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Dispersion and Safety Effects of Refinery Flare System CarbonMonoxide Emission.

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Abstract

Gas flaring is one of the most challenging energy and environmental problems facing the world today. Environmental Consequences associated with gas flaring have considerable impacts on local populations, often resulting in severe health issues. The study examined the effects of carbon monoxide emissions on the nearby neighborhood. ALOHA software (5.4.7) was used to simulate the loss of carbon monoxide containment, dispersion characteristics and the potential consequences. Gaussian models were employed to describe dispersion characteristics. It was found that, during emergency operations, the carbon monoxide discharge rate typically falls in the range 1335 - 4332 kg/hr. Although the health impact is within WHO, EPA, and NAAQS criteria, the study's findings on the discharge's health implications indicate that even at the highest release rate, a carbon monoxide concentration of 50 ppm is unlikely to be attained. Long-term exposure to carbon monoxide levels of 9.0 – 25 ppm might result in headaches, fatigue, andweakness. Carbon monoxide inhalation can exacerbate heart and/or respiratory problems in those who already have them. Government should address the issue of encroachment surrounding its infrastructure, according to the recommendation

Keywords: *:* Flare System; Toxic gas; Dispersion modeling; Health and safety; Carbon Monoxide.

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1. Introduction

Flaring is a high-temperature oxidation process used to burn combustible components, mostly hydrocarbons, of waste gases from industrial operations. The main reasons for flaring are lack of process or transport capacity for gas, continuous surplus gas flow, start up, maintenance and emergency (need for pressure relief) cases (Kindzierski, 2000). Gases flared from refineries and petroleum productions are composed largely of low molecular weight hydrocarbons with high heating value (Zadakbar *et al*., 2008). The aim of this research is to understudy the dispersion characteristics of Carbon Monoxide (CO) coming from the flare system domiciled within Kaduna Refining and Petrochemical Company (KRPC) Limited, Kaduna State, Nigeria. The pollution levels/contours were mapped with a view to assessing the potential health and environmental effects.

1.1 Case Study

KRPC Flare system comprises of two flares (normal & emergency) designed to handle discharged gases under different conditions. Despite the increase in quantity of gases discharged to the flare as a result of faulty Pressure Safety Valves (PSVs) across all process plants, passing valves on bleed lines and high temperature profiles in columns; KRPC emergency flare is the major concern in this paper, this is however not the case with the current status of the flare facility as shown in Figure 1.

Figure 1: KRPC flare activities (2017)

2.0 METHODOLOGY

2.1 Software tools / Data needed

ALOHA software tool: Areal Locations of Hazardous Atmospheres (ALOHA) Software tool (Version is 5.4.7) was adopted for the purpose of this research work, which was built upon Gaussian Dispersion model of continuous, Buoyant air pollution (NOAA and US EPA 1999).

2.2 Design Data

Table 1. List of Design Data as Input for the Modeling Exercise (Source Chiyoda 1980)

SN	Equipment	Data
1	Fluid Discharge	Composition
2	Flares Stack Height (Emerg. & Opt)	60.945(m)
3	Operating Flare Stack Diameter	28(inch)
4	Emergency Flare Stack Diameter	54 (inch)
5	Tip Length (Emergency and Opt)	4.051(m)
6	Flare Tip Diameter (Emergency)	54(inch)
7	Flare Tip Diameter (Operation)	30(inch)
8	Pipe Exit Diameter	Normal and Emergency Design Manual
9	Riser Diameter	30 inch
10	Assist Fluid	Steam
11	Blowdown Pump	$5(m^3/h) \times 50(m)$
12	Flare Blowdown Drum	3500(Ø) x 10,000(L)
13	Seal Type	Fluidic
14	Igniter	Flame Front Type (Piezo Electric)

a. Operational Data

Normal and Emergency released gases such as surplus fuel, discharge for pressure control were passed through knockout drum (to remove oil and water) and flare seal drum (final stage to separate liquid from relief gasses) before it reaches flare stack. **(**Chiyoda, 1980**)**. Table 2 shows the operating flare data.

Table 2. List of Required Operating data as Input for the Modeling Exercise **(**Chiyoda, 1980**)**.

Parameter	Configuration
Flow rate (Normal)	2332 kg/hr
Operating Temperature	45℃
Operating Pressure	0.35 bar
Methane	0.8726 mole
Ethane	0.0416 mole
Nitrogen	0.0336 mole
Carbon dioxide (CO_2)	0.0202 mole
Propane	0.019 mole
Butane	0.0067 mole
Water (H_2O)	0.0017 mole
Pentane	0.0028 mole
Hydrogen Sulphide (H_2S)	0.001 mole
n-Hexane	0.0008 mole
Minimum Flowrate (Emergency)	178,682 kg/hr.
Maximum Flowrate (Emergency	580,252 kg/hr.
Average Flowrate (Emergency)	461,880 kg/hr.

2.3 Procedure

a. Field/Survey Data

KRPC is located in Kaduna State, under Chikun local Government Area, sitting on a geographical area about 2.86 Square Kilometer, with the coordinates of 10.41192684 7643162 N, 7.4935010469218115 E (Google Maps, 2021). Public health and environmental risks due to gas flaring continues to be a major source of concern, KRPC buffer zone was encroach by the nearby settlement some of these concerns are related to potential long-term cumulative health effects on pupils around the area.

2.4 Atmospheric dispersion modeling

Data from the KRPC Flare System was carefully examined using the Operational Manuals for Both Normal and Emergency situations, and routing examination was also conducted inside the sterile KRPC Flare System area., Field survey was done through community visit, interviews, etc., to identify some of the affected area which include KRPC Buffer zone area, nearby settlement. Data generated was subjected to ALOHA to estimate the Consequences of the Toxic level and identify risk mitigation measures, Finally, Recommendation was made.

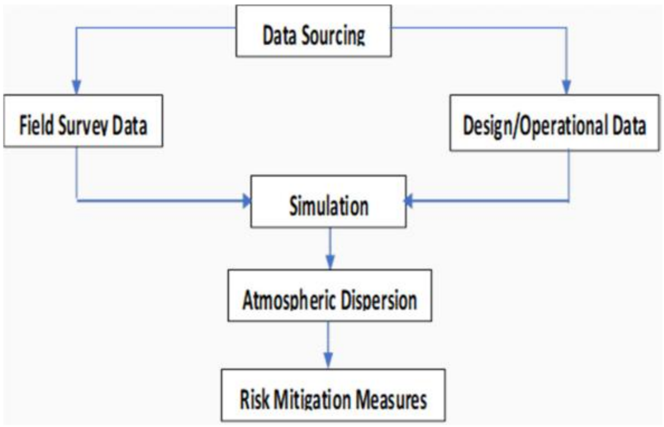

Figure 3: Atmospheric Dispersion Methodology.

Equation 1 was used to calculate the steady state concentration of an air contaminant in the ambient air resulting from a point source

$$C(x,y,z) = \frac{Q}{2\pi\pi_y\sigma_z} exp\left(-\frac{y^2}{2\sigma_z^2}\right)$$

$$\times$$

$$\left\{exp\left(-\frac{z+H}{2\sigma_z^2}\right) + exp\left(\frac{(z+H)^2}{2\sigma_z^2}\right)\right\}$$

……………………………………………………………1

where C is the time-averaged concentration at a given position, Q is the source term, x is the downwind, y is the crosswind and z is the vertical direction and u is the time-averaged wind speed at the height of the release h. The standard deviations -y and -z describe the crosswind and vertical mixing of the pollutant (Leelossy *et,al 2014).*

Table 3. Summarize the Data requirement for ALOHA Software Input and RecommendedStandard Used, Flow diagram in Figure 4 shows four stages procedure used to carry out atmospheric dispersion modeling for selected

pollutant Carbon Monoxide.

Table 3 Required input Parameters for ALOHA Carbon Monoxide Release

Parameter	Carbon Monoxide
Location	Kaduna State, KRPC
Location Coordinate: long. & lat.	10°24'42.1" N 7°29'36.2" E
Approximate Elevation	634m
Date and Time:	Assumed
Chemical Name:	Carbon Monoxide (CO)
Building:	Single Story Building
Wind speed:	5.46 m/s
Wind Direction:	North
Ambient Temperature:	29°C
Pasquill Stability:	Class B
Measurement of Height above Ground	69m
Source Height:	65m
Inversion Height:	67m
Humidity:	50 %
Cloud cover:	Clear
Ground Roughness:	Urban or Forest
Source Strength:	Direct Source (Continuous released)
Toxic level of Concern:	50ppm, 25ppm and 09ppm (OSHA US)
Scenarios:	Toxic released
Model Run:	Gaussian Dispersion
Software Version:	ALOHA 5.4.7

Consequence modeling

ALOHA software was used to forecast how the concentration of Carbon Monoxide (CO) at threedifferent Operational and Emergency (Minimum, Average, and Maximum) Conditions vary withtime and place after it has been discharged into the atmosphere.

3.0 DISCUSSION OF RESULT

Field Survey

Figure 3 shows an arial view of KRPC Plant and Nearby Settlement Obtain from Goggle Map. These settlement was capture around KRPC Buffer Zone area with a distance of 3km

from the North-East known as Industrial Layout/Sabon Gida. Table 4 Shows the Result of Mass Flowrate Release after Combustion from the Flare Tip at threestages (Minimum, Average, Maximum) Simulated for Toxic Pollutant of Carbon Monoxide fromKRPC activities.

Field/Survey Data

Obtain from Google Map. These settlement was capture around KRPC Buffer Zone area with a distance of 3km from the North-East known as Industrial Layout/Sabon Gida.

3.1 Atmospheric dispersion modeling

KRPC consequence modeling result was carryout for Both Normal and Emergency Flare stack at Minimum, Average, Maximum Flow rate. Toxic threat Release to the Atmosphere in part per Million (ppm), Level of Concern (LOC) i.e. Exposure limits and Perimeter Distance Cover by the Threat was observed. On wind direction confident lines, three separate in-build dispersion indicators at (ppm) are displayed. Toxic threat zone (Red color indicator) is a threshold for life-threatening effects, (Orange color indicator) is a threshold for escape-impairment, and (Yellow color indicator) is a threshold for moderate effects, as shown in Figures 4 - 6. No indication of a toxic hazard zone around KRPC is seen in any of the results for a normal operating flare stack at minimum, average or maximum mass flow rate with the indicator of (Level Not Reach). Based on the wind direction of 5.46 m/s, the Marplot result can be seen at the left hand indicating the release of harmful material to the environment from the flare tip traveling toward the north-western direction. According to the World Health Organization (WHO), the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the National Air Ambient Quality Standard (NAAQS), physical symptoms caused by carbon monoxide toxicity at a level of 09 ppm include exhaustion, headache, etc. Emergency Operation 25 and 09 ppm was observed, and the Marplot shows that, according to the ACGIH, an 8.0-hour average exposure to carbon monoxide at a toxicity threshold of 25 ppm may cause physical symptoms including weariness, headaches, disorientation, weakness, etc.

The 50 ppm Exposure Limit threat zone was not created because ground level concentrations never go over the LOC; nonetheless, 25 and 09 ppm were attained. The Marplot shows that, in accordance with the World Health Organization, Carbon Monoxide intoxication at concentration levels could result in headache and exhaustion among other symptoms (WHO). Therefore, exposure is restricted to no more than 8.0 hours per day.

Figure 3. KRPC Arial view and Nearby Settlement

Table 4: Nearby Settlement sited around KRPC with distance from Flares.

S/no	Region	Code	Tag Area	Distance (km) from Flare	Coordinates	Population
1	South West	KRPC 001	Sabon Gida/ Industrial Area	1.00	10°41’98.15” N 7°49’28.37’’ E	556
2	East	KRPC 002	Admin Block	1.00	10° 41’50.65” N 7°48’44.32” E	150
3	South West	KRPC 003	Marabar Rido	3.00	10 °42’86.85” N 7 °51’61.25” E	5,600
4	North	KRPC 004	Kankomi	1.34	10 °40’01.65” N 7 °49’74.21” E	1,890
5	North West	KRPC 005	Rido Village	1.85	10°40’77.70” N 7°50’97.33” E	8,500
6	East	KRPC 006	Romi	3.00	10°42’10.46” N 7°45’72.73” E	368,250
7	South East	KRPC 007	Sabon Tasha	1.75	10 °42’91.58’’ N 7°48’35.08” E	51,568
8	South East	KRPC 008	Juji/ Railway Quarters	1.27	10° 40’54.00’’ N 7°48’37.82’’ E	659

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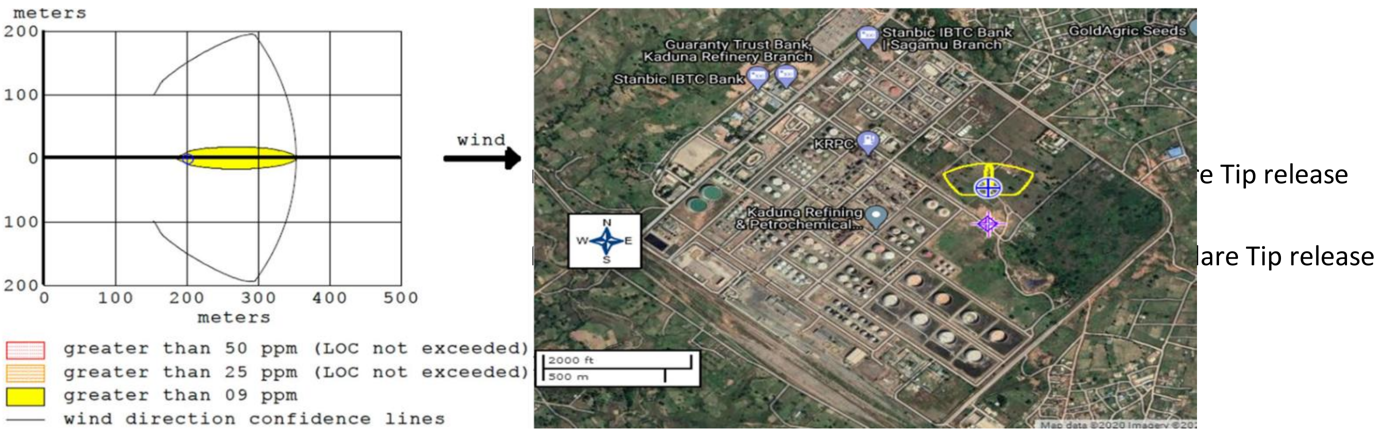

Figure 4. Aloha result for Carbon Monoxide at Minimum flow rate from KRPC flare Tip release to the Atmosphere and Marplot result for Carbon Monoxide release sited from KRPC flare stack at minimum flow rate.

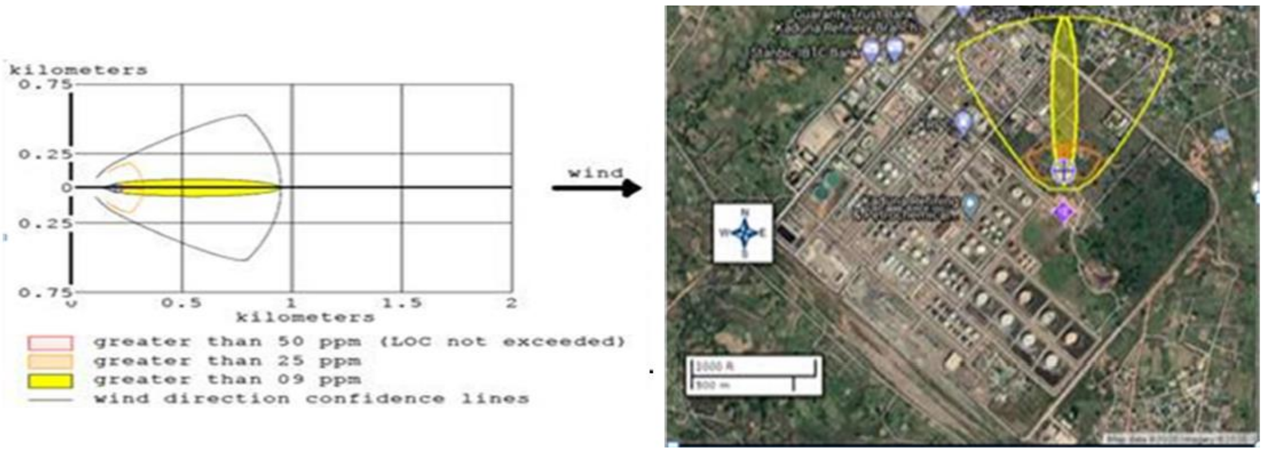

Figure 5. Aloha result for Carbon Monoxide at average flow rate from KRPC flare tip release to the atmosphere and Marplot result for Carbon Monoxide release sited from KRPC flare stack at average flow rate.

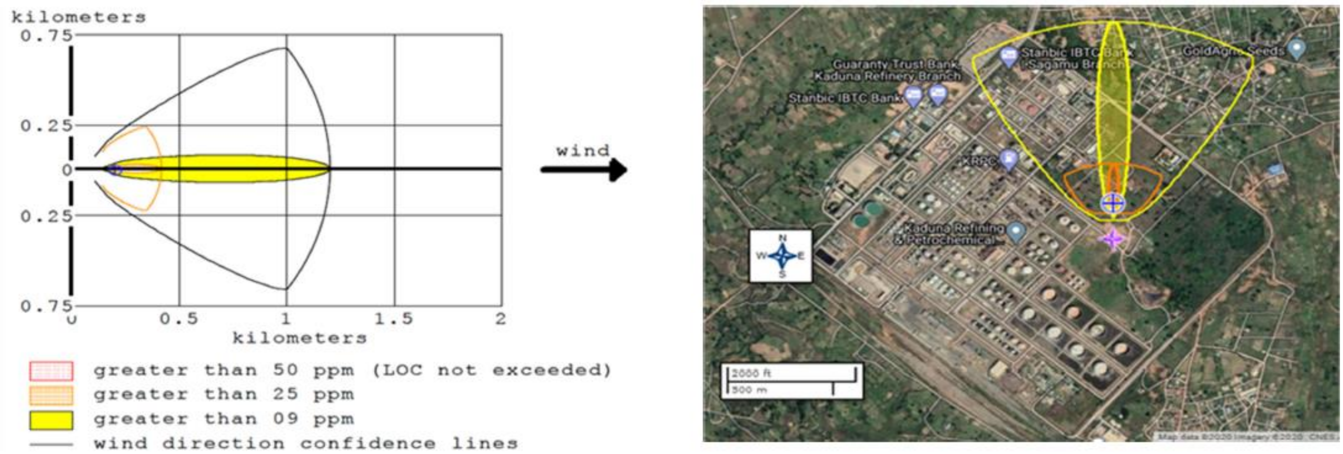

Figure 6. Aloha result for Carbon Monoxide at Minimum flow rate from KRPC flare Tip release to the Atmosphere and Marplot result for Carbon Monoxide release sited from KRPC flare stack at maximum flow rate.

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4.0 Conclusions

Carbon monoxide emission to the environment was identified as a dangerous scenario at the KPRC Flares, and buffer zone encroachment is a major problem around the KRPC neighboring town. The carbon monoxide discharge rate typically falls in the range 1335 - 4332 kg/hr at concentrations falling in the range of 9.0 and 25 ppm. The study found that even at maximum release rate, a carbon monoxide concentration of 50ppm is unlikely to be reached, although the health impact is within WHO, EPA, and NAAQS guidelines. Long-term exposure to carbon monoxide levels of 9.0 – 25 ppm might result in headaches, fatigue, and weakness. Carbon monoxide inhalation can exacerbate heart and/or respiratory problems in those who already have them. Government should address the issue of encroachment surrounding its infrastructure, according to the recommendation.

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