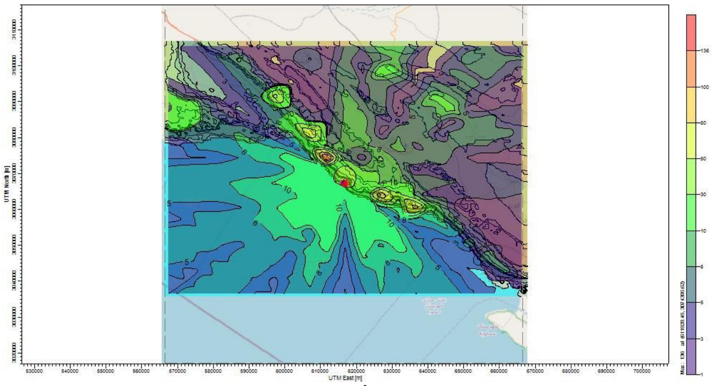


Figure 20. Sulfur dioxide emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2021

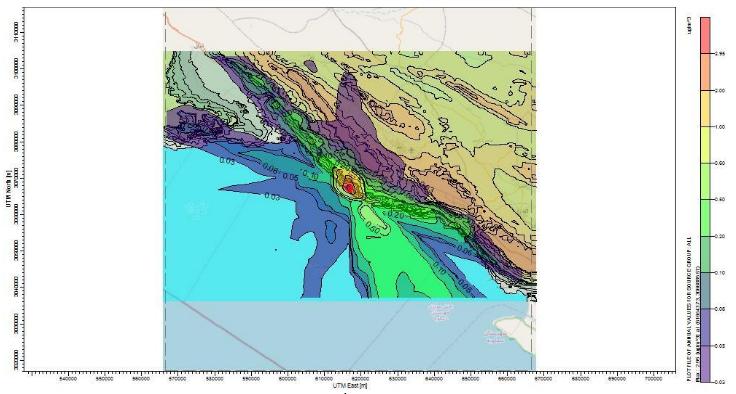


Figure 21. Sulfur dioxide emission of 9th South Pars Gas Complex, Phase 12 in 2020

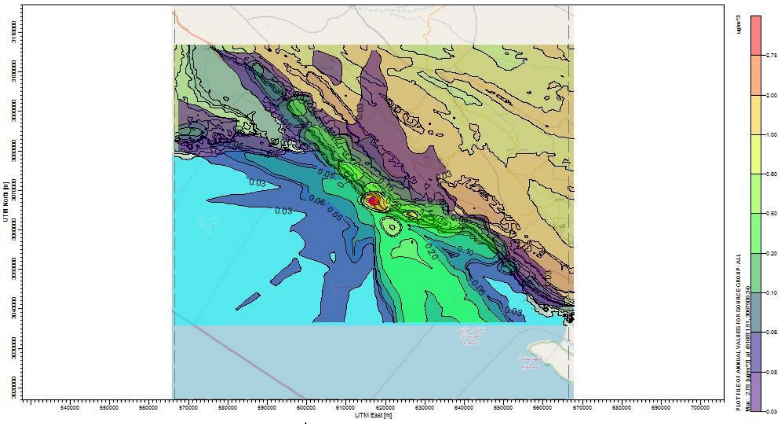


Figure 22. Sulfur dioxide emission of 9th Refinery of South Pars Gas Complex, Phase 12 in 2021

Table 3. Results of modeling using the distance of maximum pollution points from the studied refinery.

Pollutants	One hour. (μg/m^3)	X	Y	Monthly hours. (μg/m^3)	X	Y	Annual (μg/m^3)	X	Y	Distanc e(m)
CO2020	5.306	617099	3069260	39.175	617099	3069260	8.481	617099	3069260	1800
CO2021	11.553	616871	3068715	5.793	616871	3068715	2.272	616871	3068715	1400
NO_X 2020	12.197	618807	3064658	8.657	618807	3064658	2.434	618807	3064658	3000
NO_X 2021	8.809	618807	3064658	5.873	618807	3064658	9.785	618807	3064658	4500
SO_2 2020	14.413	618871	3067506	11.564	618871	3067506	2.947	618871	3067506	100
SO_2 2021	13.463	618871	3067506	9.543	618871	3067506	2.782	618871	3067506	600

Summary of the results of modeling pollutants NO_X, SO^2 and CO in 2020 and 2021 is shown in Table 3.

Results of Zoning Pollutants Caused by Burning Fuel in 9th Refinery

In this section, the model output in the form of zoning and GIS layers showing overlap with the area for the years 2020 and 2021 are presented in Figure 23. As shown in Figure 23, most of the areas around the 9th Refinery are affected by pollution caused by the burning of the refinery, which affects the population working in this area.

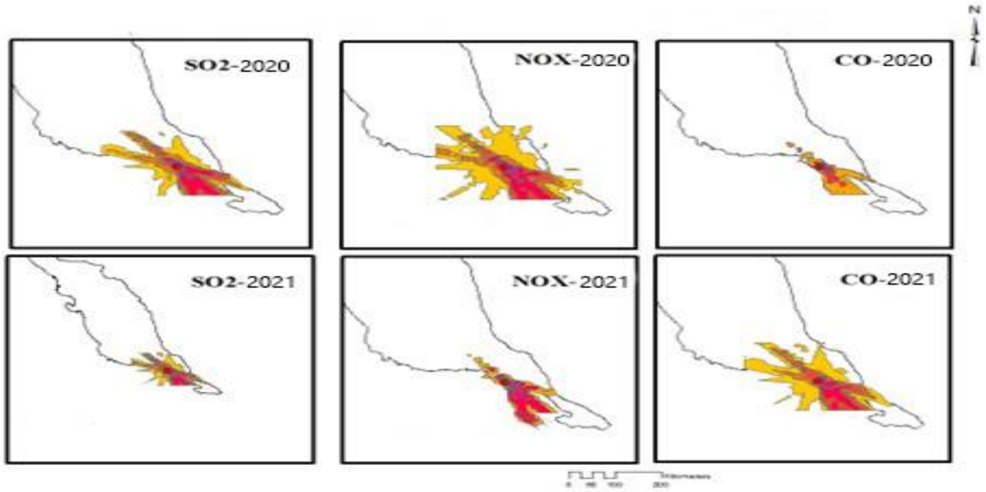


Figure 23. Emission of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2020 and 2021

Results of the cumulative effect of contaminants from torch burning

The results of this section were acquired using the distance from the emission source in the AERMOD model, prepared for 4 main directions around the source of the emission (Figure 24).

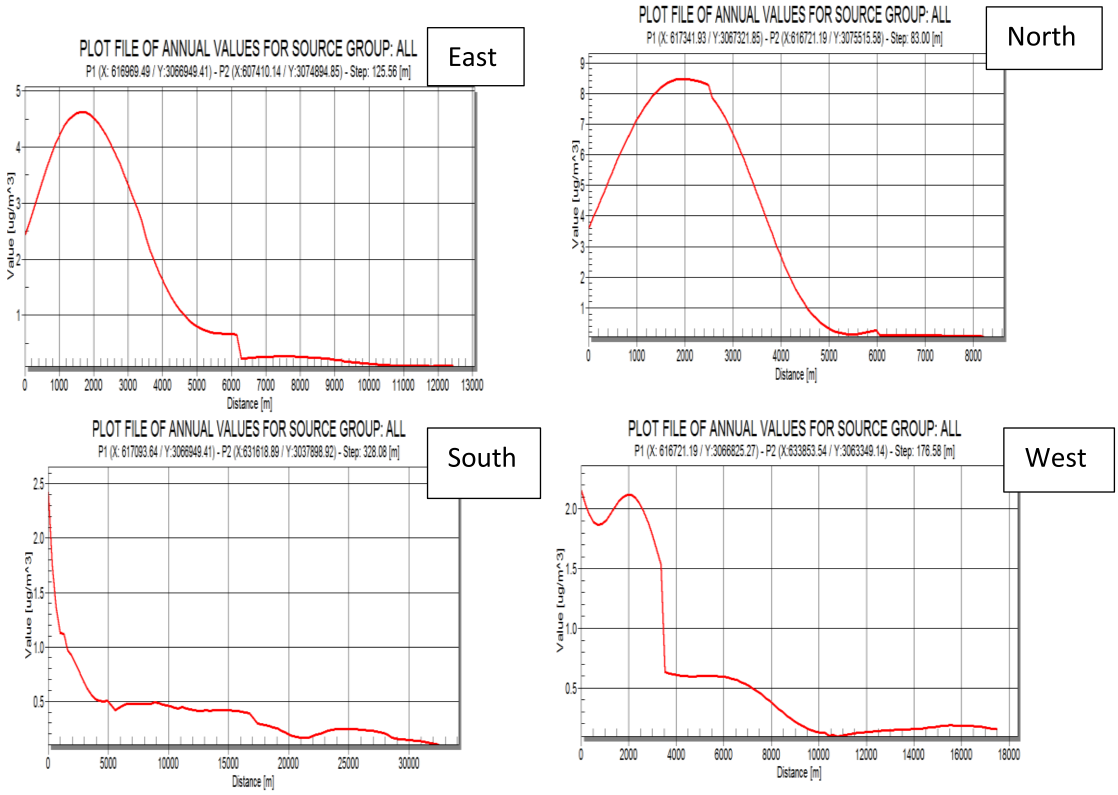


Figure 24. CO^2 emission radius in 4 main directions of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

In 2020, the AERMOD model's output indicated that pollutant dispersion in the eastern and northern directions increased up to 2000 meters from the emission source. Afterward, there was a decreasing trend, and at a distance of 5000 meters, the emission values of this pollutant reached zero. In the southern direction, the pollutant emissions started decreasing right from the source and reached zero at approximately 30,000 meters. It's worth noting that the pollutant release in the southern part is directed towards the sea (Figure 25).

In the 2021 study of the radius of carbon monoxide pollutant dispersion, using the output of the AERMOD model in the eastern, western, and southern directions, it was observed that pollutant emissions had decreased. Within a distance of 5000 meters, pollutant levels dropped below 0.5 µg/m3. In the northern direction, pollutant levels initially increased up to 3000 meters and then followed a decreasing trend. Notably, emissions of this pollutant in the south and west were directed towards the sea. Emissions were consistent in all directions around the pollutant source (Figure 26).

On the western side, the pollutant emissions increased up to 3000 meters, decreased slightly at 3800 meters, maintained a similar trend up to 7000 meters, and then gradually decreased beyond 8000 meters. Similar to the southern direction, emissions of pollutants in the western part are also directed towards the sea. The highest emission of this pollutant was observed in the northern and eastern directions, originating from the pollutant source itself.

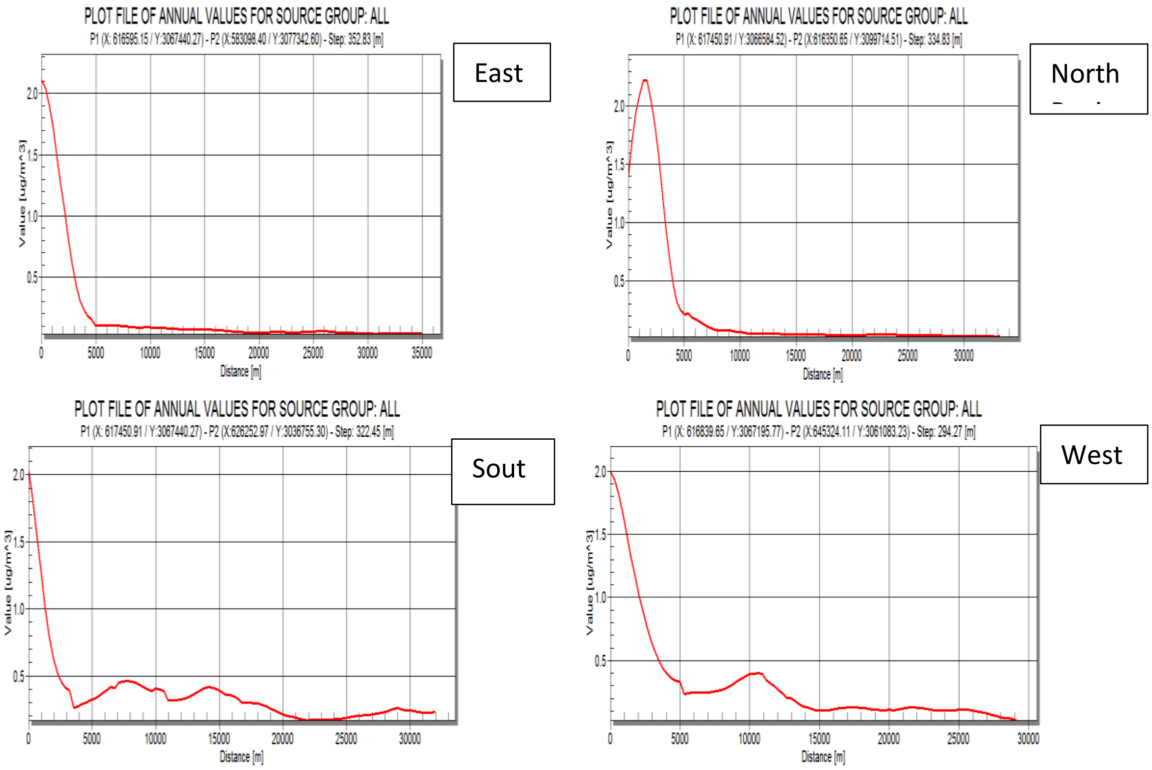
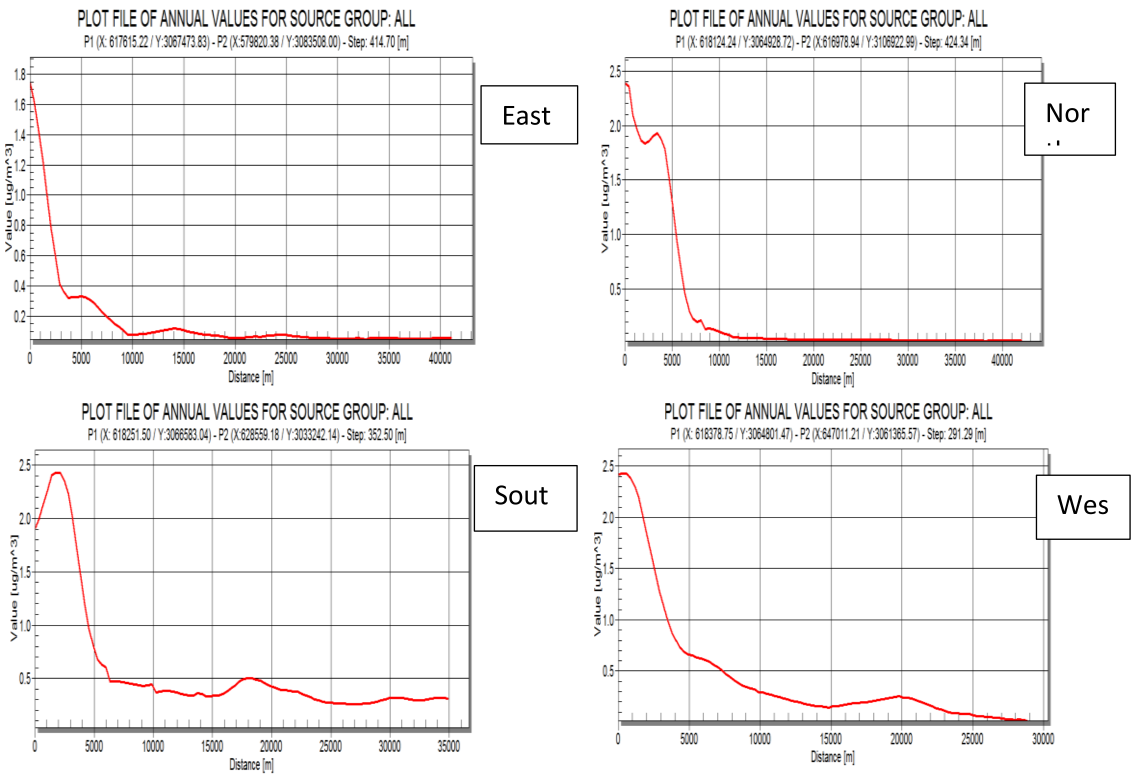


Figure 25. The radius of CO^2 emissions in 4 main directions of the 9th Refinery of South Pars Gas Complex, Phase 12 of 2021



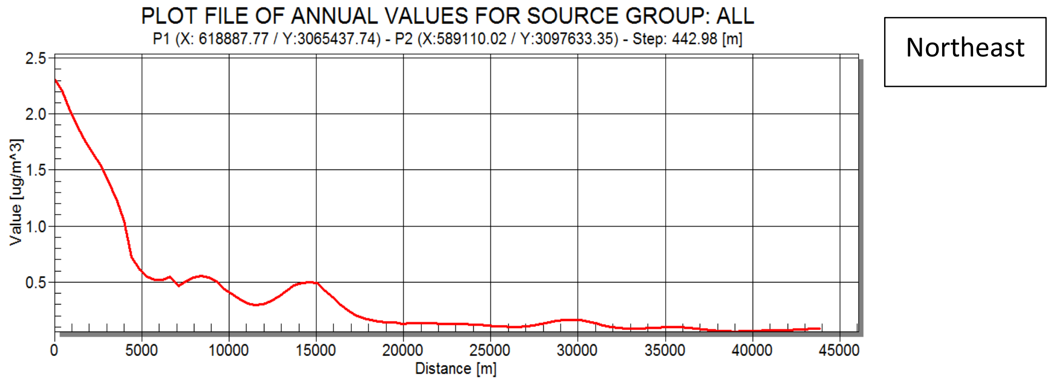


Figure 26. NO_X emission radius in 4 main directions of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

In 2020, the radius of nitrogen oxide pollutant dispersion, as predicted by the AERMOD model, showed a decrease in emissions in the eastern, northeastern, and northern directions. Emissions reached zero within an 8000-meter range in the east and north. In the northeastern direction, pollutant levels decreased from about 5000 meters to 20000 meters to approximately 0.5 µg/m3, and then dropped to zero beyond 20000 meters. Conversely, in the western and southern directions, emissions initially increased up to 3000 meters and subsequently exhibited a decreasing trend, with levels falling below 0.5 µg/m3 within approximately 5000 meters from the source. It's important to note that emissions in the southern and western parts were directed towards the sea, and emissions were consistent in all directions around the source (Figure 27).

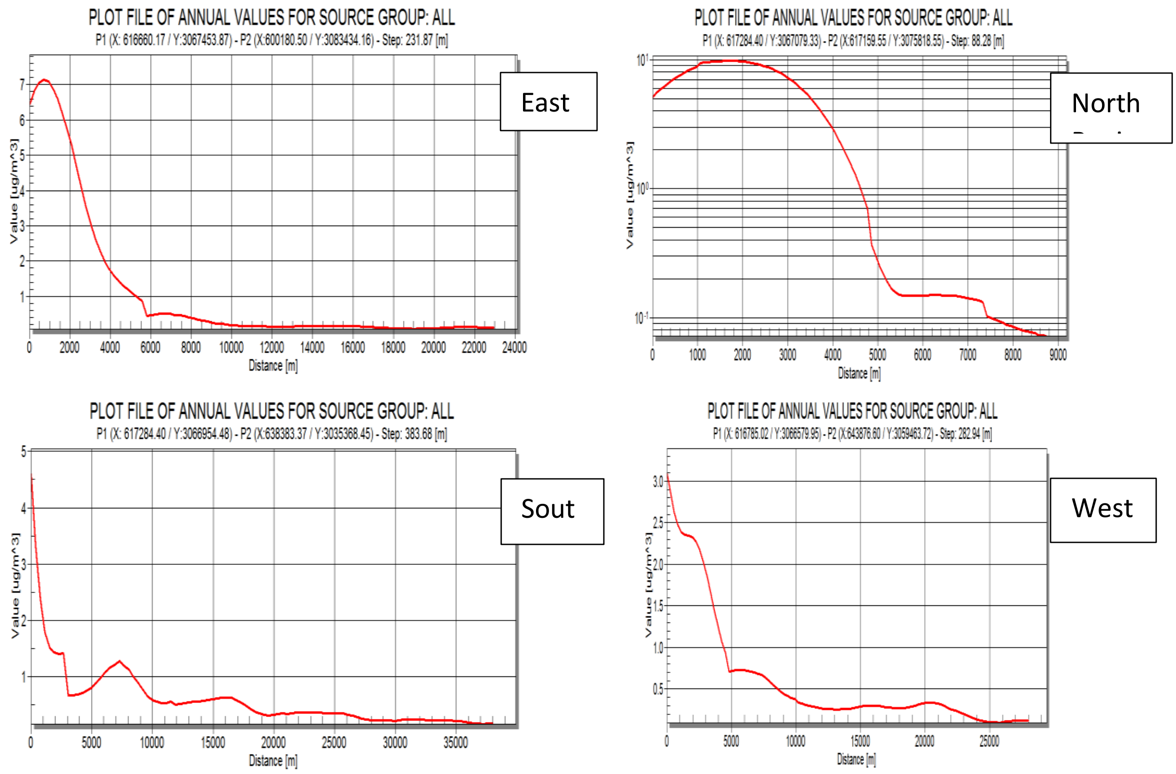


Figure 27. NO_X emission radius in 4 main directions of the 9th Refinery of South Pars Gas Complex, Phase 12 of 2021

The analysis of the nitrogen oxide pollutant's impact radius in 2021, based on the AERMOD model output, reveals that in the eastern and northern directions, the impact radius extended to approximately 2000 meters from the emission source. Subsequently, there was a declining trend, as depicted in the figure. In the northern direction, the decline was slower, and the impact radius exceeded 4000 meters. On the other hand, in the south and west directions, there was a continuous decreasing trend from the beginning, and the values reached approximately 0.5 µg/m3 within a range of 10000 meters. Notably, pollutant emissions in the southern and western sectors were directed towards the sea. The highest emission levels were observed in the eastern region, peaking at around 7.5 µg/m3 (Figure 28).

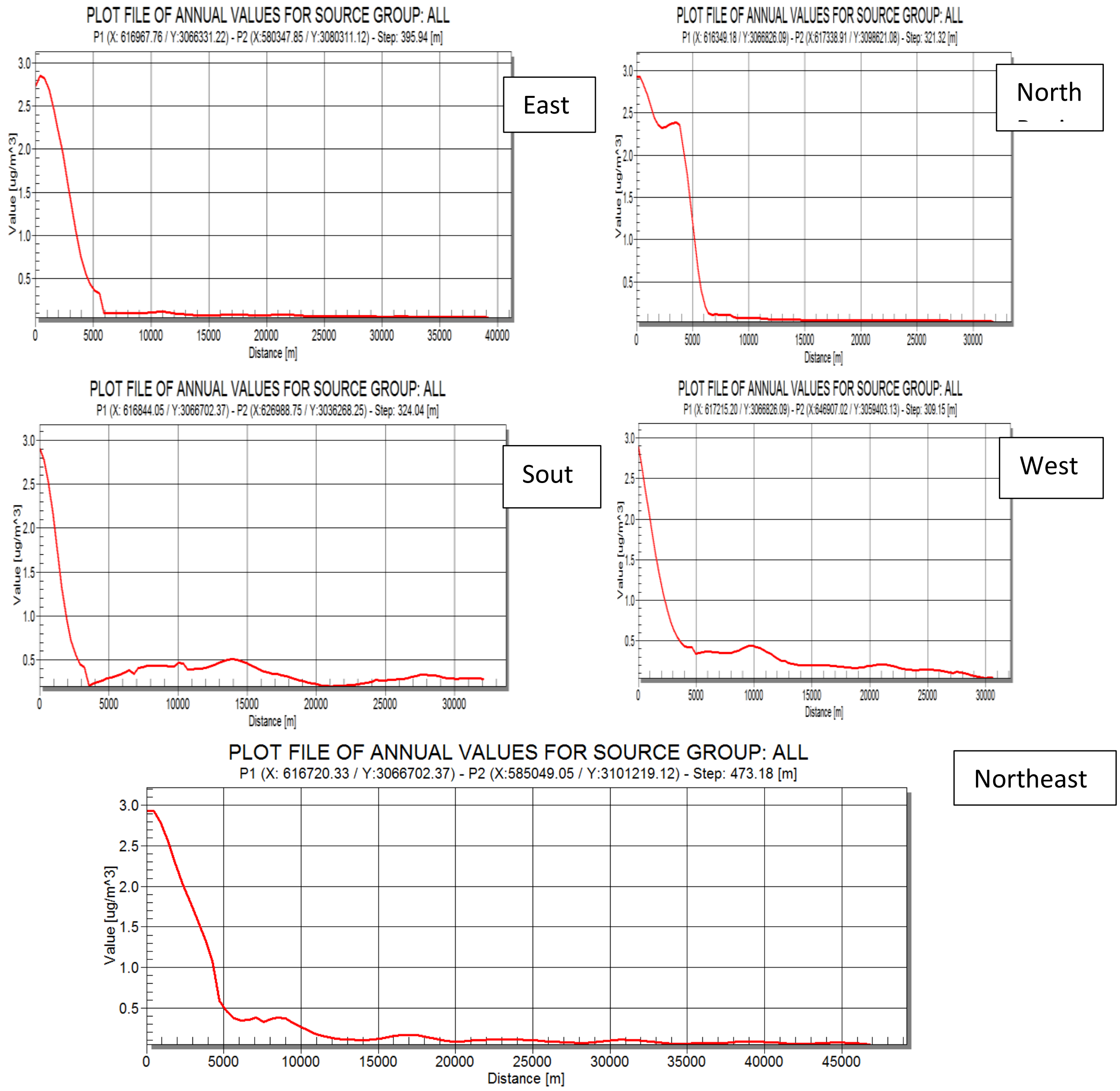


Figure 28. The SO_2 emissions radius in 4 main directions of the 9th Refinery of South Pars Gas Complex, Phase 12 in 2020

In 2020, the dispersion of sulfur dioxide pollutant, as indicated by the AERMOD model output, showed a decrease to levels below 0.5 µg/m3 within a distance of approximately 5000 meters from the emission source in the eastern, northeast, west, and south directions. In the northern direction, this decreasing trend commenced at around 5000 meters, with a slower rate observed prior to that distance. Notably, the emission of pollutants in the southern and western sectors was directed toward the sea. Pollutant emissions in all directions reached approximately 3 micrograms per cubic meter (Figure 29).

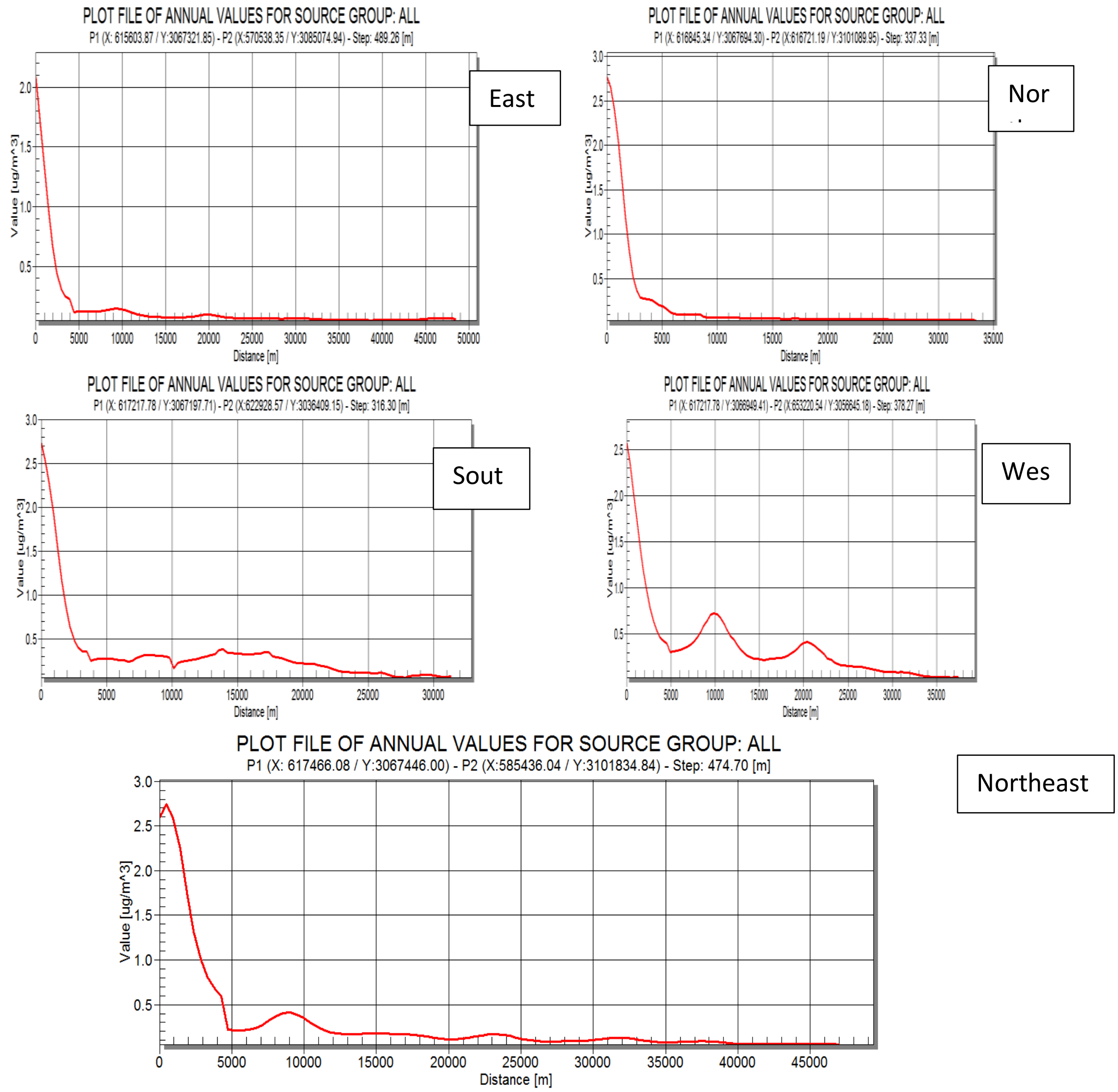


Figure 29. The emission radius of SO_2 in 4 main directions of the 9th Refinery of South Pars Gas Complex of Phase 12 in 2021

In the analysis of the sulfur dioxide pollutant's dispersion radius in 2021 using the AERMOD model, it was observed that in all directions, the trend showed a decrease to levels below 0.5 µg/m3 within a distance of approximately 5000 meters from the emission source. Notably, the emission of this pollutant in the south and west directions was directed toward the sea. The concentration of this pollutant in all directions was approximately 3 micrograms per cubic meter.

Discussion and conclusion

The Assaluyeh region in Iran is the focus of many environmental science experts due to the concentration of oil and gas industries, and air pollution is one of the challenges facing this region. Since the first step in achieving this goal is to determine the emission rate and identify the distribution of pollutants in the region, therefore, in this study we have addressed this issue and the distribution of pollutants in the 9th Refinery of South Pars Gas Complex Company was selected for modeling with the help of AERMOD software. The importance of addressing the distribution of pollutants in this section is its location in the coastal section and the margin of the common water border between Iran and Qatar. So far, no study has been conducted in the field of modeling pollutants caused by burner combustion in this refinery.

According to the findings of this study, pollutant emissions were found to be lower compared to the Environmental Organization's open-air standards. However, the area is highly polluted and one contributing factor to this pollution is the concentration of various industrial units in the Assaluyeh region. The proximity of these industrial units to residential areas has been of significant importance in improving the environmental status. Several plans, including addressing operational issues, process optimization, and the installation of complementary systems like surplus gas compressors, have been implemented by refineries in the South Pars Gas Complex to reduce environmental pollution. Additionally, the conversion of resuscitation gas to export gas has contributed to a reduction in pollution caused by burning. The replacement of old catalysts has also played a role in reducing air pollution caused by combustion.

Regarding the areas affected by pollutants in the studied years and area, it was observed that NOX and SO2 emissions and affected areas were higher in 2020 and 2021. This observation aligns with scientific principles, as it is predictable due to the elevated torch and flame height. Concentrations of pollutants tend to decrease at longer distances from the torch. The prevailing wind direction is a key factor influencing the dispersion of pollutants, with about 8% of the dominant wind at the station exhibiting a speed range of 6 to 8 m/s in the westward direction. Furthermore, CO and SO2 emissions and the population affected by these pollutants were higher in 2020, particularly in the areas around the 9th Refinery of the South Pars Gas Complex, including the 12th phase. The higher concentration of these pollutants can be attributed to gas sweetening processes, where sulfur compounds and carbon dioxide are released and subsequently burned in flares, resulting in elevated emissions of these pollutants.

`In conclusion, reducing emissions from flares is crucial in the oil, gas, and petrochemical industries. Recovering and utilizing gases, such as injecting them into oil reservoirs or transferring them to the national gas network, can effectively reduce flare emissions. Additionally, generating electricity and heat from these gases, as well as using them in various industries, can minimize energy losses. Collaboration among research teams, optimization of production processes, continuous monitoring of employee health, and implementing appropriate controls in the flaring process are essential for controlling and reducing pollutant emissions.

Suggestions:

- Based on the study's findings, the following recommendations are suggested:
- Conduct specialized research on theoretical and applied methods related to industrial flares, addressing issues and operational solutions to improve flare conditions in the study area.
- Undertake comprehensive activities related to flares, including establishing appropriate design principles with a focus on economic evaluations of the system.
- Explore new technologies for collecting and recovering flare gases, converting them into petrochemical feed, liquid fuel, electricity, and other valuable products to prevent the loss of this national resource.
- Investigate emissions of pollutants resulting from flue and flare activities in refinery industries in the Assaluyeh region, given the industry's accumulation. Comprehensive studies

should be conducted to propose pollutant reduction programs.

- Utilize the country's refinery database to assess pollutant emissions and develop control and reduction management plans.
- Develop comprehensive energy, economic, and environmental modeling tools to generate scenarios for structuring consumption, conversion, and production in the country's refineries, addressing this significant challenge.
- Conduct aggregate pollution assessments from refineries and industries in the region to determine pollutant levels and make informed management decisions for pollution control.
- Investigate safety protection distances and health protection in urban refinery development options, considering issues arising from the proximity of refineries to urban areas.
- Examine the distribution of refineries in terms of safety and security concerns, assessing the significance of this aspect.

References

Agha Mohammadi, N. 2018. Assessment of Damage Caused by CO and CO_2 Output of Low-Pressure Flares in South Pars Region Phase 1-10. Msc Thesis in Chemistry, Islamic Azad University, Qods Branch.

Alamiahi, Z. 2019. Distribution and distribution of exhaust gas pollutants from flue turbines of oil and gas exploitation unit and its health effects (Case study: Maroon 3 Oil and Gas Utilization Unit),5th International Conference on Environmental Engineering and Natural Resources,Tehran,https://civilica.com/doc/934051

Aliyarpour, R. 2020. Simulation of spatial temporal (monthly ،seasonal and yearly) distribution of H2S and SO^2 gas in Bidboland gas refinery in Behbahan Bidboland Gas Refinery ،Master Thesis Environmental Science and Engineering ،Faculty of Natural Resources. Khatam Alanbia University of Technolog. Behbahan.

Asadollah Fard, Gh., Delnavaz, M., and KhooAjooyi, A. 2020. Mathematical simulation of SO_2 emissions due to torch combustion, Case study: Abouzar oil and gas platform in Khark Island. Omran Modares. 16(2), 9-20.

Atabi, F., Jafarigol, F., Momeni, M.R., Salimiyan, M. and Bahmannia, G. 2015. Modeling the distribution of CO pollutants using AERMOD software in South Pars 4 gas refinery, Environmental Health. 4, 281-292.

Daman, F., Mohammad Asgari, H., Dadolahi, S., Khazaei, A., Ghanami, K., Javid, R., and Fowl, B. 2017. Modeling the distribution and distribution of air pollutants caused by Bandar Imam Khomeini petrochemical using SCREEN3 and AERMOD, 2nd Conference on Environment, Natural Resources, Agriculture and Clean Energy, Agricultural and Natural Resources Research Center, Hamadan.

Demirarslan, K.O., Çetin Doğruparmak, Ş., and Karademir, A. 2017. Evaluation of three pollutant dispersion models for the environmental assessment of a district in Kocaeli, Turkey. Global NEST Journal. 19(1), 37-48.

Dos Santos Cerqueira, J., de Albuquerque, H. N., and de Assis Salviano de Sousa, F. 2018. Atmospheric pollutants: modeling with Aermod software. Air Quality, Atmosphere & Health. DOI:10.1007/s11869-018-0626-9.

Elvidge, C., Baugh, K., Zhizhin, M., and Hsu, F. 2017. "Satellite Data Estimation of Gas Flaring Volumes," NOAA National Geophysical Data Center.

Farina, M.F. 2018, "Flare Gas Reduction: Recent global trends and policy considerations," General Electric Company, 2018.

Famiyan, A.S., Curtainpoosh Basmanj, M., and Khazini, L. 2019. Study of Distribution of Emissions Pollutants in West Tabriz Industrial Zone to Investigate the Impact on Tabriz Metropolis, 8th National Conference on Air and Noise Pollution Management, Tehran.

Iranian, F. 2019. Modeling of air pollutants of Genaveh combined cycle power plant using - AERMOD model, Environmental Science and Engineering, Faculty of Natural Resources, Behbahan Khatam Alanbia University of Technology.

Mohammadzadeh, R., Mirza Ebrahim Tehrani, M., Jozi, S.A., and Moogui, R. 1400. Identification of risk factors for environmental pollution of offshore gas platforms. Animal Ecology. 13(4), 209-216.

Momeni, I., Danehkar, A., Karimi, S., and Khorasani, N. 2011. Modeling SO^2 Distribution Caused by Ramin Power Plant in Ahvaz Using AERMOD Model, Human and Environment, 18, 3-9.

Rahimi, R., Mansouri, N., Alsheikh, A.A., and Haji Seyed Mirza Hosseini, S. A.R. 2021. Evaluation of the emission factor and environmental concentration of SO_2, NO_2 and CO pollutants in Ilam gas refinery, Environmental Science and Technology. 23(3), 71-86.

Rouhi, M.S. 2016. Modeling of NOX and SO2 Pollutants in Phases 9 and 10 of South Pars Oil Zone, Msc Thesis, Faculty of Natural Resources, Isfahan University of Technology.

Salahi, B. and Behrouzi, M. 2021. Assessment of distribution of exhaust air pollution from chimneys of Tabriz oil refinery using AREMOD model, Earth science research, ready to publish.

Tanzanziari, M. 2018. Estimation of Air Pollutants Emissions Caused by Gas Refinery Burner by Simulation of Torch Network, Ph.D. Thesis on Environment, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University.

Vahabpour, A., Shojaei, S.M., Tahmasezadeh, M., and Rasouli, F. 2018. Investigating the environmental effects of torch gas in Iran and its importance in line with country's commitments in the Paris agreement, Public Policy Strategic Studies. 8(27), 133-154.

Motalebi Damuchali, A., and Guo, H. 2020. Developing an odour emission factor for an oil refinery plant using reverse dispersion modeling, Atmospheric Environment, 222, 1-8.

World Bank. 2021. Global Gas Flaring Reduction Program (GGFR). Available: http://www.worldbank.org.