Criteria pollutant dispersion modeling analysis for the Harir Early Production Facility, Kurdistan Region of Iraq

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Abstract

Anticipated air emissions including NO_x, SO_2, H_2S and CO resulting from flaring of gas for the Harir Early Production Facility, Northern Iraq (where this work was carried out) were followed up for impact assessment on existing ambient air quality *via* dispersion modeling. Due to the absence of upper layer meteorological data, stability class and mixing height for the ground layer for Iraq, prediction of the Ground Level Concentration (GLC) of emissions were made using the software of Industrial Sources Complex Short Term Model version 3 (ISCST3). ISCST3 software was used by default internationally for available ground layer mixing height and stability class. GLCs were calculated using meteorological data collected from the meteorological station at site during the monitoring period i.e. from 24 Sep. 2010 to 23 Oct. 2010. Air emissions were analyzed directly at the field using a portable gas analyzer Drager-Multiwarn, Germany. Topography of the studied area $10km^2$ around the project site (considered for impact assessment) is undulating in nature with contours varying from 700m to 1550m. Two assumptions were made while using the model; no dry and wet depletion of pollutants and the EPF location of 1550m. Maximum 24 hourly averages incremental GLCs of emissions during flaring were predicted for the grid size of $250m^2$ and 81 grids. The first maximum 50 values of 24 hourly incremental GLCs of emissions were then calculated. Contours for maximum 24 hourly averages incremental GLCs of air emissions were drawn at specified concentrations given for each and corresponding isopleth were depicted. It was evident from the modeling that maximum values of 24 hourly GLCs for H_2S and SO_2 severely surpassed Environmental, Health and Safety Guidelines for Onshore Oil and Gas Development of International Finance Corporation (IFC). Suitable mitigations and recommendations were made.

Keywords: NO_x, SO_2, H_2S, CO, EPF, ISCST3.

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1 Introduction

Atmospheric dispersion modeling is the mathematical simulation of how air pollutants disperse in the ambient atmosphere (Al-Hamad and Khan [1] and Villasenor *et al.* [2]). Air quality assessment by integrating measurement techniques and modeling tools is a crucial element in pollution mitigation (Dahl and Kuralbaya [3]). However, in many countries systematic measurements for the monitoring and evaluation of air quality are not available, mainly due to lack of resources and regulations [4]. Procedures for preparing an emission summary and dispersion modeling report and analysis have been discussed by Turner [5] and Berkowicz *et al.* [6]. The most commonly used dispersion model is Industrial Source Complex – Short Term, or ISCST3. This program allows for the modeling of many stacks, building data, receptor locations and hourly meteorological data are required to run an ISCST3 model (United States Environmental Protection Agency, EPA [7]).

Iraq (including Kurdistan, the Northern Region of Iraq) is a major oil producing country and its economy directly depends on its export of crude and refined products. The processed oil is exported or refined at large refining industries. Separated gas that cannot be utilized economically is flared. This flaring produces a number of undesirable atmospheric emissions, including CO, CO_2, SO_2, H_2S, NOx. More recently, so many production facilities are established in the region. These activities result in the emission of gaseous pollutants to the atmosphere, particularly from the flaring of undesirable product and excess gases. Iraq does not have upper layer meteorological data. Even stability class and mixing height for ground layer are not available in Iraq for lower layer meteorological data. The objective of this work was to obtain an accurate estimation of the total flare emission from the Harir EPF activities, using ISCST3 software by default internationally available ground layer mixing height and stability class, thereby aiding the effective planning of mitigation strategies to control and reduce the pollution from crude related operation.

2 The project

Harir Early Production Facility/System (EPF) is located at 36.5709N by 44.3734E and 1462m.a.s.l, Northern Iraq (fig. 1). The EPF consists of the following equipment and emission sources:

- A separator with vent routed to flare;
- Process heated with vent routed to flare;
- Amine system with vent routed to flare;
- Possible crude H_2S stripper tower with vent routed to flare;
- Flare device;
- Two 30,000 barrel oil storage tanks vented to atmosphere;
- Truck loading facility;

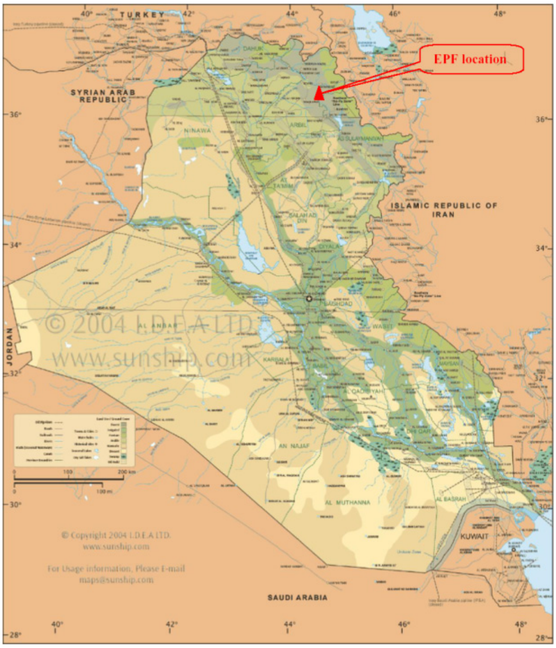

Figure 1: Map of Iraq, location of the EPF is indicated.

3 Methodology

Inputs, including gaseous pollutants NO_x, SO_2, H_2S and CO resulting from flaring of gas for the Harir Early Production Facility were analyzed directly in the field using a portable gas analyzer Drager-Multiwarn, Germany. The instrument was calibrated against high purity standard gases, following the instrument instruction manual given by Drager Laboratories. The 24 hour average concentrations of gaseous pollutants were estimated at each location. Weather conditions were normal and there was no excess wind during the measurements. The measured values were logged into the instrument memory, and subsequently downloaded.

GLCs were calculated by using hourly meteorological data collected from the meteorological station at site during the monitoring period i.e. from 24 September 2010 to 23 October 2010.

Topography of the study area (10km x 10km around the project site) considered for impact assessment is undulating in nature with contours varying from 700 m to 1550 m above m.a.s.l. The following are the assumptions made while using the model:

- No dry and wet depletion of pollutants; and
- Proposed location of EPF is at 1550 m above m.a.s.l.

The emission characteristics and other details of flaring considered for the modeling are summarized in table 1.

Table 1: Details of emission from flaring of gas.

Particulars	Details
Quantity of gas to be flared	15000 mcf/d
Number of Stack	1
Stack height (m)	150 ft (45.72m)
Stack diameter	8” (0.203 m)
Gas Temperature (^oC)	125^{o}F (324.7^{o}K)
Gas velocity (m/s)	335 ft/s (102.1 m/s)
Emission rate	
NO_x	11.03 g/s (2100 lb/day @140 lb/MMscf of gas)
SO_2	930.76 g/s (7387 lb/hr)
H_2S	495.05 g/s (3929 lb/hr)
CO	1.57 g/s (300 lb/day @20 lb/MMscf of gas)

4 Results and discussion

Output of the modeling is described hereunder:

4.1 Oxides of nitrogen (NO_x)

Maximum 24 hourly average incremental GLCs of NO_x during flaring are predicted for the grid size of 250m x 250m and 81 grids. The first maximum 50 values of 24 hourly incremental GLCs of NO_x are given in table 2. Contours for maximum 24 hourly average incremental GLCs of NO_x are drawn at an interval of 10.0µg/m^3 with minimum contour of 5.0µg/m^3 and corresponding isopleth is depicted in fig. 1. It is evident from the above discussion that the maximum 24 hourly average incremental GLC value for NO_x due to flaring is predicted as 52.2 µg/m^3 at a distance of 707 m in southwest (SW) direction with an average value of 2.05 µg/m^3 within an area of 10 km radius around the facility. Contours of the GLCs depict that the travel of emissions would be mainly in S-W quadrant.

4.2 Sulphur dioxide (SO_2)

Maximum 24 hourly average incremental GLCs of SO_2 during flaring are predicted for the grid size of 250m x 250m and 81 grids. The first maximum 50 values of 24 hourly incremental GLCs of SO_2 are given in table 3. Contours for

Table 2: 24 hourly average incremental GLCs of NO_x ($\mu g/m^3$).

S.n.	Conc.	Receptor (m)		S.n.	Conc.	Receptor (m)	
		(X)	(Y)			(X)	(Y)
1	52.2	-500	-500	26	43.1	-1250	-3000
2	51.1	-500	-500	27	42.9	-4500	-4500
3	49.1	-500	-500	28	42.9	-3000	-3000
4	48.0	-250	-750	29	42.8	-500	-500
5	47.1	-4000	-4000	30	42.5	-4750	-4750
6	47.0	-4250	-4250	31	42.5	-6250	-6250
7	47.0	-3750	-3750	32	42.3	-750	-750
8	46.8	-4500	-4500	33	42.2	-2500	-2500
9	46.7	-3500	-3500	34	42.2	-2750	-2750
10	46.5	-4750	-4750	35	42.2	-500	-500
11	46.1	-3250	-3250	36	42.0	-5000	-5000
12	46.1	-250	-500	37	41.8	-500	-250
13	46.0	-5000	-5000	38	41.7	-6500	-6500
14	45.3	-5250	-5250	39	41.6	-750	-250
15	45.2	-3000	-3000	40	41.3	-5250	-5250
16	44.6	-5500	-5500	41	41.2	-2500	-2500
17	44.5	-750	-750	42	41.0	-6750	-6750
18	44.0	-2750	-2750	43	41.0	-1000	-2500
19	43.9	-5750	-5750	44	40.9	-1500	-3500
20	43.6	-3750	-3750	45	40.6	-5500	-5500
21	43.6	-3500	-3500	46	40.3	-7000	-7000
22	43.5	-4000	-4000	47	40.2	-1500	-3750
23	43.3	-3250	-3250	48	40.1	-2500	-6000
24	43.3	-4250	-4250	49	40.0	-2250	-2250
25	43.2	-6000	-6000	50	40.0	-2250	-2250

Note: All receptors are grid card type and distances are in meters.

maximum 24 hourly average incremental GLCs of SO_2 are drawn at an interval of 500.0µg/m^3 with minimum contour of 100.0µg/m3 and corresponding isopleth is depicted in fig. 2. It is evident from the above discussion that the maximum 24 hourly average incremental GLC value for SO_2 due to flaring is predicted as 4402.2 µg/m^3 at a distance of 707 m in southwest (SW) direction with an average value of 173.3 µg/m^3 within an area of 10 km radius around the facility. Contours of the GLCs depict that the travel of emissions would be mainly in the S-W quadrant.

Table 3: 24 hourly average incremental GLCs of SO_2 (µg/m^3).

S.n.	Conc.	Receptor (m)		S.n.	Conc.	Receptor (m)	
		(X)	(Y)			(X)	(Y)
1	4402.2	-500	-500	26	3639.7	-1250	-3000
2	4308.6	-500	-500	27	3622.4	-4500	-4500
3	4141.6	-500	-500	28	3619.6	-3000	-3000
4	4050.5	-250	-750	29	3608.9	-500	-500
5	3976.6	-4000	-4000	30	3586.8	-4750	-4750
6	3969.5	-4250	-4250	31	3584.4	-6250	-6250
7	3968.6	-3750	-3750	32	3569.8	-750	-750
8	3950.2	-4500	-4500	33	3564.7	-2500	-2500
9	3942.1	-3500	-3500	34	3561.0	-2750	-2750
10	3921.1	-4750	-4750	35	3559.2	-500	-500
11	3893.1	-3250	-3250	36	3543.5	-5000	-5000
12	3890.5	-250	-500	37	3528.5	-500	-250
13	3881.6	-5000	-5000	38	3522.9	-6500	-6500
14	3825.4	-5250	-5250	39	3512.6	-750	-250
15	3817.2	-3000	-3000	40	3486.6	-5250	-5250
16	3766.9	-5500	-5500	41	3480.1	-2500	-2500
17	3754.4	-750	-750	42	3461.7	-6750	-6750

Table 3: (Continued).

18	3709.3	-2750	-2750	43	3457.9	-1000	-2500
19	3706.8	-5750	-5750	44	3455.3	-1500	-3500
20	3680.4	-3750	-3750	45	3428.6	-5500	-5500
21	3676.6	-3500	-3500	46	3401.0	-7000	-7000
22	3671.1	-4000	-4000	47	3396.0	-1500	-3750
23	3657.3	-3250	-3250	48	3387.6	-2500	-6000
24	3651.0	-4250	-4250	49	3379.4	-2250	-2250
25	3645.8	-6000	-6000	50	3377.1	-2250	-2250

Note: All receptors are grid card type and distances are in meters.

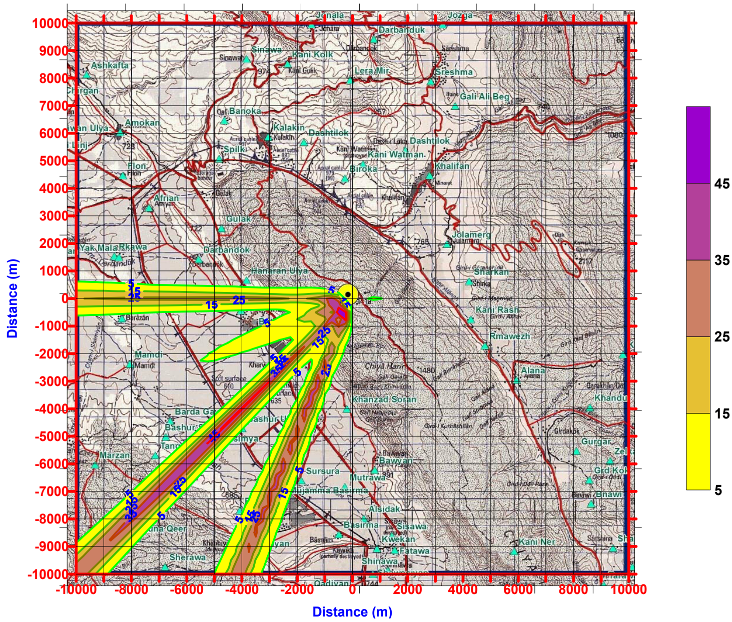

Figure 2: Contributed 24 hourly GLCs of NO_x ($\mu g/m^3$).

4.3 Hydrogen sulphide (H_2S)

Maximum 24 hourly average incremental GLCs of H_2S during flaring are predicted for the grid size of 250m x 250m and 81 grids. The first maximum 50 values of 24 hourly incremental GLCs of H_2S are given in table 4. Contours for

Table 4: 24 Hourly average incremental GLCs of H_2S ($\mu g/m^3$).

S.n.	Conc.	Receptor (m)		S.n.	Conc.	Receptor (m)	
		(X)	(Y)			(X)	(Y)
1	2341.2	-500	-500	26	1935.7	-1250	-3000
2	2291.5	-500	-500	27	1926.5	-4500	-4500
3	2202.6	-500	-500	28	1925.0	-3000	-3000
4	2154.2	-250	-750	29	1919.3	-500	-500
5	2114.9	-4000	-4000	30	1907.6	-4750	-4750
6	2111.1	-4250	-4250	31	1906.3	-6250	-6250
7	2110.6	-3750	-3750	32	1898.5	-750	-750
8	2100.8	-4500	-4500	33	1895.8	-2500	-2500
9	2096.5	-3500	-3500	34	1893.9	-2750	-2750
10	2085.4	-4750	-4750	35	1892.9	-500	-500
11	2070.5	-3250	-3250	36	1884.5	-5000	-5000
12	2069.1	-250	-500	37	1876.6	-500	-250
13	2064.4	-5000	-5000	38	1873.6	-6500	-6500
14	2034.5	-5250	-5250	39	1868.1	-750	-250
15	2030.1	-3000	-3000	40	1854.3	-5250	-5250
16	2003.4	-5500	-5500	41	1850.8	-2500	-2500
17	1996.7	-750	-750	42	1841.1	-6750	-6750
18	1972.7	-2750	-2750	43	1839.0	-1000	-2500
19	1971.4	-5750	-5750	44	1837.7	-1500	-3500
20	1957.4	-3750	-3750	45	1823.5	-5500	-5500
21	1955.4	-3500	-3500	46	1808.8	-7000	-7000
22	1952.4	-4000	-4000	47	1806.1	-1500	-3750
23	1945.1	-3250	-3250	48	1801.7	-2500	-6000
24	1941.7	-4250	-4250	49	1797.3	-2250	-2250
25	1939.0	-6000	-6000	50	1796.1	-2250	-2250

Note: All receptors are grid card type and distances are in meters.

maximum 24 hourly average incremental GLCs of H_2S are drawn at an interval of 200.0µg/m^3 with a minimum contour of 100.0µg/m^3 and corresponding isopleth is depicted in fig. 3. It is evident from the above discussion that the maximum 24 hourly average incremental GLC value for H_2S due to flaring is predicted as 2341.2 µg/m^3 at a distance of 707 m in southwest (SW) direction with an average value of 92.2 µg/m^3 within an area of 10 km radius around the facility. Contours of the GLCs depict that the travel of emissions would be mainly in the S-W quadrant.

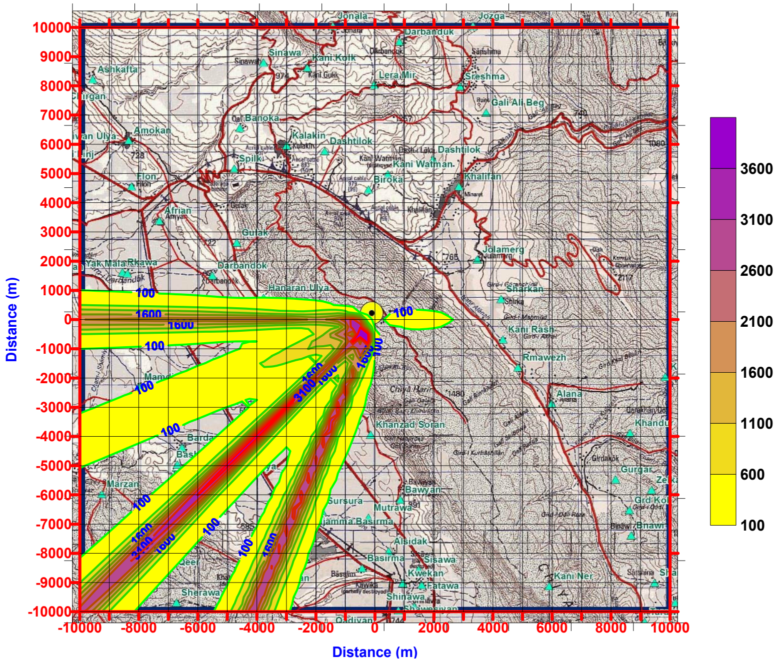

Figure 3: Contributed 24 hourly GLCs of SO_2 (µg/m^3).

4.4 Carbon monoxide (CO)

Maximum 24 hourly average incremental GLCs of CO during flaring are predicted for the grid size of 250m x 250m and 81 grids. The first maximum 50 values of 24 hourly incremental GLCs of CO are given in table 5. Contours for maximum 24 hourly average incremental GLCs of CO are drawn at an interval of 2.0µg/m^3 with minimum contour of 1.0µg/m^3 and corresponding isopleth is depicted in fig. 4. It is evident from the above discussion that maximum 24 hourly average incremental GLC value for CO due to flaring is predicted as 7.38 µg/m^3 at a distance of 707 m in southwest (SW) direction with an average value of 0.3 µg/m^3 within an area of 10 km radius around the facility. Contours of the GLCs depict that the travel of emissions would be mainly in S-W quadrant.

Table 5: 24 hourly average incremental GLCs of CO ($\mu g/m^3$).

S.n.	Conc.	Receptor (m)		S.n.	Conc.	Receptor (m)	
		(X)	(Y)			(X)	(Y)
1	7.38	-500	-500	26	6.10	-1250	-3000
2	7.22	-500	-500	27	6.07	-4500	-4500
3	6.94	-500	-500	28	6.07	-3000	-3000
4	6.79	-250	-750	29	6.05	-500	-500
5	6.66	-4000	-4000	30	6.01	-4750	-4750
6	6.65	-4250	-4250	31	6.01	-6250	-6250
7	6.65	-3750	-3750	32	5.98	-750	-750
8	6.62	-4500	-4500	33	5.97	-2500	-2500
9	6.61	-3500	-3500	34	5.97	-2750	-2750
10	6.57	-4750	-4750	35	5.97	-500	-500
11	6.53	-3250	-3250	36	5.94	-5000	-5000
12	6.52	-250	-500	37	5.91	-500	-250
13	6.51	-5000	-5000	38	5.90	-6500	-6500
14	6.41	-5250	-5250	39	5.89	-750	-250
15	6.40	-3000	-3000	40	5.84	-5250	-5250
16	6.31	-5500	-5500	41	5.83	-2500	-2500
17	6.29	-750	-750	42	5.80	-6750	-6750
18	6.22	-2750	-2750	43	5.80	-1000	-2500
19	6.21	-5750	-5750	44	5.79	-1500	-3500
20	6.17	-3750	-3750	45	5.75	-5500	-5500
21	6.16	-3500	-3500	46	5.70	-7000	-7000
22	6.15	-4000	-4000	47	5.69	-1500	-3750
23	6.13	-3250	-3250	48	5.68	-2500	-6000
24	6.12	-4250	-4250	49	5.66	-2250	-2250
25	6.11	-6000	-6000	50	5.66	-2250	-2250

Note: All receptors are grid card type and distances are in meters.

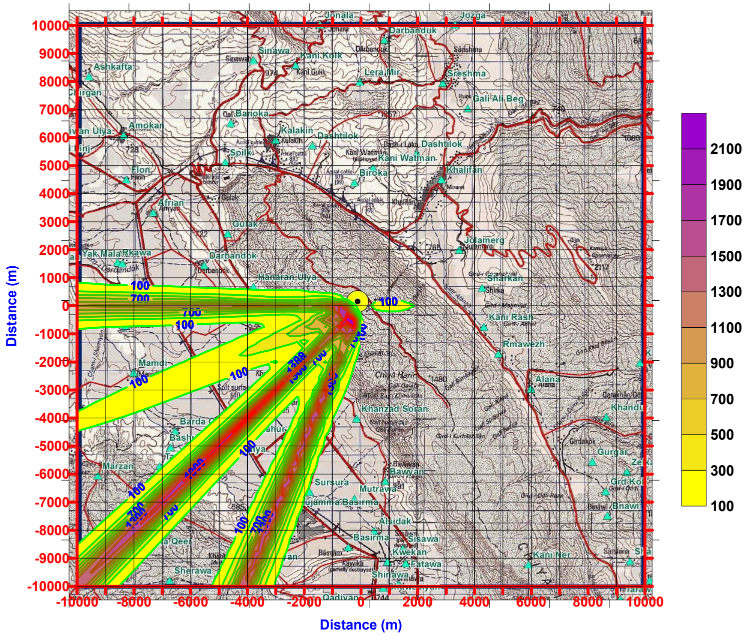

Figure 4: Contributed 24 hourly GLCs of H_2S (μg/m^3).

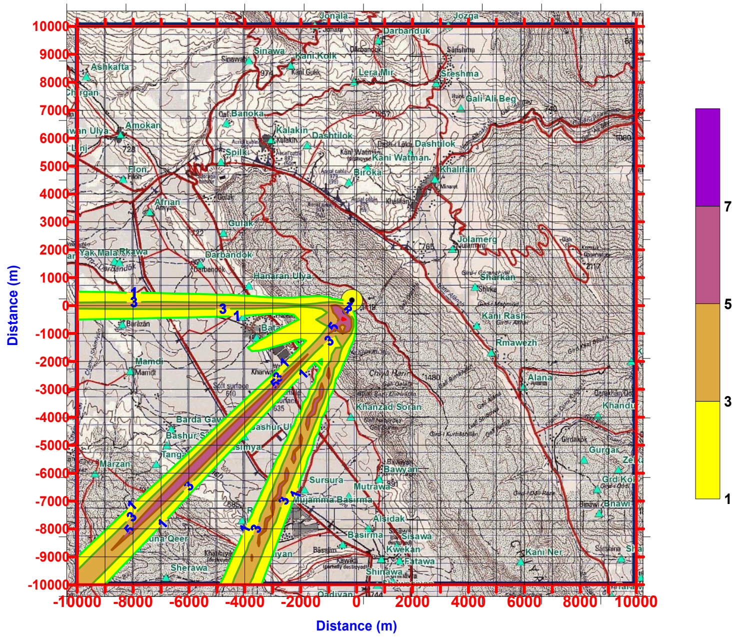

Figure 5: Contributed 24 hourly GLCs of CO (μg/m^3).

5 Conclusion

The details of GLCs for various pollutants based on modeling are summarized in table 6 below:

Table 6: Details of GLCs for various pollutants based on modelling.

Pollutants	Contributed GLCs (μg/m^3) within study area (of 10 km radius around the EPF site)	
	Maximum	Average
NO_x	52.2	2.05
SO_2	4402.2	173.3
H_2S	2341.2	92.2
CO	7.38	0.3

It is evident from the modeling that the maximum values of 24 hourly GLCs for H_2S and SO_2 are very high. It is due to considering higher emission values of H_2S during flaring for modeling. As per Environmental, Health and Safety Guidelines for Onshore Oil and Gas Development of International Finance Corporation (IFC), standard for H_2S emission during flaring should not be more than 5 mg/Nm^3. SO_2 generation shall be due to burning of H_2S. Hence, value of emission of SO_2 during flaring considered for modeling is also high however no standard has been prescribed by IFC.

6 Recommendation

Prediction of impacts are based on one month meteorological data only which are supposed to vary whole year. Hence, it is recommended that:

- Continuous online meteorological data should be monitored at the project site; and dispersion modeling should be carried out on monthly basis for the whole year.

- Development of a contingency plan for H_2S release events, including all necessary aspects from evacuation to resumption of normal operations. Installation of monitors set to activate warning signals whenever detected concentrations of H_2S exceed 7 milligrams per cubic meter (mg/m^3). The number and location of monitors should be determined based on an assessment of plant locations prone to H_2S emission and occupational exposure.

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