

Integration of GIS, Traffic Volume, Vehicular Speed and Road Grades Related-Air Pollution in Amman



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Abstract: This study involves field data and analytical technique into spatially map air pollution levels on account of traffic volumes, vehicle speeds and grades of roads at relatively high traffic volumes signalized intersections in Amman; capital of Jordan .

The study was conducted by collecting traffic and air pollution data at twelve locations in four streets, each street located in a different zone. Also the data collection process was conducted at many highly jam traffic time periods. The highest air pollution level was measured at 7th circle in Abdullah Gosheh street, where was the maximum Average traffic volume. And the least air pollution level of the studied areas was at Anas Bin Malek Street which is located in Ras Al-Ain zone , so that it can be an acceptable residential area. Results showed clearly that the highest air pollution levels found near traffic signals and at the stop lines of them, and these concentrations decrease while being more far from traffic signals. Also, increasing in road gradients leads to a decrease in speed of vehicles, this leads to an increase in the pollutants concentrations. The highest air pollution concentrations were 0.7, 0.6, 9.9, and 0.6 (in ppm) of NO₂, SO₂, CO and SPM respectively. The R-square value, square of relative coefficient, of the relationships between NO₂, SO₂, CO & SPM concentrations and traffic volume were approximately: 0.9135, 0.8822, 0.8977, and 0.8934 respectively. It is noticed that traffic volume is the most significant factor that affects SO₂, NO₂, CO & SPM concentrations. This research has illustrated that the pollutants' concentrations are larger than recommended concentrations of World Health Organization (WHO) in most locations of the studied areas, and that showing a necessity for a standard air quality monitoring, traffic management arrangement and effective procedures should be followed to reduce the resulted pollution.

Keywords: emission, pollutant, traffic volume, air pollution, road grade

I. INTRODUCTION

Urban areas with higher air pollution are commonly not desired as residential areas. Also, the land prices would be decreased there. Moreover, pollution due to traffic movements with many other major factors are taken into consideration when people choosing where to live. However, the resulted dangerous chemical pollutants make population travel from cities of high population density to search for cleaner environments.

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Therefore, governments, planners and decision makers try to build green areas and suburban areas around cities of heavy traffic volume, in order to control that issue and avoid its negative results.

Therefore, the preparation of spatial air pollution level maps would be helpful for planners, decision makers and citizens. Thus, a useful environmental impact study would be adopted by planners in their work. Further, integrating air pollution data with spatial data would measure the quantity of air pollution impacts in a digital maps domain. Those tools could measure the quantity of air pollution levels and its effect based on location of zones, population density, number of structures, and type of them. And that will help in land classification of urban areas like residential, industrial and commercial, based on the pollution scale.

This study will provide an analytical methodology to spatially map air pollution levels related to the flow rates at many intervals of the day in order to help in decision-making and planning missions by governments. This research will provide a first step to apply standardized approaches to evaluate air pollution effects and to increase air pollution searches in this domain.

II. OBJECTIVE

The aim of this research is to study and explain the relationship between air pollutant concentrations and traffic volume (mainly), speed and road grades. In this research, the measurements of concentrations of CO, NO₂, SO₂ and SPM were conducted at different locations in many zones during three peak periods of times to help planner, decision makers, researchers and citizens.

III. LITERATURE REVIEW

Some of the worst pollutants are nitrogen oxides, carbon monoxide, Sulphur dioxide, lead, and suspended particulate matter, according to the Environmental Protection Agency (USEPA, 2007). [1]

Schwela, (2000), concluded that many studies have confirmed adverse health effects associated with high concentrations of transport-related pollutants. [2]

Abu Al-Salem and Hazim, (2015), concluded that the specifications of air pollutants which resulted from traffic movements and many other highway geometric factors were found by study the relationships between them and different traffic variables. [3]

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Obaidat, 2008, concluded that integration of GIS and traffic variables related noise pollution results an efficient spatially maps which are advantageous in planning and lands classifications.[4]

Duffy et al. (1996) and Rogak et al. (1998) concluded in their studies which conducted in Canada and Australia, that Nitrogen monoxide and Carbon monoxide are the major air pollutants produced from fuel burning by the transportation modes. [5], [6]

IV. METHODOLOGY AND DATA COLLECTION

The concentrations of pollutants which are (SO₂, NO₂, CO & SPM) were measured at different locations in many zones in Amman during three peak time periods, using portable toxic gas analyzer.

The traffic volumes were collected by using direct observation and videotaping methods, for four working days, at 12 locations of 4 streets, during three peak periods, which are as follows:

- 7.30 am – 9.30am, Morning peak period
- 1.30 pm – 3.00pm, off peak period
- 9.00 pm – 11.00pm, Evening peak period

The collected data were conducted for different signalized intersections through twelve days. Air pollution data were collected at 8- signals of 4-streets located in 4- zones in Amman. Most studied areas are classified as residential ones. Table (1) shows main specifications of the involved streets in the study.

Table- I: Characteristics of studied streets

Street Name	Lane-Way	Zone Of Street	Type Of Zone
Addustour	2 Lane-2 Way	Badir	Residential
Abdullah Gosheh	3 Lane-2 Way	Wadi Assir	Residential
Anas Bin Malek	2 Lane-2 Way	Ras Alain	Residential
AlHurriyah	3 Lane-2 Way	Albunyyat	Residential

There are three and four approaches at studied signalized intersections, which differ from each other in flow rates and geometric variables such as: road gradients, percentage of trucks, number of lanes and lane width.

The data of Air pollution were collected at two locations in each street:

1. At the stop lines of traffic signals in each approach, and
2. at the mid-point between them.

Traffic Air pollution levels of the signalized intersections were measured near the traffic signal where the first vehicle stopped. However, air pollution levels between signals were measured at mid distance. Fig. 1. shows the studied streets and

traffic signal locations where Air pollution levels were measured.

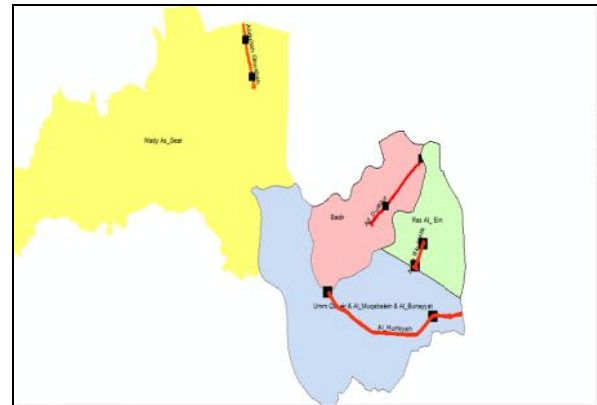


Fig. 1. Studied streets and Traffic Signal locations

V. ANALYSIS AND DISCUSSION

A. Plotting and Mapping

The factors which have been studied during this research are traffic volume, road grade and vehicular speed. As a result, it is concluded that the traffic volume was the major significant factor that affects air pollution concentrations. It was easily noticed that at zones known with their heavy traffic volumes, air pollution levels were very high; fig. 2. shows the relation between them.

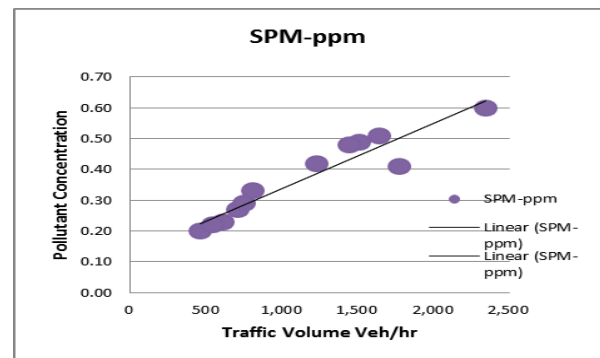


Fig. 2. Relationships between pollutant concentrations, SPM and Traffic volumes in Peak Period

Also, as grade of the street increases the air pollution levels will increase. When the grade of a road increases, the grade resistance applied on the vehicle will increase based on the dynamic characteristics of vehicle. That leads to an associated increase in engine power required. In this case the vehicle will consume additional amount of fuel which resulted in a huge amount of emissions.

Spatial maps could be used to show the air pollution levels related to the traffic volume levels, and to specify the appropriate locations, zones and areas to live regarding to national and international standards. Availability of the allowable air pollution degree information could help the authority of planning in classification the zones and the lands into suitable type, such as residential, commercial, or industrial one. And by default that will affect the land prices.

-For example, using the 9.0 ppm of CO as a maximum acceptable air pollution level value for residential areas in Jordan-. Also spatial map shows the predicted places in the best areas where citizens can live without high Air pollution level.

Fig. 3. shows the locations of exceeded air pollutant concentration of SO₂ compared with maximum WHO and NEPM air pollution Values. We conclude that those areas are not suitable for residential ones and we need solutions for the high pollution there.

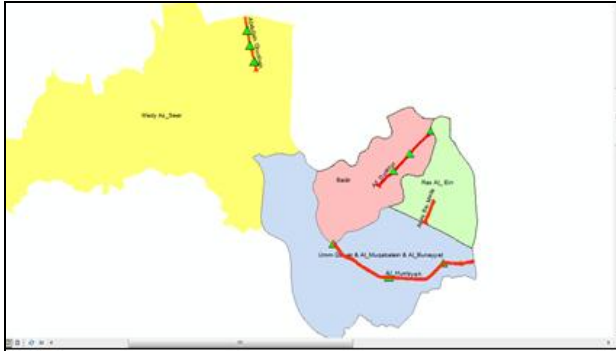


Fig. 3. Locations of Exceeded SO₂ (more than 0.20 ppm)

Fig. 4. shows that 200 meter buffering done around the studied locations; the darker circles represent high Air pollution concentrations which are not appropriate to be residential areas. In the other hand, the circles of light color represent areas which having less pollutants' concentrations and that leads to be suitable areas for the citizens to live. Also, it shows that the highest air pollution level was measured at 7th circle in Abdullh Gosheh street, where was the maximum Average traffic volume.



Fig. 4. Spatial map for Average pollutants concentrations

B. Regression Analysis

Simple linear regression analysis is used to test the strength of the significant factors in affecting the pollutant concentrations linked with studied locations, by get developed models from SPSS software. Table (2) shows these relations.

Table- II: Models represent the average pollutant concentrations (CO)

NO	Models	R ²	F-value	P- value
1	Pollutant conc.= 0.00217 *V	0.934	358	3.44E-18
2	Pollutant conc.= 0.392*G	0.895	279	3.38E-16
3	Pollutant conc.= 0.0231*S	0.884	137	7.35E-13

Multiple linear regression is used to provide the best multivariable equation that includes the most significance independent variables. The model shown in Table (3) is significant. So it is possible to use in predicting the pollutants' concentrations in any location in Amman.

Table- III : The developed model related to the significant independent variables for (CO)

Models	R ²	F-value	P- value
Pollutant conc.= 3.609+0.00225 V+0.434 G+0.0283 S	0.946	412	5.68E-22

VI. CONCLUSION

By making a comparison between the results found from this research and the recommended and standard levels of pollutants' concentrations in (EPA), EPNA and WHO, it is found that most studied areas having higher air pollution levels than the acceptable ones. So the main concluded points are:

- The conducted spatial maps might be taken as references and reliable tools in pricing of lands, zones classification and commercial activities.
- The highest air pollution level was measured at 7th circle in Abdullh Gosheh street, where was the maximum average traffic volume.
- The least air pollution level was at Anas Bin Malek Street in Ras Al-Ain zone so that it can be an acceptable residential area.
- Peak hour of pollutant concentrations was during morning period, (07:30 AM – 08:30 AM).
- The traffic volume is the most significant factor in predicting pollutant concentrations in any location.
- Spatial maps showed that increase in traffic volume leads to increase in air pollutants concentrations.
- The highest air pollution levels were found near traffic signals and at the stop lines of them, and vice versa. That because of traffic signals' effect on the vehicular speed (at signals the vehicular speed equals zero while vehicles' engines are ON, and as known in this case a vehicle consumes considerable amount of fuel so it produces high amount of emissions).

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AUTHOR PROFILE



Eman A. Shehadeh, I am a Civil Engineer holding MSc Degree in Civil Engineering/ Highway and Transportation Engineering from Jordan University of Science and Technology with Honors Grade (Graduated in 2017). I have obtained my BSc Degree in Civil Engineering from The Hashemite University with a “Very Good” Grade in 2010. I have 7 Years’ experience in Civil Engineering

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2.Eman A. Shehadeh, “Trip Rates and Parking Requirements for Restaurants and Coffee Shops in Amman-Jordan”, Volume-9 Issue-2, December 2019, Page No. 2898-2901.

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