Atmospheric stability classes and its effect on co concentration emission around Kirkuk refinery

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Abstract. Atmospheric stability defines as the atmospheric tendency to reduce or intensify vertical motion, in other words, suppress or enhance existing turbulence, thus atmospheric stability play important role in transport and dispersion of air pollutant. In this study relationship between air pollutant of CO gases in 2019 resulted from burning three types of fuels (fuel gas, gas oil, naphtha) in 8 production units inside Kirkuk refinery (located in north-east of Iraq), and atmospheric stability analysis in different directions to know the effect of atmospheric stability classes on the emission of CO poison gas. Atmospheric element such as wind speed, cloud amount and solar altitude used by the Turner method to calculate seven stability classes, these classes are compared with CO pollutant at a different distance from the source point. From samples taken from stacks and fuels burned in a refinery, emission rate and exist velocity from 11 stacks calculated and used to estimated CO gas by Gaussian equation for dispersion at two months (January, July) in 2019. The comparison values of the concentrations with the distances from the point source for January and July was carefully examined, as it was noticed that the concentrations during the month's classes B and F varies in percent between January and July reach %120 - %170, while in the rest classes C, D, and G were close to 80% it decreases with the distance through (1000m – 10000m) by 81% - 59%, in Class A and E there is a difference in one of the two months.

Keywords Stability Classes, CO concentration, Emission rate, Kirkuk Refinery.

1. Introduction

Atmospheric stability plays the most important role in the transport and dispersion of air pollutants. It can be defined as the atmospheric tendency to reduce or intensify vertical motion or to suppress or enhance existing turbulence. The degree of stability of the atmosphere must be known to estimate the ability of the atmosphere to disperse pollutants [1]. Different methods are used for stability determination with varying degrees of complexity; Most of these methods are based on the relative importance of convective and mechanical turbulence in atmospheric motions [2]. Generally, when convective turbulence predominates, winds are weak and the atmosphere is in an unstable condition. When convection decreases and mechanical turbulence increases, the atmosphere tends to be in neutral conditions. Finally, in absence of convective turbulence when mechanical turbulence is dampened and there is no vertical mixing, the atmosphere is in stable condition [3]. Stability affects the spread of
pollutants and this determines by the difference in temperature between a sample of air and its surroundings. This difference is caused by the vertical movement of the air sample (up or down). This movement has four basic conditions that describe the state of stability in general [4]. On other hand air pollution is defined as the emission of particulate toxic elements into the atmosphere by natural or anthropogenic sources. These sources can be further differentiated into either mobile or stationary sources [5]. Most important processes cause pollutant is combustion of fossil fuels and biomass which produces carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NOₓ), volatile organic compounds (VOCs), and black carbon (BC) aerosols [6]. Compared to most urban air pollutants, carbon monoxide has a long atmospheric lifetime, from 1.1 to 2.4 months in the tropical boundary layer, and from 2 to 3 months in the mid-latitude lower troposphere. The long lifetime has several implications, the gas has often been utilized as a tracer of long-distance and intercontinental pollution transport. This makes CO relevant to people concerned with ambient air quality management as well as officials responsible for protecting public health and safety [7]. The world health organization (WHO) put guideline for CO exposures, it’s taken average times to exposure with maximum concentrations, as [8-hour for 10 mg/m³ (9 ppm), 1-hour for 30mg/m³, 30min for 60 mg/m³ and 15min for 100mg/m³ (90ppm)] [8]. There are many study deals with effect of the stability on the concentration of pollutant resulted from fuel burning in the refinery and industrial officials, for example Ahmed F. Hassoon used atmospheric data from European center for medium range weather forecasts (ECMWF) at suburban in north west of Baghdad city (33.75, 43.87) to calculate atmospheric stability classes by used pasquill- Gifford method at 8hour from each day. Through one year the stability rates is 54.4%, 8.7%, 36.9% at stable, neutral and unstable conditions [1]. Abbas M. Anad concentrated on the SO₂ gas resulted from processing of fuel in Daura refinery south west of Bagdad city at January month where stability classes quantities compared with concentration of this gas and the effect of air stability classes. The results show that atmospheric stability class F concentration of sulfur oxides is 54442 mg/m³ at distance 100m and 5127mg/m³ at distance 10000m were the highest in this region [4]. Moutaz A. AL-Dabas used sniffer devise to determine TSP concentration in Kirkuk oil refinery and area around it, and in two month October and March, the results show there is increases in TSP in two locations over limits of Iraqi national determinate (350µ/m³) and would limits (60-90)µg/m³ [9],Szep R. study the relationship between air pollution and atmospheric stability (calculated by different method ) in the Ciuc Basin at Bucharest Romania city; results show that conditions of stable condition Correspond with cold atmospheric period, this make pollutants such as PM10 and CO gas have high concentrations. In this research author notes high relationship between two these pollutant, because it have the same source, the relationship be negative in high temperature, this refer to important of photochemical processes[10].

The aim of this study is to explain effect of atmospheric stability classes by Turner-Pasquill method on concentration CO gas emitted from Kirkuk refinery area, through the processes of treatment of fuel gas, naphtha, and gas oil inside the refinery.

2. Location

Kirkuk oil refinery located northeast of Baghdad city between the latitude (35°24′ - 44°26′) to north and longitude (44°20′ - 44°26′) to the east [11], figure 1 show the location of Kirkuk province and location of a refinery in this province by image processed by GIS from sentinel satellite. Kirkuk province is covered by recent sediments and sedimentary rocks, the common rocks are limestone and with a small rate from gypsum rocks. Kirkuk province is divided into two main geomorphological parts. The first part is a flat floor that includes the hills and the study area is located within this region, the second part contains the mountainous areas and those located in the north and northeast of the province. The study area is located within the mountains foothill zone, this range is an extended area of the unstable shelf and has a broad belt between the Iraq - Turkey and the Iraqi-Syrian. Kirkuk refinery occupied area about 111739m² where first location kirkuk1 have an area about 69330m², while second location Kirkuk2 occupied area about 42409m². The refinery has a rectangular ship from
the east, northeast, north and northwest side’s refinery is surrounded by hills, with a height of approximately 10-20 meters.

3. Data
3.1 Atmospheric Data
Many papers included analysis of atmospheric data elements for Kirkuk meteorological station, most find that the mean monthly maximum temperature is about 43.5°C during July and low minimum value is 14°C during January. The maximum rainfall was 70.9mm during January while the minimum Was 0.1mm during August, the Maximum wind speed was 2.1m/s during June, while the minimum was 1.1m/s during December and January during the period 1980-2011. The prevailing annual wind direction for Kirkuk meteorological station is north-westerly direction [9][12]. In this study, local hourly atmospheric elements such as wind speed, cloud amount and air temperature at only January and July from 2019 is analysed to examine its effect on the dispersion of air pollution in the area of refinery this period is very suitable to represent two extreme seasons such as winter and summer. Fortunately, there is hourly missing in Kirkuk station thus only 8 hours included in this analysis, this data consider as the basis for calculating hourly stability classes. The maximum wind speed record is in a range from (1-7) m/s and (1-5) m/s in January and July respectively, but the amount of its value is in the range from (0-8) and (0-3) respectively at January and July see figure 2(a, b). The difference between the two months is very clear according to air temperature, cloud amount, see figure 2(a, b). Overall known this climatic parameter is a very important effect on the concentration of pollutants in the air that leads to a key role in controlling the spread of various air pollutants, specifically CO gas.

Figure 1. location of the study area, (a) Iraq map (b) Kirkuk province projected by sentinel satellite image (c) boundary of Kirkuk refinery and area surrounding.
Figure 2. Hourly Wind speed, Temperature and Total amount of cloud for Kirkuk station at (a) January (b) July.

3.2 Fuel Data
Fuel used in Kirkuk refinery consists of three types (fuel gas, naphtha and gas oil), it’s supplied to units of the refinery according to its structures, columns 1, 2, 3 in table 1. There are eight units in the refinery divided into two locations, (Kirkuk1 and Kirkuk2). There are two steam boilers at the kirkuk1 location that working in rotation (meaning that one works). As for the third steam boilers at the site Kirkuk2, it works continuously, as well as for the self-generation unit at the site it's working in Rotational also. Kirkuk1 location have 3 furnace units, The first, second and third production units operate continuously, each unit have two stacks and each furnace has two (flues) stack close to each other of the same size and height, first and second units used fuel gas and Naphtha as the burned fuel, while the third unit used gas oil, it’s used annually about 9299000m$^3$/h and 10643m$^3$/h respectively. In addition to these units in location1, also there steam generation boilers that burn annually about 1867 m$^3$/h of gas oil. The second location (Kirkuk2) consists of 4 units, they involved the steam generation boilers that consumed annually about 2737m$^3$/h from gas oil, and there are units 107 and 105 annually consumed about 1570251 m$^3$/h from fuel gas. In addition to these units, the Kirkuk2 location contains also self-electric power generation that burns about 1132m$^3$/h from gas oil, table 1, (column 5). Furnaces Units are a large combustion box designed to give the required heat by burning fuel in the air in the furnace burners. The furnaces are one of the most important parts of the operational units, the...
fuel supplied (fuel gas) by the North gas Company. Naphtha is produced from the refinery and the aim is to heat the crude oil and reach the required temperature for refining in the distillation tower [13]. All above these units work by 11 stacks in heights between (7.34-41) meter and stack diameter between (0.59-2) meter and stack gas exist temperature between (398.15 to 681) degree, Table 1.

Table 1. Fuel type and operation units (This characteristic such as stack number, stack diameter, stack gas exit temperature) for the year 2019.

| Units         | Name Of Operation Unit | Equipment Symbol | Location | Type Of Burned Fuel | Total Of Burned Fuel (m3/h) | Stack’s Number | Stack Height (m) | Stack Diameter (m) | Stack Gas Exit Temp (K) |
|---------------|------------------------|------------------|----------|---------------------|-----------------------------|----------------|------------------|-------------------|----------------------|
| Steam Boilers| B1&B2                  | Kirkuk 1         | Gas Oil  |                     | 1067                        | 1              | 7.54             | 0.355             | 398.15               |
| Unit 1        | Furnace No.1           | H-241            | Kirkuk 1 | Furnace Gas & Naphtha | 9290000 Fuel Gas & 10643 Naphtha | 2              | 15               | 1.22              | 681.15               |
| Unit 2        |                       |                  |          |                     |                             |                |                  |                   |                      |
| Furnace No.1  | H-241                  | Kirkuk 1         | Fuel Gas |                     | 2050                        | 1              | 15               | 1.22              | 681.15               |
| Steam Boilers| B1                     | Kirkuk 2         | Gas Oil  |                     | 2537                        | 1              | 7.55             | 0.795             | 481.15               |
| Unit 106      | Furnace No.1           | F-001            | Kirkuk 2 | Fuel Gas            | 7573065                     | 1              | 41               | 2                 | 598.15               |
| Unit 106      | Furnace No.1           |                  |          |                     |                             |                |                  |                   |                      |
| Self Electric | Gas & Gen2             | Kirkuk 2         | Gas Oil  |                     | 1132                        | 1              | 12               | 0.59              | 623.15               |

Table 2. Percentages of fuel components used in the study.

| Test Molecular Formula | Fuel Gas mol% | Test Molecular Formula | Naphtha mol% | Test Molecular Formula | Gas oil mol% |
|------------------------|---------------|------------------------|--------------|------------------------|--------------|
| CH₄                    | 86.18         | C₇H₈                   | 1.1731       | C₉H₁₂                  | 0.7524       |
| C₃H₈                   | 10.25         | C₇H₈                   | 5.5097       | C₉H₁₂                  | 4.4446       |
| C₃H₈                   | 2.11          | C₇H₈                   | 0.3485       | C₉H₁₂                  | 0.1340       |
| C₂H₆                   | 0.43          | C₇H₈                   | 10.250       | C₉H₁₂                  | 7.3556       |
| C₂H₆                   | 0.5           | C₇H₈                   | 3.3333       | C₉H₁₂                  | 1.6491       |
| C₂H₆                   | 0.3           | C₇H₈                   | 16.6524      | C₉H₁₂                  | 11.3764      |
| C₂H₆                   | 0.23          | C₇H₈                   | 6.5056       | C₉H₁₂                  | 3.5427       |
|                       |               | C₇H₈                   | 16.8411      | C₉H₁₂                  | 10.7021      |
|                       |               | C₇H₈                   | 4.2564       | C₉H₁₂                  | 3.1965       |
|                       |               | C₇H₈                   | 14.4363      | C₉H₁₂                  | 9.0794       |
|                       |               | C₇H₈                   | 1.2498       | C₉H₁₂                  | 0.9102       |
|                       |               | C₇H₈                   | 5.4650       | C₉H₁₂                  | 4.0593       |
|                       |               | C₇H₈                   | 1.8184       | C₉H₁₂                  | 1.8548       |
|                       |               | C₇H₈                   | 2.1445       | C₉H₁₂                  | 3.5000       |
|                       |               | C₇H₈                   | 4.8000       | C₉H₁₂                  | 5.0000       |
|                       |               | C₇H₈                   | 2.9000       | C₉H₁₂                  | 3.2000       |
|                       |               | C₇H₈                   | 0.3000       | C₉H₁₂                  | 9.2000       |
| Aromatic              | 8             |                       |              |                       |              |
| Paraffin              | 72.5          |                       |              |                       |              |
| Naphthene             | 17.5          |                       |              |                       |              |
|                       |               |                       |              |                       |              |
| Totals                | 98.0001       |                       |              |                       |              |
| Totals                | 100           |                       |              |                       |              |
3.3 Emission rate data
To calculate the concentration of CO pollutant resulted from fuel gas, naphtha and gas oil fuels that burn in 8 processing units, laboratory analysis done for the samples of fuels before burning and samples of burning gas. The sample of fuel consists of fuel gas provided from the north gas company while naphtha and gas oil is produced from a refinery. fuel gas sample is taken by Football bag after discharge it from the air and accurate closed, table 2, while the second and third sample is taken from the production units and put in the plastic clean bottle have size about ½ litre, results of analysis samples archived in table 2, by Thermo Electron Trace GC Ultra Multi-Channel Gas Chromatography. Fuel samples analysis Ratio used to calculate the density mass of fuel gases according to table 3. Overall by using chromatography (GC), the average volumetric percentage for exit gases from the stack, and the Average molecular weight of exit gases is about 28.9747 Kg. The total mass of C in 1 Kg of gases = 0.0041 + 0.0083 = 0.0124 Kg, this data obtained from analysis exist gas from the stack for units 105 and 107 for sample from fuel gas.

July and emission rate resulted in July month for the fuel gas, naphtha larger than Jan, while it’s relatively equal in gas oil. Overall this depends on the amount of fuel consumed.

4. Methodology
4.1 Atmospheric Stability Classes
Turner method has seven classes, resulted from intersecting wind speed data with Insolation Class Number (ICN), at daytime have values from (1-4), and cloud cover amount at night-time have negative insolation values (-1 and -2). The amounts of cloud cover available at daytime sometimes modified the ICN, if cloud cover greater than 1/2, and cloud level height are less than or equal to 7000ft, where it will become (ICN-2), and if greater than or equal to 7000ft became (ICN-1). If total cloud cover equal to 1 became (ICN-1), where cloud cover level height greater than 7000ft [14]. The Pasquill-Turner Method (PTM), which is employed in this study, is based upon the work of Pasquill that has been reviewed by Turner (1964) and introducing incoming solar radiation in terms of solar elevation angle, cloud amount or cloud height table 4. It classifies atmospheric stability with seven distinguishable categories. The importance of this method lies in the relation of atmospheric dispersion coefficients and classified stability for mechanically and thermally generated boundary-layer turbulence. Also, PTM can simply modify to model used evenly to compute stability.
Table 3 (a),(b),(c),(d),(e). The emission rate of Co for three types of fuel burned at months January, April, July, and October.

| (a) Name of an operation unit | Stack height (m) | Months | burned fuel | wt% of carbon | Emission of CO (kg/h) | Emission of CO (mg/s) |
|------------------------------|------------------|--------|-------------|---------------|-----------------------|-----------------------|
| UNIT 1 , 2 , 3              | 15 , 15 , 18     | January | 778         | 76            | 578                   | 160569                |
|                              |                  | April   | 543         | 76            | 403                   | 112079                |
|                              |                  | July    | 1010        | 76            | 750                   | 208421                |
|                              |                  | October | 738         | 76            | 548                   | 152275                |

| (b) Name of an operation unit | Stack height (m) | Months | burned fuel | wt% of carbon | Emission of CO (kg/h) | Emission of CO (mg/s) |
|------------------------------|------------------|--------|-------------|---------------|-----------------------|-----------------------|
| UNIT 105 , 107              | 41 , 41          | January | 1116        | 76            | 1326                  | 368456                |
|                              |                  | April   | 1763        | 76            | 2095                  | 581892                |
|                              |                  | July    | 1494        | 76            | 1775                  | 493005                |
|                              |                  | October | 1438        | 76            | 1709                  | 474804                |

| (c) Name of an operation unit | Stack height (m) | Months | burned fuel | wt% of carbon | Emission of CO (kg/h) | Emission of CO (mg/s) |
|------------------------------|------------------|--------|-------------|---------------|-----------------------|-----------------------|
| UNIT 1 , 2                   | 15 , 15          | January | 759         | 85            | 625                   | 173671                |
|                              |                  | April   | 1075        | 85            | 885                   | 245951                |
|                              |                  | July    | 1040        | 85            | 856                   | 237802                |
|                              |                  | October | 743         | 85            | 612                   | 170012                |

| (d) Name of an operation unit | Stack height (m) | Months | burned fuel | wt% of carbon | Emission of CO (kg/h) | Emission of CO (mg/s) |
|------------------------------|------------------|--------|-------------|---------------|-----------------------|-----------------------|
| Steam boiler 1 , 2           | 7.34 , 7.34      | January | 445         | 87            | 402                   | 111634                |
|                              |                  | April   | 490         | 87            | 442                   | 122872                |
|                              |                  | July    | 413         | 87            | 373                   | 103520                |
|                              |                  | October | 474         | 87            | 428                   | 118908                |

| (e) Name of an operation unit | Stack height (m) | Months | burned fuel | wt% of carbon | Emission of CO (kg/h) | Emission of CO (mg/s) |
|------------------------------|------------------|--------|-------------|---------------|-----------------------|-----------------------|
| Self Electric Power Generation | 12               | January | 134         | 87            | 91                    | 25181                 |
|                              |                  | April   | 76          | 87            | 52                    | 14311                 |
|                              |                  | July    | 50          | 87            | 34                    | 9443                  |
|                              |                  | October | 135         | 87            | 91                    | 25390                 |
Table 4. Pasquill-Turner Method (PTM) scheme, to calculate stability classes according to wind speed, net radiation index.

| Wind Speed (knots) | Net Radiation Index |
|--------------------|---------------------|
| 4                  | 3                   | 2      | 1 | 0 | -1 | -2 |
| 0-1                | 1                   | 1      | 2 | 3 | 4 | 6 | 7 |
| 2-3                | 1                   | 2      | 2 | 3 | 4 | 6 | 7 |
| 4-5                | 1                   | 2      | 2 | 3 | 4 | 4 | 5 | 5 |
| 5-6                | 1                   | 2      | 3 | 3 | 4 | 4 | 5 | 5 |
| 7                  | 2                   | 2      | 3 | 4 | 4 | 5 | 6 |
| 8-9                | 2                   | 3      | 3 | 4 | 4 | 5 | 5 |
| 10                 | 3                   | 3      | 4 | 4 | 4 | 5 | 5 |
| ≥12                | 3                   | 4      | 4 | 4 | 4 | 4 | 4 |

Solar Altitude (a) | Insolation Class Number
--- | ---
60° < a | Strong 4
35° < a < 60° | Moderate 3
15° < a < 35° | Weak 2
a ≤ 15° | Very Weak 1

4.2 Gaussian model

The Gaussian plume model, consider the core of almost all regulatory dispersion model, obtained from the analytical solution of the simplified diffusion equation. For a continuous point source released at the origin in a uniform (homogeneous) turbulent flow, the final form of the Gaussian plume equation, for an elevated plume released, figure 3 at \( z = H \) is mathematically expressed by the following general equation [14][15].

\[
C(x, y, z) = \frac{Q}{2\pi \nu_p \sigma_y \sigma_z} \exp \left( -\frac{y^2}{2\sigma_y^2} \right) \left\{ \exp \left( -\frac{(z-H)^2}{2\sigma_z^2} \right) + \exp \left( -\frac{(z+H)^2}{2\sigma_z^2} \right) \right\} \tag{1}
\]

Where:
- \( C \) = point concentration at receptor, in \( \mu g/m^3 \);
- \( (x, y, z) \) = ground level coordinates of the receptor relative to the source and wind direction, in meters;
- \( Q \) = mass flow of a given pollutant from a source located at the origin, in \( \mu g/s \);
- \( \bar{u}_p \) = wind speed, in m/s;
- \( \sigma_y \) and \( \sigma_z \) = crosswind and vertical dispersion coefficient in (meter)
- \( H \) = effective stack height (m) = \( H_s + \Delta H \) in meters (m), \( H_s \) stack height (m).
- \( \Delta H \) = plume rise (m),

\[
\Delta H = \frac{21.425 F^{0.75}}{U} \quad \text{for} \quad F \leq 55 \frac{m^4}{s^3} \tag{2}
\]

\[
\Delta H = \frac{38.7 F^{0.75}}{U} \quad \text{for} \quad F \geq 55 \frac{m^4}{s^3} \tag{3}
\]
\[ F = \frac{gVd (T_s - T_a)}{4T_s} \]  (4)

Where 
\( F = \text{Bouncy flux} \)
\( V = \text{stack exist velocity (m/sec)} \)
\( d = \text{top inside stack diameter (m)} \)
\( T_s = \text{stack gas temperature (K)} \)
\( T_a = \text{Ambient temperature (K)} \)
\( g = \text{gravity (m/s}^2) \)

5. Results and dissuasion
5.1 Atmospheric stability classes
Stability classes by turner-Pasquill are adopted in this study to give stability classes and compared to pollutant resulted from CO concentration. Turner-Pasquill has about 7 classes ranged from 1 to 7 built up according to table 4 and paragraph 4.1. Each class by Turner opposite by class in Pasquill thus method will be the Turner-Pasquill method. Atmospheric element observed every 3 hour is dependent on the calculated stability classes, in this study only January and July hours adopted every day (8 hours and 7 classes) figure 4a, b. From the comparison between two months it finds that most classes are in neutral class it has a large frequency in two months but it’s very large in July month that considers as an unstable class according to classification and calculation by Gaussian equation model, figure 4b. Thus if class (D) consider as an unstable percent of unstable classes in July will be domain. In figure 4 period of study selected only January and July to represent the extreme period in 2019. In January month about 248 classes adopted, stable classes E, F, G have about 127 class while the unstable classes B, C have about 66. Thus while in stable condition E, F, G have 94 class most other classes are unstable A, B, C, D, Class D in this month very large about 112 (23.3%) of monthly hourly stability. The classes rate can be compared with research [4] but for compassion with SO2 concentration. Also atmospheric stability classes by Pasqual-turner calculated in the same method in references [1],[16].
5.2 Concentration of CO

Crude Oil contains many hydrocarbons components such as Paraffinic, Naphthenic, Aromatic and Olefinic. Kirkuk refinery has 8 units (first location 4 unit and second location 4 unit) used to refine about 56 thousand barrel of Crude Oil to its compounds such as Naphtha, kerosene, gas oil, fuel oil and some burning gases in the air. The important processes of extracted these compounds need to heat Crude Oil to high temperature in the furnace. There are three types of fuel burn inside furnace and boiler its fuel gas, Naphtha and gas oil, table 5 shows the total amount burn in 8 unit of these fuels in 2019 according to the type of unit consumption.

From the analysis of fuels consumption for the three types of fuels, It shows that July month have a large value for consumption, this month represent the summer season that has a specified atmospheric condition review paragraph 3.1 and figure 5. This study concentrated on the air pollution of CO at two months only (January) that represent winter month and (July) which represent summer month, the monthly consumption depicted in figure 5 according to production units.

The emission rate of CO gas from 8 units in table 4, used in Gaussian equation to calculate the hourly concentration of CO information of emission rate to calculate the exit velocity from the stacks of 8 production unit. Information in table1 used to calculate effective stack height according to equation 2 and 3.

Gaussian plume equation 1 at z=H where H is effective stack height m, used in this study to calculate concentration dispersion of CO at a different distance from a point source in the circular have radius 1000, 2000, 3000 ……1000m. See figure 6.
Table 5. The total annual amount of burn fuels in the production units, according to its structure.

| Production unit                                      | Fuel type    | Annual fuel consumption in units |
|------------------------------------------------------|--------------|---------------------------------|
| Units 1, 2, 3 and units 105, 107                      | Fuel gas     | 25001510 34237 26260            |
| Self-electric generation Steam generation boiler (Kirkuk1) | Gas oil      | 5736 7.849 6515                 |
| Steam generation boiler (Kirkuk2)                     |              |                                 |
| Furnace of units 1, 2                                | naphtha      | 10643 14.575 10203             |

Figure 5. Total monthly fuel consumed by 8 unit’s production in Kirkuk refinery.
Figure 6. Hourly CO concentration resulted from burning fuel gas, gas oil and Naphtha at distance 3000m from sources point at (a) January (b) July.
**Figure 7.** Total hourly CO concentration dispersion at distances 1000m, 3000m, 6000m, 9000m from sources point at (a) January, (b) July.
Table 6. the average of CO concentration (mg/m³) at different atmospheric classes, the rate of percent between CO Concentration in January and July.

| Distances (m) | Months | Atmospheric Classes |
|---------------|--------|---------------------|
|               | A      | B                   | C | D | E          | F | G         |
| 1000          | Jan.   | 2.0866              | 1.5043 | 3.0403 | 0.8195 | 3.9333 | 0.8599 | 14.1594 | 21.0673 | 1.2333 | 29.0962 | 0.814 |
|               | Jul.   | 2.5151              | 1.3871 | 3.7101 | 4.5742 | 1.7937 | 0.8476 | 4.4794 | 17.0828 | 9.2091 | 35.7472 | 11.3538 |
| 2000          | Jan.   | 0.575               | 1.1798 | 1.6742 | 0.6446 | 2.1162 | 0.8476 | 2.3476 | 5.4229 | 1.2294 | 11.3538 | 0.8111 |
|               | Jul.   | 0.7446              | 0.3435 | 1.8301 | 0.2506 | 1.0592 | 0.5853 | 0.6396 | 3.4941 | 4.3268 | 5.9552 | 0.8105 |
| 3000          | Jan.   | 0.3277              | 1.4757 | 1.6991 | 0.6137 | 1.2411 | 0.8586 | 1.5136 | 2.2529 | 1.2283 | 3.1112 | 0.8103 |
|               | Jul.   | 0.138               | 0.7061 | 0.6415 | 0.6031 | 0.7259 | 0.8471 | 0.8103 | 1.7340 | 3.8406 | 1.2283 | 0.8102 |
| 4000          | Jan.   | 0.1809              | 0.0809 | 0.1706 | 0.5982 | 0.5439 | 0.8588 | 1.0902 | 1.6227 | 2.2417 | 2.7667 | 0.8102 |
|               | Jul.   | 0.1868              | 0.0869 | 0.2688 | 0.6327 | 0.4306 | 0.8407 | 1.2514 | 1.7287 | 2.1337 | 1.3956 | 0.8101 |
| 5000          | Jan.   | 0.141               | 0.0508 | 0.4494 | 0.5955 | 0.4306 | 0.8671 | 0.8101 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
|               | Jul.   | 0.0781              | 0.0348 | 0.5337 | 0.6327 | 0.5007 | 0.8671 | 0.8101 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
| 6000          | Jan.   | 0.0452              | 0.0432 | 0.5955 | 0.3549 | 0.4123 | 0.8690 | 0.8101 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
|               | Jul.   | 0.0568              | 0.0253 | 0.1558 | 0.5939 | 0.3549 | 0.8690 | 0.8101 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
| 7000          | Jan.   | 0.0328              | 0.0192 | 0.1257 | 0.5939 | 0.3549 | 0.8690 | 0.8101 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
|               | Jul.   | 0.0431              | 0.0171 | 0.0212 | 0.5929 | 0.3493 | 0.8615 | 0.8102 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
| 8000          | Jan.   | 0.0258              | 0.0152 | 0.1257 | 0.5929 | 0.3493 | 0.8615 | 0.8102 | 1.2283 | 1.7277 | 2.1337 | 0.8101 |
|               | Jul.   | 0.0339              | 0.0151 | 0.1758 | 0.5922 | 0.2607 | 0.8619 | 0.4846 | 0.7205 | 0.9953 | 1.2283 | 0.8101 |
| 9000          | Jan.   | 0.0207              | 0.0888 | 0.2297 | 0.5917 | 0.2664 | 0.8623 | 0.3751 | 0.6727 | 0.8671 | 1.2283 | 0.8101 |
|               | Jul.   | 0.0273              | 0.0121 | 0.1488 | 0.5917 | 0.2664 | 0.8623 | 0.5112 | 1.2283 | 1.0705 | 0.8101 |

Figure 8. Average CO concentration according to atmospheric classes, through the distance from 1000 m to 10000 m from the point source at (a) January and (b) July months.

5.3 Assessment effect of stability Classes on CO concentration
By comparing the stability classes for January and July of 2019, we find that row e does not exist in July, unlike January, which contains about 12 occurrences of classes E. Class E is slightly stable as most of the cultivars are among the unstable varieties, Figure 4. About stable varieties such as G, F, it is more proportionate during January, where most pollutants are concentrated in these varieties, and these varieties appear during the night time due to surface cooling of the air close to the surface, while the air above remains relatively warm and since most pollution centers are concentrated on the surface of the earth and remain it is emitted without dispersion, which raises the levels of pollution at those points and at these times. Generally, pollution decreases as we move away from the center point. Figure (8) shows the average concentration of carbon monoxide at each of the atmospheric stability classes from 1 to 7 and at different distances from the production units of the refinery. Also Results of atmospheric stability classes and CO concentration gas done in Daura refinery through Ph.D. thesis in references [17][18][19].

The change of CO concentration with distance is not constant and depends on the type of stability class and the distance from the source, as at distances close to the source there is a large reduction of the concentration values and then it changes to relatively small proportions, especially with moving away from the source point. At unstable class B Every 1000 meters is 28%, 44%, 55%, 63%,69% 73%,76% 78%, 80% at distances 1000-2000, 2000-3000, 3000-4000, 4000-5000, 5000-6000, 6000-7000, 7000 -8000, 8000-9000, 9000-10000 respectively. While at stability class F stable 31%, 52%, 64%, 72%, 77%, 80%, 83%, 85%, 87% at distances 1000-2000, 2000-3000, 3000-4000, 4000-5000, 5000-6000, 6000-7000, 7000-8000, 8000-9000, 9000-10000 respectively, during the month of January, note Table 6. During July, the decrease will be 25%, 43%, 55%, 63%, 68%, 73%, 76%, 78%, 80% at the same previous distances, respectively, for the unstable class B. The decrease rates during the same month for the stable class F are 31%, 52%, 64%, 72%, 77%, 80%, 83%, 85% and 87% respectively. It is very similar to the existing change of focus with distance in January, Table 6.

The comparison of the values of the concentrations with the distances from the source for January and July was carefully examined, as it was noticed that the B and F varieties in January had more than %120 - %170 concentrations during July, while in the rest of the classes C, D, and G were close to 80% while it decreases with the distance through distances (1000m– 10000m) by 81% - 59% Note Table 6, Class A, E There is no similarity in one of the two months and what it accepts with it and the values are empty in Table 6.

6. Conclusion
Atmospheric stability is considered one of the most important factors affecting the spread and dissipation of air pollutants, as it increases the concentrations of pollutants in a certain layer, prevents their dispersion, and at other times works to spread them and reduce their concentration. On the other hand, carbon monoxide is considered one of the toxic gases that affect living organisms and lead to Poisoning due to its combination with the hemoglobin pigment present in the blood rapidly, leading to the formation of blood carbon-hemoglobin, which leads to blood poisoning This gas is one of the main gases that are released during the combustion of fossil fuels, especially in refineries and power stations. The current study attempts to evaluate the effect of stability on CO gas through the stability classes that have been determined depending on the Pasquill Turner method and weather factors (wind speed, amount of clouds ... and others). Since stability and its varieties depend primarily on weather factors, which differ according to the season of the year, only two months have been adopted, representing the month of winter, January and July, which represents one of the summer months. The changing weather condition will be reflected primarily on the varieties and their frequency and thus will affect the concentration of carbon monoxide. Calculated from the emission ratios and the type of fuel used after analyzing the fuel samples in the laboratory, determining their volume ratios and calculating the gas density. From this study, we conclude that although the unstable and concentration are more in July than in January, the quantities of fuel that are burned during July are about more than January, although the stable items, especially the GF They are prevalent in this month and work to increase the concentrations of pollutants in the refinery area and prevent dispersion. Therefore,
stability varieties affect the concentrations of carbon monoxide, but it is not the dominant factor as the quantities of emission of gases that come from the quantities of fuel burned work substantially at the total concentrations considering other factors are constant or ineffective.

References

[1] Hassoon A F, Mohammed S K and Al-Saleem H H H 2014 Atmospheric Stability and Its Effect on The Polluted Columns of Concentrations in North West of Baghdad City *Iraqi J. Sci.* 55 572–81
[2] Mohan, M., & Siddiqui T A 1998 Analysis of various schemes for the estimation of atmospheric stability classification *Atmos. Environ.* 32 3775–81
[3] Schenelle, K.B, Dey P . 2000 *Atmospheric dispersion modeling compliance guide* (McGraw-Hill companies)
[4] Abbas M. Anad, Monim. H. Al- Jiboori A F H 2019 Simulation Effect of Stability Classes on SO2 Concentration in Daura Refinery and Neighboring Regions *Al-Mustansiriyah J. Sci.* 30 1–8
[5] Hassoon A F 2015 Assessment of air pollution elements concentrations in Baghdad city from periods (May-December *Int. J. energy Environ.* 6(2) 191
[6] Osama T. Al-Taai D A F H and D L M R A The Study of the Chemical Analysis of Gases (CO, CO2) and Find A Relationship between Some Meteorological Variables and Concentrations of Gases *Int. J. Gen. Chem.* 2
[7] Martin, B. D., H. E. Fuelberg, N. J. Blake, J. H. Crawford, J. A. Logan, D. R. Blake and G W S 2002 Long-range transport of Asian outflow to the equatorial Pacific *J. Geophys. Res.* 107
[8] Monoxide W C 1987 *In Air Quality Guidelines for Europe, WHO Regional Publications* (Copenhagen)
[9] Al-Dabbas, M. A., Ali, L. A., & Afaj A H 2012 The effect of Kirkuk Oil Refinery on Air pollution of Kirkuk City-Iraq *In Proceeding of the 1st Conference on Dust Storms and their environmental effects* p 18
[10] Szep R, Keresztes R, Korodi A, Tonk S and Craciun M E 2017 Study of air pollution and atmospheric stability in Ciuc basin-Romania *Rev. Chim* 68 1763–7
[11] Ali L A A 1995 *Environmental Impact Assessment Of Kirkuk Oil Refinery* (University of Baghdad)
[12] B.M. H 2009 *Measurement and study concentrations some air pollutants in Baghdad city.* (College of Science Al-Mustansiriyah University)
[13] Anon 2019 Annual report *North Refineries Co. / Kirkuk Refin. / Insp. Control Div. / Environ. unit*
[14] Macdonald R 2003 Theory and objectives of air dispersion modelling *Model. Air Emiss. Compliance* 1–27
[15] ALbdiri A D Z 2018 effect of atmospheric stability conditions on the dispersion and deposition rates of particulates matter on the surface of high voltage insulators *J. Eng. applied Sci.* 13 10323–33
[16] Gzar H A 1998 *Mathematical Modeling for dispersion of air pollutants estimated from AL-Daura oil refinery stacks* (baghdad univesity)
[17] AL-granny A M A 2019 *Determination Air Quality around Daura Refinery Using Gaussian Dispersion Model* (Mustansiriyah University)
[18] SHUBBAR R M J 2017 *Numerical Simulation of air pollutants using CALPUFF model at an urban area in Baghdad- Iraq* (Pukyong National University)
[19] Shubbar R M, Lee D I, Gzar H A and Rood A S 2019 Modeling Air Dispersion of Pollutants Emitted from the Daura Oil Refinery, Baghdad-Iraq using the CALPUFF Modeling System *J. Environ. Informatics Lett.* 2 28–39