The Transfer Phenomena of Air Pollutants Emitted from Power Station and Generators in Nasiriyah City and the Effect of Meteorological Parameters on its Dispersion by Using Fixed Box Model

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Abstract. The study aims to use the fixed box model to calculate the spread of pollutants (CO\textsubscript{2}, SO\textsubscript{2}, NO\textsubscript{X}, particulate) resulting from the burning of fuel used to produce electrical energy in the Nasiriyah city and to know the way they spread in the city through being affected by the wind speed and compare the results calculated from the model with the results measured by the lancom4 device. The results showed that the main pollutants for the air in Nasiriyah was emitted from burning the fuel used for the production of electric power, and the results showed that the concentration of pollutants (CO\textsubscript{2}, SO\textsubscript{2}, NO\textsubscript{X}) was much higher inside the city when compared with the upstream direction of the winds due to its increase with the movement of winds and its entry into the city. Through the application of the fixed box model and when comparing the calculated results through the model with the results measured by the lancom4 device, the error rate was (4\%, 2\%, 2\%, 5\%) for pollutants (CO\textsubscript{2}, SO\textsubscript{2}, NO\textsubscript{X}, particulate) respectively, it was also observed that the highest emission rate of pollutants was result from using heavy fuel (fuel oil) and the lowest emission was from light oil (Dry gas). We noted the spread of pollutants and dilution in the atmosphere increases with the increase in wind speed, excluding for particles mater.

Keywords: Air pollution, Fixed Box Model, Wind speed, Nasiriyah City, Iraq.

1. Introduction

Air pollution results from the release or emission of any foreign substance into the air, from natural or industrial sources, air pollution has recently become a concern and even threatens the health and happiness of all humanity due to its negative effects on human health and living organisms [1-3]. Air pollution varies from place to place according to wind speed and weather conditions, for example, nitrogen oxides interact with hydrocarbons in the presence of sunlight under special weather conditions, often in the summer season, toxic chemicals such as tetraethyl pyroxene and ozone gas are produced, and these together with some other components lead to What is known as smog is often brownish in color. Smog is formed when the emitted air pollutants exceed the carrying capacity of the atmosphere and accumulate after a series of chemical reactions in the atmosphere. Smog often occurs in cities crowded with cars and from fuel combustion in Power plants [4, 5]. Thermal power plants are considered a source of emission of pollutants (CO\textsubscript{X}, SO\textsubscript{X}, NO\textsubscript{X}, HC, and PM) due to their burning of fuel. The percentage of emission of these pollutants varies according to the type of fuel used and according to the degree of maintenance in the plants [6]. 92\% of the world’s population lives in places with average air quality that exceeds the limits of the World Health Organization’s proposed air pollution. This is due to
the use of poor fuels, old vehicles and poor maintenance. Car exhaust contributes quarter to three particulate air pollution [7]. Air pollution causes harmful health effects on humans, including infectious respiratory diseases, cardiovascular diseases and lung cancer. The World Health Organization estimates that the death rate resulting from air pollution inside and outside buildings reaches 7 million premature deaths annually [8-10]. The United Nations indicates that the number of premature deaths due to air pollution will increase to more than 50% in a year 2050 [11]. Recent studies indicate the ability of air pollutants to increase the impact and spread of the COVID-19 [12]. Air models use to description the relationship between pollution sources and atmospheric factors, pollutant concentration, way of spread in the atmosphere; and give a description of the air quality index [13]. There are many types of air dispersion models and the box model is the simplest among the types. This model was established in 1970 by Lettau, box model proposes the existence of a box with dimensions (W, H, L) surrounding the pollution area and the rate of emission of pollutants is constant and the pollutant concentration is homogeneous in the box to a certain height [14].

Many studies was applying box model for example: Sharif and Anjel, 2020 studied air pollution using fixed box model in the city of Erbil in Iraq and found that the pollutants accumulated after 8 hours of morning time, pollutants (NOX, HC, CO, PM2.5, CO2) were higher than the permissible limits, and they concluded that the increase of (CO & CO2) was due to the electrical generators in the city and the huge number of cars that caused the emission of (NOX, PM, CO2), what caused the appearance of black clouds frequently in the sky of the city, especially with the increase in the relative humidity ratio [15]. Ali et al., 2016 applied the fixed box model to predict PM10 in part of AL-Kut city on Iraq. During 5 month period from Nov. 2015 to Mar. 2016, and the results calculated from fixed box model were close to the results measured by mobile devices [16]. Zhou et al., 2020 studied the application of the single-box model in 2015 to calculate the (RAEC) and studied the pollutants (NO2, SO2) in the city of Chengdu on China. It was found that the height of the mixing layer in areas with low wind speed is the most important parameter of meteorology affecting air pollutants [17]. Ho et al., 2009 He studied the application of the box model to calculate the variance of PM10 with time and studied in the model the wind speed & mixing height in addition to the capacity of the PM10 emission source and the size of the emission area for the period from Sep. 2007 to Mar. 2008 in Hanoi city on Vietnam. It was found that the concentration of PM10 is inversely proportional to the wind speed & mixing height inside the box [18-20].

The study aims to use the fixed box model to calculate the spread of pollutants (CO2, SO2, NOX, particulate) resulting from the burning of fuel used to produce electrical energy in the Nasiriyah city and to know the way they spread in the city through being affected by the wind speed and compare the results calculated from the model with the results measured by the lancom4 device.

2. Materials and Methods

Area of the study. Nasiriyah city are located in the southeast of Iraq on the Euphrates River (31.05° N, 46.26° E), with an area of 1766 km² and it represents the center of Thi-Qar Governorate, which has an area 12900 km² (3.1% of Iraq area). The climate of the city is characterized by a long hot and dry summer and a short cold winter with little rain, and the average wind speed is estimated at 12 km/hr throughout the year, where the winds in it are one of the elements of the climate more prone to fluctuation, this is due to the location of Iraq in the subtropical belt and due to the nature of the pressure systems affecting the city’s climate. The Thi-Qar oil refinery is considered one of the most important sources of pollution in the region, which is located 5 km south of the city, and that environmental pollution in the city is a dangerous phenomenon for the residents of the region, where suffocating gases spread and black smoke, which pose a great danger to human health, as weather conditions contribute to Concentration and spread of pollutants in the air, especially when the wind direction is westerly to east.
Figure 1. Fixed box model on the Nasiriyah city.

3. Assumptions and Mathematical Calculation of Fixed box model.

The Fixed box model assumes that there is a rectangle above the study area according to Fig. 1, to calculate the concentration of air pollutants; a balance is made for the materials inside the rectangle. The assumptions on which the model is built are:

1- The study area shall be in the form of a rectangle with dimensions W, H, L, in a direction that is parallel to the direction of the winds in the area of emission of the pollutant.

2- Mixing happens complete for pollutants at H (height), and no mixing occurs beyond H.

3- Concentrations of pollutant are distributed uniformly in the atmosphere inside fixed box above study area.

4- The speed is independent of time.

5- The pollutant concentration in the air of the study area at x = 0 is constant and equal to b µgm/m³.

6- The emission rate of pollutants in the Nasiriyah city is Qi. This represents the flux per unit area q (g/s.m²) and it is converted using the following equation: Qi = q. AN So that AN represents the area of the study area.

7- No pollution enters the box from the top or the sides.

8- The rate of accumulation of pollutants and the rate of destruction is equal to zero. CN is the pollutant concentration above the Nasiriyah city.

After substituted the related equations we get the following:

\[ C_{CO_2} = b_{CO_2} + \frac{q_{CO_2} \cdot L}{uH} \] \hspace{1cm} \ldots (1)

\[ C_{SO_2} = b_{SO_2} + \frac{q_{SO_2} \cdot L}{uH} \] \hspace{1cm} \ldots (2)
\[ C_{NO_x} = b_{NO_x} + \frac{q_{NO_x} \cdot L}{uH} \] ........... (3)

\[ C_{Particulates} = b_{Particulates} + \frac{q_{Particulates} \cdot L}{uH} \] ........... (4)

Where: \( b \) is the \( C \) of any pollutant (\( \mu g/m^3 \)) in the atmosphere arriving to study area and \( u \) is average velocity of air (m/s).

4. Measurements & Calculations.

Table 1 show the totality fuel consumption for electric production in Nasiriyah city (m3/day), and the annual amount (ton/y) calculated according to the density of the fuel. Data was taken from electricity ministry & oil ministry in Iraq. From the plan of study that got from Google the length and width of the study region was \( L = 175000 \) m & \( W=115000 \) m, so the area of study was \( 20125000000 \) m2. Concentrations amount in Table 2 was determining by pollutants meters called lancom4 Fig. 2 these measurements were taken upstream of wind direction (before entering the city). Table 3 shows the Portable gas specification.

**Table 1. Burning fuel used for electrical power in Nasiriyah city.**

| No. | Fuel        | Type of Electrical power plant(EPP) | Sum of fuel burning [m3/day] | Sum of fuel burning [ton/year] |
|-----|-------------|------------------------------------|-----------------------------|--------------------------------|
| 1   | Heavy oil1  | EPP for ministry of electricity    | 2011                        | 640795                         |
| 2   | Heavy oil2  | EPP for ministry of electricity    | 13140                       | 4730400                        |
| 3   | Light oil1  | EPP for ministry of electricity    | 501                         | 95095                          |
| 4   | Light oil2  | EPP for ministry of electricity    | 900                         | 279225                         |
| 5   | Light oil3  | government generators & emergency generators | 850 | 214737 |
| 6   | Light oil4  | Small-emergency generators        | 850                         | 238891                         |

**Table 2. Normal pollutants concentration measured (before entering Nasiriyah city).**

| Average Pollutants concentration (µg/m³) | Average Velocity [m/s] |
|----------------------------------------|------------------------|
| Date of Tests | CO₂ | SO₂ | NOₓ | Particulates |\
|----------------|-----|-----|-----|-------------|
| Jan.  | 0.4 | 0.16| 0.034| 8.0 | 2.6 |
| Feb.   | 0.35| 0.15| 0.039| 8.8 | 2.9 |
| Mar.   | 0.53| 0.15| 0.035| 8.7 | 3.1 |
| Apr.   | 0.44| 0.18| 0.037| 8.1 | 3.3 |
Table 3. Specification of gas Portable

| No. | sensor | Range [ppm] | Accuracy % of range |
|-----|--------|-------------|---------------------|
| 1   | CO₂    | 0-6000      | ± 1.00 %            |
| 2   | SO₂    | 0-4000      | ± 2.00 %            |
| 3   | NOₓ    | 0-5000      | ± 2.00 %            |

Figure 2. Lancom4 gas measure and Probe.

5. Results and Discussion

Fig. 3 displays the total emission amount (calculated from the amount of fuel used) for CO2 in the Nasiriyah city, where we note that the emissions percentage according to the fuel used is as follows (20.70%, 59.69%, 4.77%, 6.82%, 5.61%, 2.38%) for (heavy oil1, heavy oil2, light oil1, light oil2, light oil3, light oil4) respectively, we notice that the highest emission rate was (59.69%) when using heavy fuel (fuel oil) and less The emission ratio was (2.38%) when using light oil (Benzene).
Fig. 3 displays the total emission amount (calculated from the amount of fuel used) for CO2 in the Nasiriyah city, where we note that the emissions percentage according to the fuel used is as follows (14.09%, 66.31%, 3.31%, 7.16%, 4.14%, 4.97%) for (heavy oil1, heavy oil2, light oil1, light oil2, light oil3, light oil4) respectively, we notice that the highest emission rate was (66.31%) when using heavy fuel (fuel oil) and less. The emission ratio was (3.31%) when using light oil (Dry gas).

Fig. 4 displays the total emission amount (calculated from the amount of fuel used) for SO2 in the Nasiriyah city, where we note that the emissions percentage according to the fuel used is as follows (14.09%, 66.31%, 3.31%, 7.16%, 4.14%, 4.97%) for (heavy oil1, heavy oil2, light oil1, light oil2, light oil3, light oil4) respectively, we notice that the highest emission rate was (66.31%) when using heavy fuel (fuel oil) and less. The emission ratio was (3.31%) when using light oil (Dry gas).

Fig. 5 displays the total emission amount (calculated from the amount of fuel used) for NOX in the Nasiriyah city, where we note that the emissions percentage according to the fuel used is as follows (11.21%, 75.62%, 1.59%, 3.87%, 1.86%, 5.81%) for (heavy oil1, heavy oil2, light oil1, light oil2, light oil3, light oil4) respectively, we notice that the highest emission rate was (75.62%) when using heavy fuel (fuel oil) and less. The emission ratio was (1.59%) when using light oil (Dry gas).
Figure 5. Amount of NOX emitting from Nasiriyah city According to fuel types

Fig. 6 displays the total emission amount (calculated from the amount of fuel used) for particulate in the Nasiriyah city, where we note that the emissions percentage according to the fuel used is as follows (5.21%, 81.11%, 0.32%, 5.79%, 2.13%, 5.41%) for (heavy oil1, heavy oil2, light oil1, light oil2, light oil3, light oil4) respectively, we notice that the highest emission rate was (81.11%) when using heavy fuel (fuel oil) and less. The emission ratio was (0.32%) when using light oil (Dry gas).

Figure 6. Amount of particulate emitting from Nasiriyah city According to fuel types

We note from the previous Figures that the highest emission rate of pollutants (CO2, SO2, NOX, particulate) occurred when using (fuel oil), because it is considered the one of heaviest type of oils due to its formation from long hydrocarbon-chains, alkanes, and cyclic & aromatic alkanes.

Table 4 shows the calculated values of pollutants (CO2, SO2, NOX, particulate) by using the Fixed box model and comparing them with the values measured by the lancom4 device.

We note from the table 4 that the average of the error was (4 %, 2%, 2%, 5%) for pollutants (CO2, SO2, NOX, particulate) respectively, and we note that the relationship between wind velocity & dilution of the pollutant and its spread in the atmosphere is positive relationship.
Table 4. Average Pollutants concentration measuring & calculated through Fixed Box Model in Nasiry city

| Data of test | Pollutants concentration [µg/m³] |
|--------------|----------------------------------|
|              | CO₂ Mea. | CO₂ Cal. | CO₂ Cal. | CO₂ Cal. | SO₂ Mea. | SO₂ Cal. | SO₂ Cal. | SO₂ Cal. | Average velocity [m/s] |
| Jan.         | 2.9      | 2.88     | 2.6      | 2.7      | 17       | 18.2     | 16.1     | 16.3     | 2.6                     |
| Feb.         | 2.6      | 2.55     | 2.41     | 2.44     | 17       | 16.1     | 15.3     | 15.0     | 2.9                     |
| Mar.         | 2.4      | 2.4      | 2.32     | 3.33     | 11       | 14.1     | 15.3     | 15.3     | 3.1                     |
| Apr.         | 2.4      | 2.35     | 2.16     | 2.2      | 13       | 14       | 15       | 15.1     | 3.3                     |
| May.         | 2.6      | 2.5      | 2.4      | 2.41     | 18       | 18.9     | 17.3     | 17.2     | 3.2                     |
| Jun.         | 2.2      | 2.2      | 2.11     | 2.1      | 12       | 11.5     | 10.2     | 10.2     | 3.8                     |
| Jul.         | 1.5      | 1.6      | 1.3      | 1.1      | 10       | 11       | 8.9      | 9        | 4.0                     |
| Aug.         | 1.7      | 1.62     | 1.54     | 1.45     | 13       | 12.5     | 11.8     | 11.6     | 3.4                     |
| Sep.         | 1.6      | 1.8      | 1.43     | 1.41     | 14       | 16.1     | 11       | 12       | 2.9                     |
| Oct.         | 2.4      | 2.32     | 2.25     | 2.22     | 18       | 17.9     | 16       | 16.6     | 2.6                     |
| Nov.         | 2.3      | 2.2      | 2.11     | 2.18     | 16       | 17.9     | 15.3     | 15       | 2.7                     |
| Dec.         | 2.6      | 2.56     | 2.32     | 2.33     | 18       | 18.7     | 19       | 18.4     | 2.7                     |

| Data of test | Pollutants concentration [µg/m³] |
|--------------|----------------------------------|
|              | NOₓ Mea. | NOₓ Cal. | NOₓ Cal. | NOₓ Cal. | PM Mea. | PM Cal. | PM Cal. | PM Cal. | Average velocity [m/s] |
| Jan.         | 40       | 44.1     | 49       | 48       | 8       | 8.1     | 9       | 9.1      | 2.6                     |
| Feb.         | 36       | 39.5     | 40.3     | 40.9     | 7.6     | 8.1     | 8.4     | 8.3      | 2.9                     |
| Mar.         | 35       | 34.6     | 33       | 32.9     | 7.1     | 7.6     | 7.7     | 7.8      | 3.1                     |
| Apr.         | 31       | 34.6     | 35       | 36.1     | 8.3     | 7.8     | 9.1     | 9.2      | 3.3                     |
| May.         | 28       | 33.6     | 33.8     | 34       | 7.7     | 7.8     | 7.9     | 8        | 3.2                     |
| Jun.         | 29       | 28.4     | 27.5     | 27       | 6.8     | 7.1     | 7.5     | 7.6      | 3.8                     |
| Jul.         | 23       | 26.9     | 27       | 27.3     | 6       | 7       | 6.9     | 7.7      | 4.0                     |
| Aug.         | 28       | 30.8     | 29.1     | 28.2     | 7.6     | 7.5     | 8       | 7.8      | 3.4                     |
| Sep.         | 30       | 31.5     | 36       | 35       | 7.6     | 7.9     | 7.2     | 7.1      | 2.9                     |
| Oct.         | 43       | 44.2     | 46       | 46.3     | 8.3     | 8.3     | 8.5     | 8.6      | 2.6                     |
| Nov.         | 40       | 44.2     | 50       | 51       | 8.1     | 9.3     | 10      | 10.2     | 2.7                     |
| Dec.         | 47       | 46.2     | 55       | 51       | 8.2     | 9.4     | 10      | 9.9      | 2.7                     |
6. Conclusions
The results showed that the main pollutants for the air in Nasiriyah was emitted from burning the fuel used for the production of electric power, and the results showed that the concentration of pollutants (CO2, SO2, NOX) was much higher inside the city when compared with the upstream direction of the winds due to its increase with the movement of winds and its entry into the city. Through the application of the fixed box model and when comparing the calculated results through the model with the results measured by the lancom4 device, the error rate was (4%, 2%, 2%, 5%) for pollutants (CO2, SO2, NOX, particulate) respectively, it was also observed that the highest emission rate of pollutants was result from using heavy fuel (fuel oil) and the lowest emission was from light oil (Dry gas). We noted the spread of pollutants and dilution in the atmosphere increases with the increase in wind speed, excluding for particles mater.

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