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Determination of Sulfur Dioxide Dispersion in the Atmosphere from Petroleum Production Unit No. 9 and Its Proximity to Masjid-I-Suleiman

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Masjid-I-Suleiman became the first petroleum city in Iran and the Middle East and the petroleum production unit located nearby, due to its aging installation and technology for petroleum and natural gas exploration has now become the largest SO_2 polluter among the petroleum producing regions in southern provinces. Petroleum production unit No. 9, located in the residential area of Masjid-I Suleiman, separates gases which are dissolved in petroleum. Every day about seven million cubic feet of gas are burnt in the flares. The amount of sulfur compounds in this gas is about 7 percent by volume, which after burning are released as SO_2 in the air. This research was conducted to determine the amount of dispersion of SO_2 in the atmosphere in proximity to Masjid-I Suleiman. In the present study lead peroxide absorbent plates were used to absorb SO_2 from air for six months. The amount of SO_2 was measured using a standard laboratory procedure and expressed in units of μg SO_2 cm^{-2} day^{-1}. The minimum and the maximum of SO_2 adsorption on absorbent plates in six month sampling (summer and autumn) was equal to 0.32and 30.08 μg SO_2

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cm^{-2}day^{-1} respectively. The average amount for the whole period was 8.74 µg SO_2 cm-^{2}day^{-1}. Results of this study were compared with ISO-9223 standard, the Poland research institute, and some other petroleum production units. The amount of sulfur dioxide pollution is at a high level in the areas studied. Moreover, the influence of meteorological factors such as temperature, relative humidity and wind speed on the dispersion of SO_2 was investigated. The results of this investigation demonstrate an inverse relationship of SO_2 concentration with relative humidity, and a direct relationship with the temperature and wind speed.

Keywords: Sulfur dioxide; dispersion; production unit; meteorological factors.

NOMENCLATURE

A : *Area of the plate*
T : *Time*
0.667 : *SO_2 molecular weight to SO4-molecular weight ratio*
P values : *SO_2 precipitation on the area according to ISO-9223 standard*

Classification	*SO_2 precipitation on the area*
P_0	$P_{d} \leq 10$
P_1	$10 < P_d \leq 35$
P_2	$35 < P_d \leq 80$
P_3	$80 < P_d \leq 200$

P_d= precipitation rate per unit area

1. INTRODUCTION

Air pollution is one of the main environmental problems in today's societies. The petroleum (oil) process and related industries may be considered the main causes of this pollution in petroleum and natural gas rich regions of the world.

The most common air pollutants are CO_2, SO_2, NO_2, Hydrocarbons (HC) [1] and particulate matter. A lot of gas emissions are released into the atmosphere by the combustion processes and sour gas processing [2-3]. These pollutants and secondary compounds which may be produced by some of them can cause a number of adverse human health effects and global climate change. Since these pollutants affect human health and environment, some limitation has been legislated for the release of pollutants into the atmosphere [4-5]. Because of huge petroleum and natural gas fields in Iran, large amounts of gases and petroleum are burned, especially in some areas in the south, creating unfavorable conditions which seriously threatening the health of residents [6-7]. Sulfur dioxide (produced by burning sulfur containing organic compounds in the air) is a dangerous air pollutant which is hazardous to health [8-9] and it causes corrosion in some metals [10-11]. The percentage of sulfur containing compounds is relatively high in the remaining gas from oil production unit 9. This unit is located in the residential area of Masjid-I-Suleiman. Because of an aging installation the oil fountains and wells leak gaseous hydrocarbons into the air. These harmful air pollutants are the source of allergic respiratory diseases in the region.

Data presented in this work can help to determine the most polluted areas in Masjid-I Suleiman. In this work much attempt has been made to determine the amount of SO_2 present in the air around oil unit No.9 and other installations operating in the city. In addition, the effect of climatic data has been recorded for temperature, relative humidity and wind speed on the distribution of SO_2.

2. MATERIALS AND METHODS

The project study area includes a part of Masjid-I-Suleiman where oil production unit No. 9, oil fountains and oil wells are located. The Masjid-I-Suleiman petroleum field was discovered in 1908 by drilling oil wells No.1 which is the first oil well in the Middle East. The size (dimension) of oil field is 31 by 7 KM^2. Economic production from this field began with a production rate of 500 bbl (barrels) per day in 1908, which was increased in 1929 to 120 thousand bbl per day. Later by drilling and commissioning of new wells, the oil production reached to its peak (i.e. 127 thousand barrels per day) in 1935. Since 1969 the production rate was declined to 10 thousand barrels per day in 1990 (due to excessive brine and gas production and reducing oil column thickness). Today oil production is 4.2 thousand bbl per day (Masjid-I- Suleiman engineering report (Persian)).

The aim of this study is to measure the SO_2 concentration in the air at the selected regions. Measurements were carried out during the entire summer and fall seasons. The climatic

Fig. 1. Geographical location of studying scope

parameters are temperature, relative humidity, rainfall and wind speed [12]. These parameters affect the SO_2 concentration in air. The influences of climatic parameters on the SO_2 concentration were also studied. The results were recorded and the relationship between the climatic parameters was examined. A Portable TESTO Xl-350 was used to measure the concentration of hydrogen sulfide (H_2S); however, the device could not indicate any concentration due to the low amount of pollutants in the air. Instead lead peroxide absorbent plates were placed at selected sampling stations for one-month periods, in accordance with the standard method of sampling (ASTM D2010) [13].

In general there are two methods for measuring air pollutants. One is called the laboratory method based on laboratory analysis. The samples are taken at the study area and then moved to the laboratory for analysis. Although this method is expensive and time consuming, it is most accurate. Another method is the use of direct reading instruments to measure air pollutants at any time in the area. These devices provide the amount of pollutants in the sampling times. Although the accuracy of this method is less than previous one, easy operation and quick results, made it popular and are widely used in measuring air pollutants. There are two techniques that can be used for gas and vapor sampling in ambient air condition; one is active method and second is passive method [14]. The passive sampling method has been chosen for this study (it's based on laboratory analysis in accordance with ASTM D 2010/D 2010-98 Reapproved 2004) [13]. To carry out this research, eight sampling stations were selected on the basis of oil production unit No.9, other oil and sour gas sources in the Syberenj region, and the abundance of oil wells and population density.

3. EXPERIMENTAL PROCEDURE

In the standard procedure, a lead peroxide plate (18 cm^2) with UV (sunlight) and chemical reaction resistance was placed at an altitude of 1-2 meters higher than the ground level in each station. The SO_2 adsorption time was one month, based on standard procedure. After this period of time, the plates were transferred to the laboratory to measure the adsorbed sulfur. Each lead peroxide plate was scraped under the hood and the scrapings transferred into the 50mLgraduated cylinder. 20 mL of sodium carbonate solution (50 gr per liter) was added to the graduated cylinder, which was then placed in a shaker for about 24 hours. After that the solution was put in a hot water steam bath for 30 minutes. The solution was filtered; the filtrate was transferred to a volumetric flask. 4 mL of 0.1 M HCl solution was added to the flask, and then distilled water was added to make the final volume of 50 mL. 3.0 gr of barium chloride was added to the flask and mixed by a shaker for 1 minute. Finally, a sample of the solution was placed inside the spectrophotometer and the absorbance at 394 nm recorded. Using a calibration curve, the value of sulfate was obtained.

The amount of sulfate represents the total amount of sulfur dioxide absorbed by the lead peroxide plates. The amount of sulfur dioxide was calculated in micrograms per cubic meter (per day), based on the following relation:

$$\mu g\ SO_2\ /cm^3/day = \mu g\ so_2 * 0.667\ /\ T*A \quad (1)$$

T and A are time and area respectively. The SPSS software was used for data processing and analyzing the samples.

4. RESULTS AND DISCUSSION

Table 1 shows the results of calculated sulfur dioxide concentration (μg SO_2 /cm^2/day) for a period of six months from July to December for eight designated locations. The climatic influence on the accumulation of SO_2 in the air was investigated. As Fig. 2 shows, the amount of SO_2 present in air has no direct relation with the change of seasons; no linear relation could be found in pollutant concentration.

A graphical presentation of the average sulfur dioxide concentration is presented in Fig. 3. Table 2 demonstrates the average temperature °C, relative humidity in air and wind speed (m/s) in designated sampling locations for a period of six months.

During the time of the research (6 months) the average temperature was 31.2° C; the average relative humidity approximately 27.5%, and average wind speed, 8.3 m/s. The results show that the maximum concentration of sulfur dioxide is 30.08 (μg/cm²/day) (December- Station No.1) which is close to oil production unit. The lowest concentration has been measured around 0.32 (μg/m² on sq. per day). At Station No. 5 in the same month (far from oil activity).

The Table 3 and Fig. 3 indicate the average, standard deviation, the minimum and maximum concentrations of sulfur dioxide (in μg SO_2 /cm^2/day) in all eight sampling areas per month. All time measurements are the same for the average concentrations of sulfur dioxide except for October and November. The reason is oil production unit No. 9 had been shut down (for repair) in these months.

SPSS software was used to study the climatic effects on SO_2 concentration. However, any significant relationship was not found (P. Value<0.05) among the pollutant concentrations and temperature, relative humidity and wind speed (Table 4).

The results indicate that given a concentration of 300mg/m^3, the highest concentration of sulfur dioxide occurred in December and in Station No.1 (the closest place unit No. 9). The result of this study is similar to the study conducted by Kazemi in Asaluyeh (Boushehr- Iran). The maximum amount of sulfur dioxide was 93 mg/m^3 in December [15]. This difference between 30.08 and 93 mg/m^3 is because of ambient temperature. There is a general trend that SO_2 concentration decreases as temperature increases because the heat reduces the air density [16]. The highest SO_2 concentration was reported in the cold season Elâzığ (Kpunar et al. Turkey).

There is no significant relationship observed between temperature and the amount of SO_2 in air. This may be due to a low temperature difference, during the study period. The analysis of the experimental results show that there is an inverse relationship between the amount of SO_2 and relative humidity in air, but it has a direct relationship to the wind speed. These results are similar to Dmyrychin Study in Trabzan (Turkey). Dmyrychin reported that there is a poor

Table 1. Sulfur dioxide concentration during measurement time (μg SO_2 /cm^2/day)

μg so_2/cm^2/day	July	August	September	October	November	December
Station 1	22.32	21.6	21.6	13.2	10.72	30.08
Station 2	16.8	18.16	18.48	9.52	12	14.96
Station 3	2.72	3.68	3.76	3.6	2.32	3.44
Station 4	1.92	3.12	3.52	3.76	3.2	1.2
Station 5	4.24	3.04	3.44	1.52	1.6	0.32
Station 6	8.08	7.52	9.12	9.36	8.16	3.52
Station 7	11.92	8.24	8.8	4.72	3.52	6.72
Station 8	9.52	13.36	10	13.44	11.68	12

correlation between meteorological factors (such as wind speed and relative humidity) and the pollutants. There is no generality (P.Value>0.05) due to the lack of relationship among pollutant, and relative humidity, and wind speed. The inverse relationship between humidity and the amount SO_2 in air can be explained. In air SO_2 molecules absorb water molecules after collisions. As SO_2 molecules become heavier their mobility decreases and they may precipitate as rainfall. Masjid-I-Suleiman is surrounded by mountains and high hills; therefore wind has not much effect on SO_2 pollutant distribution.

A comparison of sampling stations (Fig. 4) indicates that, stations 1 and 2 have the largest amount of pollutants as they are in the vicinity of oil production unit No 9. SO_2 concentration at stations 3, 4 and 5 are diminished gradually by getting distance from the plant. The abundant oil wells (station 8) and oil fountains (station 6 and 7) increased the amount of SO_2 in air.

4.1 Comparison of the Results

4.1.1 ISO 9223 standard

Comparison of analytical results obtained from the proposed classification based on ISO 9223 standard [17], which specifies the key factors in the atmospheric corrosion of metals and alloys. These are the temperature-humidity complex, pollution by sulfur dioxide and airborne salinity, indicating that:

1) The concentration of pollutants is in the level P3 in 62.5% of cases
2) 12.5% is in the level P2
3) And 25% is in the level P1

This indicates that a high level of pollution exists in the region; moreover, there was not any sample in the low level P0.

4.1.2 Poland research institute

Comparison of sulfur dioxide values obtained in the study and the Polish report shows that the SO_2 are in high and extremely high levels in the most of samplings areas (86%). (Fig. 5)

To present further information about SO_2 pollutant in the region, we would like to mention part of a study conducted by the research institute of petroleum industry in some oil production units in south of Iran (Table 5). The level of SO_2 pollution is high in all over studied areas.

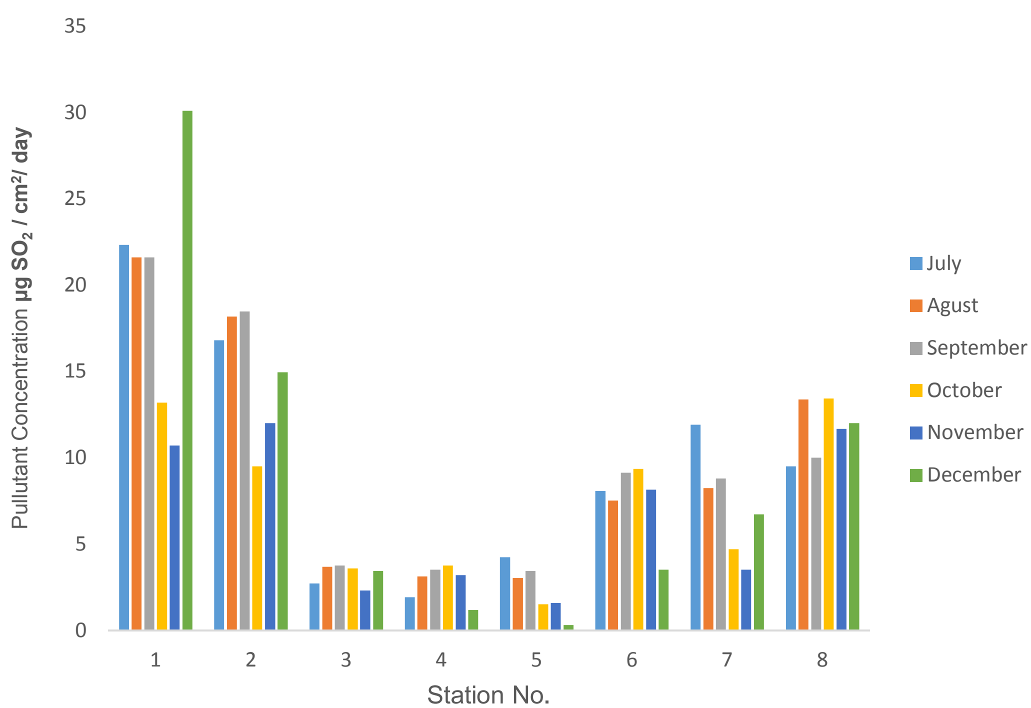

Fig. 2. SO_2 concentrations during measurement time in each station

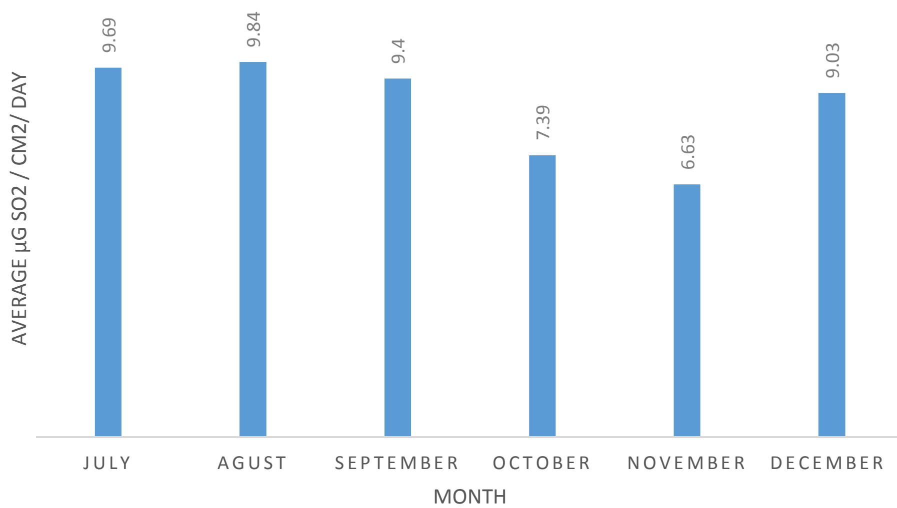

Fig. 3. Average SO_2 concentration diagram in designated areas

Table 2. Sulfur concentration during measurement time (µg SO_4^{2-} / cm^2/ day)

µg so_2/cm^2/day	July	August	September	October	November	December
Station 1	33.48	32.4	32.4	19.8	16.08	45.12
Station 2	25.2	27.24	27.72	14.28	18	22.44
Station 3	4.08	5.52	5.64	5.4	3.48	5.16
Station 4	2.88	4.68	5.28	5.64	4.8	1.8
Station 5	6.36	4.56	5.16	2.28	2.4	0.48
Station 6	12.12	11.28	13.68	14.04	12.24	5.28
Station 7	17.88	12.36	13.2	7.08	5.28	10.08
Station 8	14.28	20.04	15	20.16	17.52	18

Table 3. Average temperature, relative humidity, and wind speed during measurement time

Meteorological factors	July	August	September	October	November	December	Average
Average Temperature (ºC)	38.4	39.8	36.5	31.2	24	17.3	31.2
Average relative humidity (%)	21	20	23	26	36	39	27.5
Average wind speed (m/s)	10	10	7	7	7	9	8.3

Table 4. Average, maximum and minimum of sulfur dioxide concentration and standard deviation of it during sampling period

Month	Maximum	Minimum	Standard deviation	Average
July	22.32	1.92	7.13462	9.69
August	21.60	3.04	7.14340	9.84
September	21.60	3.44	6.89142	9.84
October	13.44	1.52	4.59663	7.39
November	12.00	1.60	4.46803	6.63
December	30.08	0.32	9.93698	9.03
Total mean	30.08	0.32	6.68797	8.74

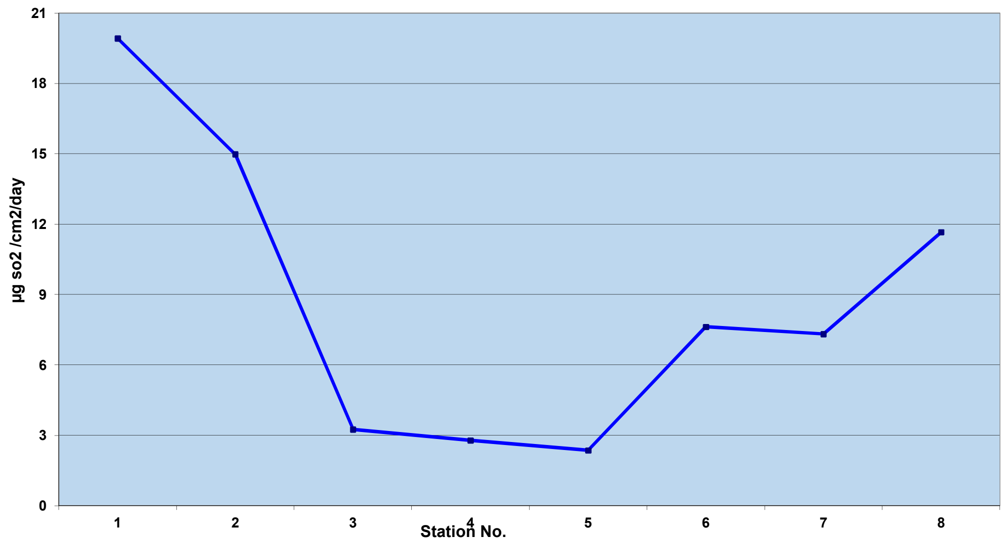

Fig. 4. Average SO_2 concentration diagram in designated areas

Table 5. Comparing the masjid-I-Suleiman oil production unit with other units in south of Iran ((µg SO_4^{2-} / cm^2/ day) [18]

Station No.	Mahshahr pressure boosting unit	Ramshir pressure boosting unit	Maroon-3	Ahwaz-2	Masjid-I-Suleiman
1	37.16	41.63	31.18	90.91	199.2
2					149.9

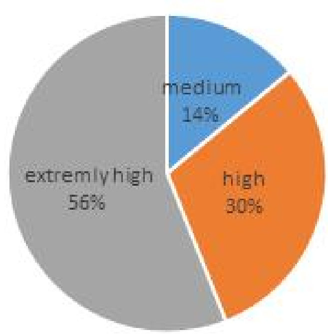

Fig. 5. Classification of SO_2concentrations according to the dangerous pollutant potential

5. CONCLUSION

In this study the level of sulfur dioxide in air within the oil production unit No.9 (Masjid-I-Suleiman) was measured and analyzed. The results show that:

- The concentration of SO_2 is different in all sampling locations.
- The highest concentration of SO_2 was observed in the vicinity of the oil production unit.
- Due to the topography of the area around the Masjid-I-Suleiman which is surrounded by mountains, climate parameters do not effectively disperse air pollutants such as sulfur dioxide.
- The existence of old oil installations, abandoned wells, gas & oil leakage as well as using unrefined gas (sour gas) for domestic consumption has increased the pollution levels.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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