Air pollution assessment at University of Al-Qadisiyah associated with traffic from neighbouring roads

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Abstract. Air pollution is one of the most complex environmental problems, and transportation is one of the most important factors that contribute to air pollution in urban areas. This study aims to examine the relationship between traffic volumes and air pollution, the effect of emissions according to the type of vehicle and the effect of the presence of bumps, and the change in vehicle driving speed. The University of Al-Qadisiyah street has been selected as a study area that faces frequent traffic congestion on neighboring roads and does not have an air quality monitoring system Therefore, mathematical models are useful for assessing the environmental impact of air pollution. Sidra Trip software is used to calculate the vehicle's source emission rate while Arc GIS software is used to represent pollutant maps based on geographical statistical models using a digital city model. The traffic volumes have been also calculated in the peak times. The receivers are identified from weather, topography, and emission data sources. The air pollutants resulting from traffic movement were measured in the study area (PM2.5, PM10, NO\textsubscript{X}, SO\textsubscript{X}, CO, CO\textsubscript{2}, and other gases). It is found that the air quality index (AQI) within the range of 150-249 is completely unhealthy. The simulations results showed the weather and topographical conditions of the campus district in favour of dispersal of the air pollutants, as the vehicles greatly affect the air quality in the area. The simulation results showed a good agreement between the modelling results and the developed mathematical models.

Key Word: Air Quality Index, Campus, Traffic pollution, Mathematical Model, Emission, GIS.

1. Introduction

The issue of pollution is one of the most important problems facing the world today. Perhaps air pollution is one of the most dangerous types of pollution due to the greatness of humans need for air, as it consumes more air than it consumes food and water. Air quality has become an important criterion for the urban environment in any city [1]. The city of Ad Diwaniyah is the capital city of Iraq's Al-Qadisiyah Governorate, and nearly a third of the governorate’s population resides in it. Iraq is one of the developing countries that is still lagging behind in the field of urban environment management and lacks the information and expertise needed to confront the problem of the times - pollution - the need to confront this problem has arisen [2].
The city of Ad Diwaniyah is considered a model city that the rest of the province’s cities can monitor in the face of its issues in Iraq, especially the problem of air pollution resulting from transportation [3]. As these activities represent the most important sources of air pollution in cities. The university city (University of Al-Qadisiyah) located in the north of Ad Diwaniyah and the adjacent roads were chosen as a model to study the relationship between traffic movement and air pollution (Figure 1).

The increasing need for mobility, which is one of the consequences of the modern development of society, has led to a continuous increase in transportation means, which has led to an increase in congestion, especially in the urban city community. Air pollution is one of the more complex problems, and vehicles are one of the main reasons for this. The rapid growth in vehicle numbers, which is one of the consequences of the urban development of society, increased traffic congestion, especially in urban areas [4]. This increase is followed by an increase in travel time, a decrease in speed, an increase in fuel consumption, the occurrence of stops and non-continuous movement, and thus the emission of various pollutants from the exhaust of these vehicles. As the vehicles are equipped with combustion engines for propulsion, where the used fuel is converted into mechanical energy during this process, incomplete combustion of the fuel takes place and these pollutants are emitted as carbon monoxide CO, carbon dioxide CO2, nitrogen oxide NOx and hydrocarbons HC [5]. As these emissions adversely affect the public health of the people exposed to these emissions in the residential and educational complexes surrounding these streets, according to the European Environmental Agency, the pollutants emitted from car engines are among the most important contributions to the pollution of the urban environment [6]. All of these emissions have an adverse effect on public health, especially particle matter PM. These particles are classified according to their ability to penetrate the lung into two sizes: PM10 and PM2.5, and their danger lies in being deposited in the airway [7].

Because air pollution is a complex and important matter, it has aroused the interest of many researchers to study it. Where there are studies of air pollution in different Iraqi cities that have dealt with the issue of air pollution in various ways. Some of them focused on building models that drive emissions from the sources of air pollution and the means of their dispersion and spread. Other studies focused on the issue of pollutants' properties and their geographical distribution. Jassim 2006 [8] dealt with a study of pollution from car exhaust in Basra. As the researcher conducted a field study for the city of Basra to measure emissions from car exhaust, in coordination with the General Petrochemical Company, where he took samples from the air for the period from 12/3/2002 to 28/2/2003 and examined them using a gas chromatography device. It was found that the average levels of CO, CO2 and methane are 1151, 3423, 6853 PPM, respectively. He also collected samples of suspended
materials to find out the level of contamination with the element lead, using the Atomic Absorption Spectrometer, where it was found that the average level of lead was less than 1 PPM.

Hamid 2008 [9] dealt with the study of assessing air pollution in Baghdad city due to fuel combustion resulting from traffic congestion in selected intersections of the city of Baghdad, by adopting a chemical equation for fuel combustion, and the study presented planning proposals to reduce air pollution in the city of Baghdad.

Maryam's 2010 [10] mission aimed to study the concentrations of air pollutants (CO, CO2, PM, and the concentration of lead, cadmium, sulfates and nitrates in them), in the areas covered by the study and a comparison in the governorate of Kirkuk, the measured pollution levels with the global determinants of environmental pollution, as well as the quantitative analysis of the influencing factors and minutes The relation to the environmental capacity of air pollution, then building a statistical model to predict the level of CO pollution in the study area.

Atab 2014 [11] covered a geographical analysis of pollutant concentrations in Al-Qadisiyah Governorate. It has identified 21 ambient air sampling sites and 13 soil sampling sites, and has identified their locations based on the proximity to the sources of pollutants in the area. It was distributed between industrial areas such as the industrial district, sites close to factories, such as the rubber plant, asphalt plants, and brick factories, near commercial areas, crowded traffic areas (intersections and parking), and sites of high population density.

Hasnawi et al., 2015 [12], they studied the effect of increased consumption of vehicle fuel (gasoline) on environmental pollution in Diyala province, as a result of the large increase in vehicle entry to the governorate, which is offset by the increased consumption of gasoline fuel. Where the study was concerned with the characteristics of the fuel used and its comparison with the international standards, as it was found that the local fuel is 9% less than the international standards regarding the amount of energy generated. As for the flash point, the domestic fuel is about 6.5% higher than the international limits, and the octane ratio is less than 7%, which led to an increase in the emission of CO, HC, NOx, and thus increased pollution. A proposing a set of solutions to reduce this increase, including mechanical ones represented by improving vehicle design in proportion to the Iraqi environment or improving the type of fuel used.

Muhaisin 2015 [13] studied determining the concentrations of pollutant gases for the air and the noise level in the city of Nasiriyah and adopted ambient air pollution as the researcher monitored air pollution and measured the noise level in 146 sites, which are close to different air pollution sources, so the basis for choosing monitoring sites was proximity to the sources of air pollution.

Al-Razaq 2018 [14], it studied and analyzed the specifications of Iraqi car emissions and environmental pollution resulting from the combustion of car fuel. As the maximum permissible limits for the standard specifications of Iraqi emissions were compared with the standard specifications of European emissions. This study was conducted on 35 cars and the emissions data were obtained using an exhaust gas analyzer and represented by using the ($X^2$ control charts). Minitab 2016 program was used to create quality control charts. The results showed that about 30% of car emissions exceed the limits of the Iraqi standard, and this, in turn, negatively affects the environment, as emissions directly and indirectly affect the environment and health. Zainab et al., 2019 [15], they addressed the issue of assessing air pollution using fixed annual stations and GIS technologies. Where he chose the city of Baghdad, which is considered one of the most polluted and densely populated cities in Iraq, to map the distribution of air pollutants and the total pollution levels using ARC GIS techniques. Six of the main monitoring stations were selected at a specific location after which the data were projected using the ARC GIS projection techniques. The results showed that the concentration of NO2 was within the international limits of global health of about 0.11 PPM. Sulfur dioxide concentrations exceeded the limits in all stations of the study area. Carbon dioxide concentrations ranged from 0.484-7.027 PPM, which was within the acceptable limits of international standards of 9 PPM. The nitrogen oxides ranged between 0.01506 -0.214 PPM which was above the acceptable limits.

It was noticed that there were no previous studies in Iraq that dealt with the impact of air pollution resulting from traffic on educational complexes, the effect of emissions according to type, speed,
number of vehicles, the effect of bumps and transit areas, and a change in driving speed. Therefore, the University of Al-Qadisiyah area was chosen as a model for the study, as it is a crowded area, where more than 67,395 students and employees visit it daily and thousands of vehicles, and often they do not use the pedestrian crossing when entering and leaving the university. What is happening is great congestion at the university gate and the presence of bumps in the streets opposite the main gate, all of which have led to the increasing importance of studying this area. As this study aims to know the relationship between traffic volume and air pollution. Pollution rates were assessed using a mobile laboratory that continuously measures CO, CO2, SO2, O3, NOX, PM10 and PM2.5 and meteorological data. The emission of pollutants from vehicles was measured and the SIDRA TRIP program was used to analyze the current traffic situation and the ARC GIS program was used to represent the proportions and spread of these pollutants in the study area.

2. Material and Methods

Due to the nature of this study and its objectives in measuring gaseous pollutants and particulate due to traffic movement near University of Al-Qadisiyah in Ad Diwaniyah. It was necessary to use the devices and programs that support this study, including those in the field of environment, climate and traffic. Automated analysis methods have also been used in geographic information systems.

2.1. Study area

The study area is represented by the University of Al-Qadisiyah (Figure 2). University of Al-Qadisiyah is one of the Iraqi universities. It is located in the city of Ad Diwaniyah, the capital of Qadisiyah Governorate, one of the governorates of the Middle Euphrates in Iraq. Founded in 1987. The astronomical location of the governorate is determined between latitude 31.17 and 32.24 north, and longitudes 44.24 and 45.49 east [16]. The public site is divided into several areas frequented by the occupants of the buildings, whether they are students, faculty members, administrators or technicians. The university’s buildings are distributed over several sites. In its main site (the study area) in the north of Ad Diwaniyah, on the road linking Ad Diwaniyah, Babil Governorate, and Baghdad, also Ad Diwaniyah and the southern governorates, are located the Faculties of Education, Sciences, Arts, Veterinary Medicine, Law, Biotechnology, Computer Science and Mathematics, Education for Girls, Faculty of Physical Education, College of Nursing, College of Dentistry, College of Archeology, College of Engineering, University Presidency, University Housing, Research Centers, and Consulting and Multi-Purpose Places with a total area of 1770000 square meters. Where the number of users reaches 67,395 individuals [17] (Figure 2).

Figure 2. Study area, Al-Qadisiyah University - Ad Diwaniyah City.
An engineering description for the traffic and geometric design of the university street (the study area), it is a major multilane highway urban road. It extends between the Al-Jazeera neighborhood and the university district. It consists of two directions (two lanes), the first for going and the other for the return, separated by a central carrot. In addition to two roundabout, the first is the (Al-Jedaria) and the second (Hawalli Roundabout). The length of the street from in front of the College of Engineering gate to the Hawalli roundabout (2.31 km) and the width of the street (40 m). Each path (direction) consists of three lanes that are undivided, the width of the three-lane direction (10 m). Being a street that extends along an active restricted area that requires daily and frequent traffic trips, it is designed to withstand high traffic loads.

The first roundabout (Al-Jedaria) represents a crossroads between University Street and the road (Ad Diwaniyah - Hilla). It contains inside it an carrot around which vehicles revolve to change the direction of their movement. It does not exceed 45 km / h. The shape of the inner island is oval, but unequal in radii of the entrance radius (48 m), the outlet radius is (30 m) and the island is 107 m long. This roundabout is located at a distance (868 m) ) From the main gate of University of Al-Qadisiyah. The second roundabout (Hawalli Roundabout) is circular in shape linking University Street, Hawalli Road and Hilla-Diwaniyah Road. It is located (846 m) from the main gate of the university. It contains circular carrot with a diameter of (29 m). A pedestrian crossing bridge has also been constructed 54 meters from the main gate of the university to reduce the gatherings that occur in the gate area during the morning and evening rush hours to avoid traffic accidents. Also an industrial speed hump was placed before the pedestrian crossing bridge near the gate in order to reduce the high speed of vehicles as these bumps of height (7.5-12 cm) are designed to reduce the risk of accidents in front of educational places or parks. This bump is located 35 meters from the main university gate (Figure 3).

![Figure 3. Most of the important roads around the study area.](image-url)

2.2. SIDRA TRIP software

In this study, SIDRA TRIP 1.1, a vehicle trip evaluation program, rapid traffic analysis, and network traffic performance evaluation software was used. In this program, the initial and final speed of the
vehicles is determined, the fuel consumed and the delay due to the speed change are determined. Where it was used in this study because of its advantages in terms of it could be compare traffic and travel conditions before and after entering traffic management charts, road and intersection improvements, residential street traffic calming plans. Also we can calibrate precise network simulation models, such heavy vehicle acceleration - idle profiles, or macroscopic models, for example excess fuel consumption and pollutants emission factors.

SIDRA TRIP software uses an energy-based model with default vehicle parameters for fuel consumption and emissions rates of carbon dioxide, hydrocarbons and nitrogen oxides for heavy vehicles. Carbon dioxide is estimated directly from fuel consumption by applying a CO2 emission factor to the average fuel consumption.

The default vehicle profile is used for heavy vehicles. This was done by specifying vehicle type, travel distance, travel time, road grade (road slope) and event data for each scenario investigated. Data entered into SIDRA TRIP for each scenario investigated include Vehicle type, Total travel distance, Total travel time, Number of stops, Stop duration. Average speed, average acceleration, average deceleration, grade (slope of the road), and driving side (Figure 4) [18].

The following function is used to estimate the value of fuel consumed or emissions produced during the simulation period (Akcelik et al., 2012) [19]:

\[
\frac{\dot{f}}{a} = \alpha + \beta_1 P_T + [\beta_2 a P_I] \quad \text{for } a > 0
\]

\[
P_T = \min (P_{\text{max}}, P_C + P_I + P_G)
\]

\[
P_C = b_1 v + b_2 v^3
\]

\[
P_I = M_v a v/1000
\]

\[
P_G = 9.81 M_v (G/100) v /1000
\]

Where all above equations simples and factors could see it details in Sidra Tripe user guide (2011) [20].

Figure 4. SIDRA TRIP user interface.
2.3. Geographic Information System (GIS)

In this study, ArcGIS 10.2 software was used to diagnose and analyze air pollution in automobile exhaust in the study area, where maps were prepared for environmental variables of air pollutants as well as studying the relationship between weather factors and pollutants concentration (Figure 5). The 5-months period measurements will analyzed here statistically and comparably using ArcGIS 10.2 software. Then, the results will be presented in terms of thematic distribution maps for further visualization enhancement. The use of the ArcGIS 10.2 allowed plotting the recorded data in thematic maps and representing those pollutants all over the measured site areas.

![Figure 5. 3D GIS for Al-Qadisiyah University.](image)

2.4. Measurement methodology

2.4.1 Air Pollutant measurement

The study included conducting field measurements for most of the crowded streets surrounding the study area at different times. Outdoor air pollution was measured using PEMS mobile field laboratory in cooperation with Ad Diwaniyah Environment Directors. It is characterized by measuring real pollutants in real time. It measures the emission and dispersion of gaseous pollutants and minutes, and measures the meteorological conditions such as temperature, humidity, pressure, speed, wind direction and solar radiation. As these readings are very important to measure pollution. This station works with different operating principles. It measures single and multiple components in the ambient air. The measuring station (Air Quality Monitoring Station) consists of a group of analyzers to measure different emissions (CO, CO₂, SO₂, HC, and NOₓ), an automatic calibrator and an LCD screen (Figure 6). PM2.5, PM10, and AQI were measured using a portable air quality meter.

In this study, the concentrations of outdoor air pollutants were measured, with the aim of linking air pollution with traffic movement in the streets around University of Al-Qadisiyah. Where 9 sites were selected to measure air pollutants and meteorites outside and inside the university. Where pollutants and meteorological measures continued for 6 months, from August 2020 to December 2020, the
measurement was carried out within 8 daily hours and divided into the morning and evening period, beginning and end of work. Where the highest traffic movement and the highest presence of students and associates.

Figure 6. The measuring station PEMS (Air Quality Lab Monitoring Station).

Figures 7 to 9 show wind direction, wind speed, and the rate of temperature change during the year 2020, respectively, in Ad Diwaniyah Governorate.

Figure 7. The wind direction in Ad Diwaniyah.
2.4.2 Traffic and Emission Measurement

In this study the important part is the vehicle so we need to account this vehicles and to do that was used camera filming way in the points of measuring in different times and the stop watch was used and tape measure to measuring the geometric details of the section which was included in the point of measuring. The points which measuring are (front of collage of engineering, front of the Hawalli Roundabout & front of the University). Conduct a survey of traffic volume and environmental pollutants. The traffic volume used in this survey are collected by video recording technology and manual counting of at two hour intervals of observations in August 2020 to December 2020 (Table 1).

Traffic survey To assess the contribution of major sources of traffic pollutants, a traffic volume survey by vehicle type was conducted in conjunction with measurements of PM10, PM2.5 and ozone. The variants are classified into five categories; Motorbikes, cars, taxis, buses, good light vehicles as well as good heavy vehicles.
To increase the accuracy of the work, we refer to the specifications of vehicles that have been adopted in the process of measuring the rate of speed as well as the amount of emission of air pollutants by using E Instruments E4400-S (Figure 10), and used in Sidra Trip 1.1 software, which is used to calculate the emissions ratios produced by these vehicles and compare the results with field measurements.

In this study, emissions data were collected through an exhaust gas analyzer in a mechanical workshop at the College of Engineering for 40 cars within the gasoline engine classes. The selected engine size is (1.6 - 3.0 liters) within the (2004 - 2020) models, which include 92% of the types of cars in Iraq. The study focused on the pollutant gases emitted from the exhaust (Co, Hc, Nox, and SO2), which differ from one car to another according to the type of engine and its conditions such as (operating condition, type of gasoline, driving type and catalyst condition).

Table 1. The volume of traffic in Study area.

| Mode       | Passenger car | Heavy vehicle |
|------------|---------------|---------------|
| Time       | 7:15-9:15 AM  | 13:15-15:15 PM| 7:15-9:15 AM  | 13:15-15:15 PM |
| Saturday   | 2366          | 3091          | 722           | 785           |
| Sunday     | 3280          | 2916          | 912           | 1304          |
| Monday     | 3172          | 3021          | 987           | 1074          |
| Tuesday    | 3164          | 2655          | 1021          | 1174          |
| Wednesday  | 2312          | 2745          | 825           | 1069          |
| Thursday   | 2425          | 2868          | 711           | 991           |
| Total      | 16719         | 17296         | 5178          | 6397          |
|            | 49%           | 51%           | 44%           | 56%           |
|            | **75%**       |               |               |
|            |               |               | **25%**       |

Figure 10. E-Instruments E4400-S Combustion Gas & Emissions Analyzer
2.5. Air Quality Index (AQI)

The Air Quality Index is a simplified way to define the state of air quality, and it is based on data received from air quality monitoring and control stations, where pollutant concentrations are converted into simple numbers that can be understood by the general public and shown in the form of specific colors. In the city of Ad Diwaniyah, there are no monitoring stations for air pollution that show evidence of air quality. Therefore, in this study, a relationship between traffic, meteorology and pollution will be determined to find evidence of air pollution in the university district. The Air Quality Index provides an easily analyzed number between different pollutants, locations and time periods. Each index category corresponds to a different level of health risk, and daily results for the index are used to inform the public of an estimate of the level of air pollution. An increase in the air quality index indicates increased air pollution and severe threats to human health, and the AQI focuses on the health effects our may experience within a few days or hours after inhaling polluted air.

The Air Quality Index is based on the measurement of PM2.5 and PM10, O3, NO2, SO2 and CO. Most of the stations on the map monitor data for both PM2.5 and PM10. Table 2 shows the limits and colors of the air quality index, where a low value (green colors) means good air quality, while a high value (red colors) means bad air quality. In Iraq the scale of AQI is 0-19 Excellent, 20-49 Fair, 50-99 Poor, 100-149 Unhealthy, 150-249 Very Unhealthy, and +250 Dangers [21].

| AQI category(range) | PM10 µg/m³ (24hr) | PM2.5 µg/m³ (24hr) | NO2 µg/m³ (24hr) | O3 µg/m³ (8hr) | CO mg/m³ (8hr) | SO2 µg/m³ (24hr) | NH3 µg/m³ (24hr) |
|---------------------|--------------------|--------------------|------------------|----------------|----------------|------------------|------------------|
| Good (0-50)         | 0-50               | 0-30               | 0-40             | 0-50           | 0-1.0          | 0-40             | 0-200            |
| Satisfactory (51-100)| 51-100             | 31-60              | 41-80            | 51-100         | 1.1-2.0        | 41-80            | 201-400          |
| Moderately polluted (101-200) | 101-250          | 61-90              | 81-180           | 101-168        | 2.1-10         | 81-380           | 401-800          |
| Poor (201-300)      | 251-350            | 91-120             | 181-280          | 169-208        | 10-17          | 381-800          | 801-1200         |
| Very poor (301-400) | 351-430            | 121-250            | 281-400          | 209-748        | 17-34          | 801-1600         | 1200-1800        |
| Sever (401-500)     | 430+               | 250+               | 400+             | 748+           | 34+            | 1600+            | 1800+            |

3. Results and Discussion

Road traffic is among the main sources of urban air pollution. Pollutant maps are based on geostatistical models (GIS) using a digital city model along with traffic parameters that allow for continuous analyzes and forecasting of the state of the environment. In this part of the research, the size of the studied areas exposed to the risk of pollution with various air pollutants resulting from road traffic will be determined in this part of the research along with determining the number of residents exposed to increased levels of pollutants using geographical modeling on the example of the university city. The SIDRA TRIP software was used to calculate pollutant emissions from vehicles and compare them with field measurements. The results also show the way in which statistical tools can be used to determine the spatial variability of air pollution in a city [23]. The obtained spatial detail can be used to refine the estimated concentration based on the interpolation between direct observation and prediction models.


Table 3. Delay results by SEDRA TRIP 1.1 for study area.

| Day  | Time | Flows (Vehicle/Hour) | Delay (Sec) |
|------|------|----------------------|-------------|
| Sat. | AM   | 1839                 | 4435.42     |
|      | PM   | 1802                 | 4548.7      |
| Sun. | AM   | 3009                 | 18171.8     |
|      | PM   | 3952                 | 30422.5     |
| Mon. | AM   | 3106                 | 36648.65    |
|      | PM   | 3230                 | 18879.41    |
| Tue. | AM   | 2971                 | 15905.15    |
|      | PM   | 3099                 | 17045.99    |
| Wed. | AM   | 2646                 | 24145.32    |
|      | PM   | 3420                 | 19600.78    |
| Thu. | AM   | 2456                 | 10494.33    |
|      | PM   | 3106                 | 11624.91    |

3.1. SIDRA TRIP 1.1 Analysis

Service level of roads at junctions, turns and bumps depends on the average stalled delay time per vehicle. You also know that service levels range from A to F with A being the best when drivers are not affected by other vehicles, and F being the worst [24]. Also, service level is a metric by which transportation planners determine the quality of service on transport devices or transportation infrastructure. The results of the traffic analysis using the SIDRA TRIP software showed that most of the university road runs on type (F) as shown in Table 3. Tables 4 and 5 show the amount of emissions from vehicles in the peak hour in the study area. Table 4 shows that emissions of gases as a result of the consumption of vehicle fuel in the study area were on all days, except on Saturday, due to the time of students and employees working hours. The most emission is at the end of working hours due to weather factors, high temperatures, low wind speed and an increase in the number of vehicles.

It is also indicated in Table 5 that the university gate has more delays and more pollutants emission due to students not using the pedestrian bridge to cross the roads at the university gate, as well as the presence of humps to reduce speed. As the pedestrian ladder is mechanical and not electric, which is why it is not used. This led to the stopping of vehicles at the university’s gate, which led to traffic jams, with less speed, more fuel consumption, and consequently more pollutants emissions.

Table 4. The emissions from vehicles using SIDRA TRIP 1.1.

| Day  | Time | (CO₂) (mg/h) ×10^5 | (HC) (µg/h) ×10^5 | CO (mg/h) ×10^4 | NOx (µg/h) ×10^6 |
|------|------|---------------------|--------------------|-----------------|------------------|
| Sat. | AM   | 49283               | 96050              | 11340           | 3882             |
|      | PM   | 51115               | 9779               | 11001           | 3778             |
| Sun. | AM   | 179264              | 374205             | 31020           | 11388            |
|      | PM   | 298789              | 622808             | 49102           | 18255            |
| Mon. | AM   | 363991              | 749880             | 59688           | 22083            |
|      | PM   | 189595              | 390040             | 33374           | 12171            |
| Tue. | AM   | 163037              | 328918             | 28297           | 10330            |
|      | PM   | 175557              | 352768             | 30643           | 11179            |
| Wed. | AM   | 245261              | 497980             | 42694           | 15525            |
|      | PM   | 195678              | 405155             | 34783           | 12651            |
| Thur.| AM   | 106386              | 218668             | 19902           | 7143             |
|      | PM   | 11971               | 244570             | 23842           | 8421             |
| Total|      | 2029925             | 4290819            | 375685          | 136805           |
Table 5. Results of SEDRA TRIP 1.1 analyses.

| Time          | NOx (kg/h) | CO (kg/h) | HC (kg/h) | CO2 (kg/h) |
|---------------|------------|-----------|-----------|------------|
| Hawalli Roundabout | 61.264     | 15978.78  | 367.12    | 9243.74    |
| Total         | 61.264     | 15978.78  | 367.12    | 9243.74    |
| AM            | 25.272     | 15036.55  | 303.75    | 42625.75   |
| PM            | 36.25      | 0.9425    | 5.75      | 49.814     |
| Gate of Collage of Engineering | 19.251     | 2219.25   | 92.52     | 14453.75   |
| Total         | 19.251     | 2219.25   | 92.52     | 14453.75   |
| AM            | 9.636      | 1909.25   | 61.672    | 593.51     |
| PM            | 9.5        | 0.310     | 31        | 8.11       |
| Gate of University of Al-Qadisiyah | 215.874    | 1830.46   | 56.00     | 93083.25   |
| Total         | 215.874    | 1830.46   | 56.00     | 93083.25   |
| AM            | 98.232     | 1128      | 92.031    | 187767.6   |
| PM            | 117.75     | 7.015     | 33.0      | 46.55      |

Table 6 shows a comparison between the standards limits for emissions of pollutants from vehicles and the results of the analysis of the Sidra Trip 1.1 program for the university road. As it was observed a rise in the emission concentrations of CO2, HC, CO, and NOX more than the permissible limits cumulatively. This is due to traffic congestion, irregular driving speed and sudden stops of vehicles. Likewise, most of the vehicles in Iraq are Iranian-made, Chinese-made, and Korean-made, which operate with little efficiency and have no determinants to control air pollution. Likewise, the type of fuel used is not good and the fuel does not fully combust. Figures 11 to 13 show the average driving speed, acceleration, emission rate of CO, CO2, HC, and NOX, and average fuel consumption respectively.

Table 6. SIDRA TRIP 1.1 results comparison with IS.

| Day          | Time | CO2 (mg/m³) | HC (µg/m³) | CO (mg/m³) | NOx (µg/m³) |
|--------------|------|-------------|------------|------------|-------------|
| Sta. for hr. |      | 644400(mg/m³) | 160(µg/m³) | 32 PPM    | 350 PPB     |
| Sat. AM      | 98566| 192100      | 2268       | 77630      |
| PM           | 102230| 19559       | 2200       | 75555      |
| Sun. AM      | 358529| 748410      | 6204       | 227735     |
| PM           | 597577| 1245615     | 9820       | 365105     |
| Mon. AM      | 727982| 1499760     | 6675       | 441655     |
| PM           | 379189| 780080      | 6675       | 243420     |
| Tue. AM      | 326074| 657835      | 5659       | 206605     |
| PM           | 351114| 705535      | 6129       | 223575     |
| Wed. AM      | 490522| 995960      | 8539       | 310500     |
| PM           | 391357| 810310      | 6957       | 253020     |
| Thur. AM     | 212771| 437335      | 3981       | 142855     |
| PM           | 239415| 489140      | 4768       | 168415     |
| Total        | 4275324| 8581639    | 54645      | 564333     |
Figure 11. (a) Vehicles acceleration (m/s²), (b) Average vehicles speed, (c) Vehicles speed, and (c) variation with time (km/h).
Figure 12. Vehicles CO (a), CO2 (b), HC (c), and NOX (d) emissions rate variation with time (kg/h).

Figure 13. Vehicles fuel consumption time rate (l/h).

3.2. GIS Analysis of air pollution diffusion due to traffic

All information and data related to air quality in the study area were obtained from field tests that were carried out in cooperation with the Ad Diwaniyah Environment Directorate, using the air quality monitoring system. As it was provided with air quality data for each day and hour for pollutants (PM2.5, PM10, NOx, SOx, CO, and CO2) as well as most of the gaseous pollutants resulting from burning diesel and gasoline vehicles fuel, as well as meteorological data (wind speed and direction, temperatures and surfaces. Solar radiation and relative humidity. As well as the number, types and speed of vehicles in the study area. 9 sites inside and outside the university were selected for the
The purpose of measuring the diffusion and concentration of pollutants emitted from vehicles on the university road. Figures 14 to 17 and tables 7-9 show the concentration of different pollutants outside and inside the university and their relationship to the number and speed of vehicles and their relationship to weather factors. Where the measurements showed that the gaseous pollutants inside the university are within the permissible limits due to the presence of large open spaces, and the absence of buildings of great heights surrounding the study area. That is, the weather and topography contributed to reducing the concentration of gaseous pollutants. The very small particles matter are PM2.5, PM10, and AQI was in very high concentrations and completely unhealthy inside and outside the university. It increases with the increase in the number of vehicles, their less speed and less wind speed. That is, AQI is within the range of 150-249. The air quality standard for field measurements was 150 - 249 which is completely unhealthy. As this range of the air quality standard, health consequences may appear immediately on allergy sufferers, and healthy people will often experience difficulty breathing and irritation of the throat. As we have shown previously, more than 67,000 students and employees are exposed to this daily danger from air pollution. This irregular traffic movement leads to delays, paving problems, losses in time, congestion and accidents, affecting the speed of vehicles, reducing it by 55%.

Figure 14. Vehicles number and speed. NH$_3$, NO$_2$, SO$_2$, O$_3$, and MC concentrations in ($\mu$g/m$^3$), from 7.15 AM to 9.15 AM.
Figure 15. Vehicles number. CO, H$_2$S, CH$_4$, THC, and NHMC concentrations in (PPM) from 7.15 AM to 9.15 AM.

Figure 16. Wind speed (m/h), weather temperature °C and relative humidity, from 7.15 AM to 9.15 AM.
Figure 17. Vehicles number. PM2.5, PM10, and AQI concentrations in (µg/m³), from 7.15 AM to 9.15 AM.

Table 7. Traffic volume and speed, air pollutant concentrations, AQI, and wind speed from 7.15 AM to 9.15 AM

| Vehicle No (x10^4) | AQI | PM2.5 | PM10 | Wi Sp. | CO | CO2 | SO2 | NH3 | NO2 | Ve. Sp. | Ve. No. | Y  | X   |
|------------------|-----|-------|------|--------|----|-----|-----|-----|-----|---------|--------|----|-----|
|                  | ug/m³ | ug/m³ | µg/m³ | m/s   | ppm| ppm | µg/m³| µg/m³| µg/m³| km/hr   | No.    | E  | N   |
| 182              | 115  | 136   | 1.4  | 0.9   | 669 | 32  | 90  | 35  | 55  | 4100    | 44 52 10 | 32 00 03 |
| 167              | 94   | 146   | 1.7  | 1.9   | 629 | 49.2| 110.4| 54  | 41  | 4200    | 44 52 41 | 31 59 53 |
| 94               | 99   | 122   | 4.6  | 2     | 624 | 28.2| 85.8| 37.1| 46  | 5120    | 44 53 26 | 31 59 39 |
| 145.6            | 92   | 108.8 | 1.4  | 0.72  | 585.2| 25.6| 70.4| 28  | 55  | 4100    | 44 52 21 | 32 00 09 |
| 150.3            | 77.4 | 131.5 | 1.7  | 1.64  | 534.2| 41.82| 93.84| 48.6| 41  | 4200    | 44 52 48 | 32 00 01 |
| 74.52            | 86.6 | 114.5 | 4.6  | 1.26  | 393 | 27.8| 61.4| 23.4| 46  | 5200    | 44 53 30 | 31 59 40 |
| 81               | 89.1 | 120.6 | 4.6  | 1.4   | 436.8| 20.32| 68.2| 26.0| 46  | 5200    | 44 53 23 | 31 59 44 |
| 120.4            | 54.1 | 74.88 | 1.7  | 0.969 | 320.9| 25.09| 56.03| 29.6| 41  | 4200    | 44 52 48 | 32 00 13 |
| 108.21           | 48.76| 70.95 | 1.7  | 0.8772| 288.1| 22.55| 50.67| 26.24| 41  | 4200    | 44 52 58 | 32 00 10 |
### Table 8. Traffic volume and speed, air pollutant concentrations, AQI, and wind speed from 10.15 AM to 12.15 PM

| AQI | PM2.5 | PM10 | Ve. Sp. | CO  | CO2  | SO2  | NH3 | NO2  | Ve. Sp. | Ve. No. | Y    | X    |
|-----|-------|------|---------|-----|------|------|-----|------|---------|---------|------|------|
| µg/m³ | µg/m³ | µg/m³ | km/hr   | ppm | µg/m³ | µg/m³ | µg/m³ | µg/m³ | km/hr   | No.     | E   | N     |
| 177 | 105  | 143  | 1.7     | 0.9 | 635  | 32   | 111 | 31   | 69      | 3487    | 44   | 52   |
| 176 | 106  | 144  | 2.5     | 1.9 | 622  | 45.6 | 126 | 39   | 47      | 3747    | 44   | 52   |
| 81  | 85   | 116  | 4.7     | 2   | 624  | 39.96| 110 | 21.6 | 54      | 3185    | 44   | 53   |
| 144 | 88.8 | 121.4| 1.7    | 0.88| 520  | 29.6 | 83.2| 16.8 | 69      | 3487    | 44   | 52   |
| 158.6 | 92.7 | 125.1| 2.4    | 1.62| 530  | 37.1 | 106 | 32.2 | 47      | 3747    | 44   | 52   |
| 74.52 | 84.5 | 114.2| 4.7    | 1.26| 393.7| 25.2 | 69.2| 16.8 | 54      | 3185    | 44   | 53   |
| 76.2 | 81.2 | 110.7| 6.2    | 1.4 | 435  | 27.9 | 77.2| 18.7 | 54      | 3185    | 44   | 53   |
| 128.2 | 69.3 | 71.82 | 2.4    | 0.969| 313.2| 19.5 | 67.9| 15.12| 47      | 3747    | 44   | 52   |
| 115.6 | 62.32 | 64.63 | 2.4    | 0.821| 282.1| 15.4 | 68.8| 20.09| 47      | 3747    | 44   | 52   |

### Table 9. Traffic volume and speed, air pollutant concentrations, AQI, and wind speed from 13.15 PM to 15.15 PM

| AQI | PM2.5 | PM10 | Ve. Sp. | CO  | CO2  | SO2  | NH3 | NO2  | Ve. Sp. | Ve. No. | Y    | X    |
|-----|-------|------|---------|-----|------|------|-----|------|---------|---------|------|------|
| µg/m³ | µg/m³ | µg/m³ | km/hr   | ppm | µg/m³ | µg/m³ | µg/m³ | µg/m³ | km/hr   | No.     | E   | N     |
| 196 | 145  | 198  | 2.9    | 2   | 599  | 45   | 144 | 45   | 44      | 4550    | 44   | 52   |
| 193 | 125  | 176  | 3.2    | 2.3 | 625  | 50.4 | 170.4| 60   | 32      | 4982    | 44   | 52   |
| 111 | 112  | 159  | 2.4    | 1.5 | 627  | 45.62| 154.8| 47.6 | 37      | 5354    | 44   | 53   |
| 158.4 | 117.4 | 160  | 2.9    | 1.6 | 480.2| 33.6 | 116 | 36.2 | 44      | 4550    | 44   | 52   |
| 175.5 | 126.9 | 169.2| 4.7    | 1.7 | 579.2| 43.86| 148.3| 54   | 32      | 4982    | 44   | 52   |
| 91.9 | 104.31 | 150.48| 2.4    | 1.192| 396.9| 21.78| 100.2| 30.5 | 37      | 5354    | 44   | 53   |
| 105.2 | 112.5 | 169.2| 0.7    | 1.38| 441  | 23.24| 110.4| 32.9 | 37      | 5354    | 44   | 53   |
| 140.4 | 88.8 | 108  | 4.7  | 0.969| 317.2| 24.76| 89.21| 34.21| 32      | 4982    | 44   | 52   |
| 125.06 | 77.11 | 96.22 | 4.7    | 0.821| 285.2| 22.9 | 80.2 | 31.2 | 32      | 4982    | 44   | 52   |

### 3.3. Model verification

The measured AQI data over three months were compared with the mathematical model results of the SIDRA TRIP and GIS program. The mathematical model will be used to predict the state of air quality and thus to predict all damages or losses that may have occurred to any other party according to the air quality index, either directly or indirectly, as a result of any information obtained from the data related...
to air quality. The results showed a great match between the practical and mathematical model, as shown in Figure 18.

![Comparison observed and mathematical model predicted daily AQI.](image)

**Figure 18.** Comparison observed and mathematical model predicted daily AQI.

4. Conclusion

This study showed that whenever the number of vehicles increases and decreases their speed by driving at unstable speeds and moving a gear lever for gears that are not continuously based on the vehicle speed, the AQI falls within the completely unhealthy limits 150-249. The use of the mathematical model to predict the quality of AQI as a result of traffic movement and the presence of aging and old vehicles is less expensive and more accurate because it is difficult to provide measurements continuously. That is, mathematical models provide accurate measurements. We can use them to improve our tests and better understand the process. The study also showed the effect of the age of vehicles and the existence of a close correlation between the percentage of emissions of air pollutants and the age of vehicles, where the percentage of gases emission from the exhausts of old vehicles is significantly more than new ones. The results showed that the concentrations of gases emitted from the vehicles are within the standards limits within the university hallways. Part of the PM emission carries toxic particles emitted by car engines PM2.5, and PM10, which were more than the EPA, and WHO limits.

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