Bayik et al, 2018

Volume 4 Issue 1, pp.129-142

Date of Publication: 22nd March 2018

DOI-https://dx.doi.org/10.20319/mijst.2018.41.129142

This paper can be cited as: Bayik, G. D., Alpan, M. P., Bayik, C., & Taniş, M. (2018). Mapping Of Vehicle Emissions in Zonguldak Province. MATTER: International Journal of Science and Technology, 4(1), 129-142.

MAPPING OF VEHICLE EMISSIONS IN ZONGULDAK PROVINCE

Gülçin Demirel Bayik
Faculty of Engineering Department of Environmental Engineering, Bülent Ecevit University, Zonguldak, Turkey
gulcindemirel7@gmail.com

Mine Polat Alpan
Faculty of Engineering Department of Civil Engineering, Bülent Ecevit University, Zonguldak, Turkey
mine_pol@hotmail.com

Caglar Bayik
Faculty of Engineering Department of Geomatics Engineering, Bülent Ecevit University, Zonguldak, Turkey
caglarbayik@beun.edu.tr

Mustafa Taniş
Faculty of Engineering Department of Civil Engineering, Bülent Ecevit University, Zonguldak, Turkey
tanis@beun.edu.tr

Abstract

Increase in the rate of individual vehicle use and decrease in the usage habits of public transportation results in significant increase in traffic-related emissions. One of the most important factor among these is the number of vehicles that increases day by day especially in developing countries. In Zonguldak, the number of vehicles have also increased by 21% in the *last five years. For that reason we focused on to determine the effects of urban transportation on air quality in the city center of Zonguldak/Turkey. The main objective of the study was to determine pollutant emissions in different parts of a highway and present it on emission maps. In this context, hourly vehicle counts were conducted at Zonguldak D010 highway in four zones in the coastal area. In addition, speed counts were carried out in the same zones. Emissions were calculated by the obtained data and IPCC guidance was used for these calculations. The IPCC guidelines include main headings such as energy, industrial processes, agriculture and waste. In this study, emission related data under the head of "energy" were used. Emission intensity maps for Zonguldak province were established by using the obtained values. The results of the study show that fuel consumption was the highest between 08:00 and 09:00 a.m. It decreases between 12:00 and 13:00 at noon and then tends to increase again between 18:00 and 19:00 p.m. Pollutant emissions were also higher in the morning and evening hours, depending on fuel consumption. In this study only the main arterial road was selected as study area. In future studies, by choosing whole road segments, the study area can be expanded and more accurate and reliable results can be obtained.*

Keywords

Air pollution, Traffic, ArcGIS, Vehicle Emission, Traffic Volumes, Tier 1, Air pollution mapping

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1. Introduction

The global warming and climate change phenomenon, which is called one of the biggest environmental problems that threaten our Earth, has emerged as a result of fossil fuel use, industrialization, energy production, deforestation and other human activities, and the economic growth and population increase accelerated this process even more (Kumar, Soni, Sharma, & Srivastava, 2016). The amount of greenhouse gas emissions emitted by human induced in the atmosphere, which can be seen as the reason for this situation, is increasing day by day. The transportation sector is one of the important factors in the emission of greenhouse gas emissions with a share of approximately %16 (Yanarocak, 2007). Traffic systems has been developed to allow mobility, and road transport is the most preferred system for the transportation of people and goods which results in the intense use of fossil fuels (Azhari, Latif, & Mohamed, 2018).

Gasoline and diesel are the most popular fossil fuels. Especially diesel is more preferable than gasoline due to its lower price (Özgür, Tosun, Özgür, Tüccar, & Aydın, 2017).

Motor vehicle emissions, one of the most important sources of air pollution, are emerging as a growing problem in cities. Use of motor vehicles generates more air pollution than any other single human activity. It has very high contribution to CO_2 emission, next to CO, HC, and NOx emissions. In urban areas pollutant emissions are higher due to dense traffic and human activities (Colls, 2003). Of all emissions worldwide, transportation is responsible for 30% of NOx, 14% CO_2, 54% CO, and 47% non-methane hydrocarbon (Requia, Roig, Koutrakis, & Adams, 2017). World Energy outlook predicted that carbon emissions from traffic would increase at an annual rate of 1.7% from 2010 to 2030. Moreover, for developing and moderately developing countries it is projected as 3.4 % and 4.2 % (Sun, Zhang, Xue, & Zhang, 2017).

There are several factors effecting the traffic related emissions. The number of vehicles, technology of vehicle, environmental factors and driver behavior has significant effects on emissions. CO_2 emissions are the most emitted greenhouse gases emitted from transportation activities. They result from the incineration of petroleum-based products such as gasoline in internal combustion engines. Relatively smaller amounts of methane (CH_4) and nitrogen oxide (N_2O) are released during combustion of the fuel. The largest sources of transport-related greenhouse gas emissions include passenger cars and light trucks, including sports-use vehicles, pickup trucks and minivans. These sources constitute more than half of the emissions in the sector (USEPA, 2017).

2. Research Issues

Zonguldak is a small city that have high traffic intensity. For that reason it was concluded that one of the main sources of air pollution in city center includes traffic related emissions. In this context, determination of traffic emissions' contribution to air quality is of importance in terms of taking proper precautions. The main objective of the study was to calculate and evaluate the vehicle emissions in the certain part of Zonguldak city center and to take the initiative role for upcoming studies.

3. Literature Review

Calculation of motor vehicle emissions can be very useful for air quality managers and environmental engineers to examine different transport plans and develop new strategies for sustainable transport system. There are several studies conducted on calculation and mapping of emissions on road.

Some literature studies have used programs specifically developed for air pollution modeling and mapping. Namdeo et al. (2002), conducted air pollution modeling and mapping studies in large cities in the UK using the Traffic Emission Modeling and Mapping (TEMMS) program. It was envisaged that the program could be used in a very useful way in the regulation and management of the traffic flow by considering the air pollution values by the researchers (Namdeo, Mitchell, & Dixon, 2002).

In the study of Soylu (2007), road emissions in were calculated by using the COPERT III program in Turkey for the year 2004. The contribution of these emissions to local and global air pollution were determined. It is reported that automobiles were the main source of CO, HC and Pb emissions, while heavy vehicles were found to cause more NOx, particulate matter and SO_2 emissions (Soylu, 2007).

Singh et al. (2008), have used Tier I emission estimation approach for calculate emission estimates in India. CO_2, CH4, N2O, Co, NOx and NMVOC emissions were calculated between 1980 and 2000 using the number of vehicles registered in local works. At the end of the study, CO_2 emissions were 27 metric tons in 1980 and 105 metric tons in 2000. Similar results have been observed for other gases (Singh et al., 2008).

Waked and Afif (2012), have used EEA/EMEP emission factors calculated emissions for four different situations. These situations were hot emissions, cold-start emissions, emissions resulting from volatilization and emissions from the road. In the study, emissions were calculated in 14 middle-eastern countries and compared to more developed countries. Authors indicated that in the Middle East, carbon monoxide and nitrogen oxides emissions were mainly generated by countries with a population of over 20 million. These countries are Saudi Arabia, Iraq, Turkey and Egypt (Waked & Afif, 2012).

Mc. Donald et al. (2014), by mapping CO_2 emissions in the state of California using fuel sales and national vehicle counts. The mapping process is separately calculated for gasoline and heavy vehicles and mapped at 10 km, 4 km and 1 km resolution. As a result of the mapping study, the researchers stated that the map of the 10 km resolution maps shows that the emission intensity on the highway is not clear (McDonald, McBride, Martin, & Harley, 2014).

In this study, traffic related NOx, CO_2, NMVOC and CO emissions were calculated in Zonguldak, Turkey by Tier 1 method and then they were mapped with ArcGIS program.

4. Methodology

4.1. Traffic Volume Counts

Traffic volume is the number of vehicles or pedestrians passing by a certain section within a certain period. Traffic volume study is done for the counting and classification of vehicles moving on a certain road, to determine the number, movements, and classifications of roadway vehicles at a given location. Collected traffic volume data is used to determine the effects of heavy vehicles and traffic on traffic volumes, to establish critical flow time relationships, and to prepare traffic volume documents. Traffic volume study is conducted to reduce traffic intensity and determine the intensity of passing vehicles. These data can help identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow, or document traffic volume trends. In this study, the counts were carried out in the 5 different sections of D010 state road in Zonguldak. The sections and their lengths are shown in Figure 1.

- Section 1 (S1) City Center-Harbor
- Section 2 (S2) Harbor-Terminal
- Section 3 (S3) Police Local-Kozlu
- Section 4 (S4) Kozlu-Fatih Street.
- Section 5 (S5) Terminal-Police Local

Figure 1: *Road sections and their lengths in study area, Zonguldak*

All counts were made in the determined road sections, in 60 minute with 1 minute intervals, to determine the maximum traffic volume during the day, taking into consideration the type separation. Traffic volume counts were made in the morning (08.00 - 09.00), lunch (12.00 - 13.00) and evening (18.00 - 19.00) at peak hours.

As the days to be counted; it is considered appropriate to select other days except for the weekend (Saturday and Sunday) and the start and end days of the week (Monday and Friday). Censuses were carried out by determining the appropriate days and hours for each segment. At each designated road segment, one was considered to count vehicles for a strip. Counting papers and stopwatches were used for counting. The numbers of vehicles counted in each road section are given in Table 1.

Table 1: *The number of vehicles passing from the each road section in the morning at noon and evening*

	Time Period	Passenger Car	Minivan	Bus	Track	Trailer	Total	Unit Passenger Car
S1	08:00-09:00	872	163	29	27	18	1109	1307
	12:00 - 13:00	577	122	39	28	10	776	933
	18:00 - 19:00	711	122	41	16	6	896	1048
S2	08:00-09:00	861	179	27	21	21	1109	1290
	12:00 - 13:00	611	112	36	32	16	807	998
	18:00 - 19:00	710	127	41	17	11	906	1079
S3	08:00-09:00	474	82	37	25	18	636	840
	12:00 - 13:00	537	68	32	24	8	669	788
	18:00 - 19:00	580	102	43	19	21	765	924
S4	08:00-09:00	654	150	40	27	22	893	1103
	12:00 - 13:00	548	107	56	29	26	766	1017
	18:00 - 19:00	592	119	42	19	11	783	991
S5	08:00-09:00	734	144	35	25	21	960	1172
	12:00 - 13:00	631	99	37	31	13	812	982
	18:00 - 19:00	710	126	46	20	18	919	1102

4.2. Emission Calculations

Emissions were calculated by using the "Air Pollutant Emissions Manual and Emissions Factor Database" published by the European Environment Agency in 2016. The guidance submits 3 different methods to calculate emissions namely; Tier1, Tier2 and Tier 3. Tier 1 method was selected in this study because its calculation based on little data. In Tier 1 method, emissions can be calculated by based on fuel consumption. Specific fuel-related emission factors are used in the calculations. The emissions can be calculated by the formula given in IPCC 2006 guidelines;

$$Emission = \sum_a Fuel \times EF_a \qquad (1)$$

Where;

Emission: Emission (kg)

EF_a: Emission factor

$Fuel_a$: Fuel consumed

a: Fuel Type (diesel, gasoline, natural gas or LPG) .

Emission factor were gathered from European Environment Agency emission factors database in April 2017. Used factors are presented in Table 2.

Table 2: *Emission factors based on fuel and vehicle type(g/kg) (EEA, 2017) TIER 1*

Pollutant	Passenger Car			Minivan			Truck-Trailer-Bus		
	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG
NOx	14,5	11	15,5	24	15	-	37	-	13
CO_2	3,18	3,14	3,02	3,18	3,14	3,02	3,14	3,02	-
NMVOC	14	1,1	10	14	1,75	-	1,6	-	0,26
CO	132	4,7	68	155	11	-	8	-	5,7

Fuel types of the vehicles were estimated by using the national statistical database, TUIK. According to the national statistics at the end of January, 10166778 cars were registered in traffic, accounted for 40.2% LPG, 31.8% diesel and 27.6% gasoline. The rate of cars with unknown fuel type is 0.4% (TUIK, 2017). Fuel consumptions for each vehicle and fuel type according to the European Environment Agency are given in Table 3.

Table 3: Fuel *Consumptions (g/km).*

Vehicle Type	Fuel Type	Typical Fuel Consumption (g/km)
Passenger Car	Gasoline	70
	Diesel	60
	LPG	57,5
	CNG	62,6
Light Vehicle	Gasoline	100
	Diesel	80
Heavy Vehicle	Diesel	240
	CNG	500

5. Results and Discussion

Total fuel consumptions at different road sections were determined in kilograms and are given in Table 4. According to Table 4 fuel consumption is the highest between 08:00 and 09:00 a.m. It decreases between 12:00 and 13:00 at noon and then tends to increase again between 18:00 and 19:00 p.m. Total fuel consumption is the highest for S5, followed by S3, S4, S1 and S2 for all vehicle types and all fuel types.

Table 4: *Total fuel consumption on road sections based on fuel type*

Section	Distance (km)	Total Fuel Consumption (kg)					
		Time Period	**Passenger Car**			**Light Vehicle**	**Heavy Vehicle**
			Gasoline	**Diesel**	**LPG**	**Diesel**	**Diesel**
S1	0.64	08:00-09:00	13.50	9.15	7.61	8.45	5.94
		12:00-13:00	8.93	6.06	5.04	7.08	5.02
		18:00-19:00	11.00	7.46	6.21	7.17	2.90
S2	0.47	08:00-09:00	9.69	6.57	5.47	6.59	4.03
		12:00-13:00	6.88	4.66	3.88	4.74	4.61
		18:00-19:00	7.99	5.42	4.51	5.38	2.69
S3	2.15	08:00-09:00	23.34	15.83	13.08	16.66	18.06
		12:00-13:00	26.44	17.93	14.82	14.00	13.44
		18:00-19:00	28.56	19.37	16.01	20.30	16.80
S4	1.14	08:00-09:00	20.24	13.73	11.37	16.72	12.94
		12:00-13:00	16.96	11.50	9.53	14.34	14.52
		18:00-19:00	18.32	12.42	10.29	14.17	7.92
S5	2.04	08:00-09:00	42.19	28.48	23.70	29.18	22.54
		12:00-13:00	36.27	24.48	20.38	22.17	21.56
		18:00-19:00	40.82	27.55	22.93	28.04	18.62

NO_X, CO_2, NMVOC and CO emissions calculated based on fuel consumptions are given in Table 5. As can be seen from the table, CO contribution to transport related emission is the highest for all road sections. Emissions are greatest between 08:00 and 09:00 a.m. for all pollutants. This is due to heavy traffic between these hours. Public transportation and school services are the main reason for high traffic intensity in the morning. Individual vehicle use also affects the number of vehicles and consequently the emissions. Emissions at road section 5.2 are relatively high when compared to other sections. Especially it is approximately two to three folds higher when compared to S1, S2, S3 and S4.

Table 5: *Total Pollutant Emissions on Road Sections.*

Section	Total Emission (kg)				
	Time Period	**NO_X**	**CO_2**	**NMVOC**	**CO**
S1	08:00-09:00	760.82	139.81	299.41	2482.49
	12:00 - 13:00	566.01	100.61	202.47	1667.77
	18:00 - 19:00	552.85	108.80	241.52	2011.74
S2	08:00-09:00	545.59	101.32	215.55	1786.58
	12:00 - 13:00	452.67	77.57	155.86	1282.44
	18:00 - 19:00	425.44	81.36	176.62	1467.50
S3	08:00-09:00	1633.45	272.45	533.07	4372.89
	12:00 - 13:00	1517.69	271.32	584.16	4844.32
	18:00 - 19:00	1801.40	316.48	643.66	5307.46
S4	08:00-09:00	1350.22	234.94	462.19	3797.40
	12:00 - 13:00	1272.57	209.47	393.75	3215.04
	18:00 - 19:00	1067.50	197.73	410.62	3396.45
S5	08:00-09:00	2564.08	457.57	946.20	7816.57
	12:00 - 13:00	2241.32	391.06	811.81	6705.09
	18:00 - 19:00	2359.67	432.02	909.84	7533.46

Emission maps generated by ArcGIS are presented in Figure 2 and Figure 3. High emission intensity in the morning times for all pollutants can be obviously seen from the figures.

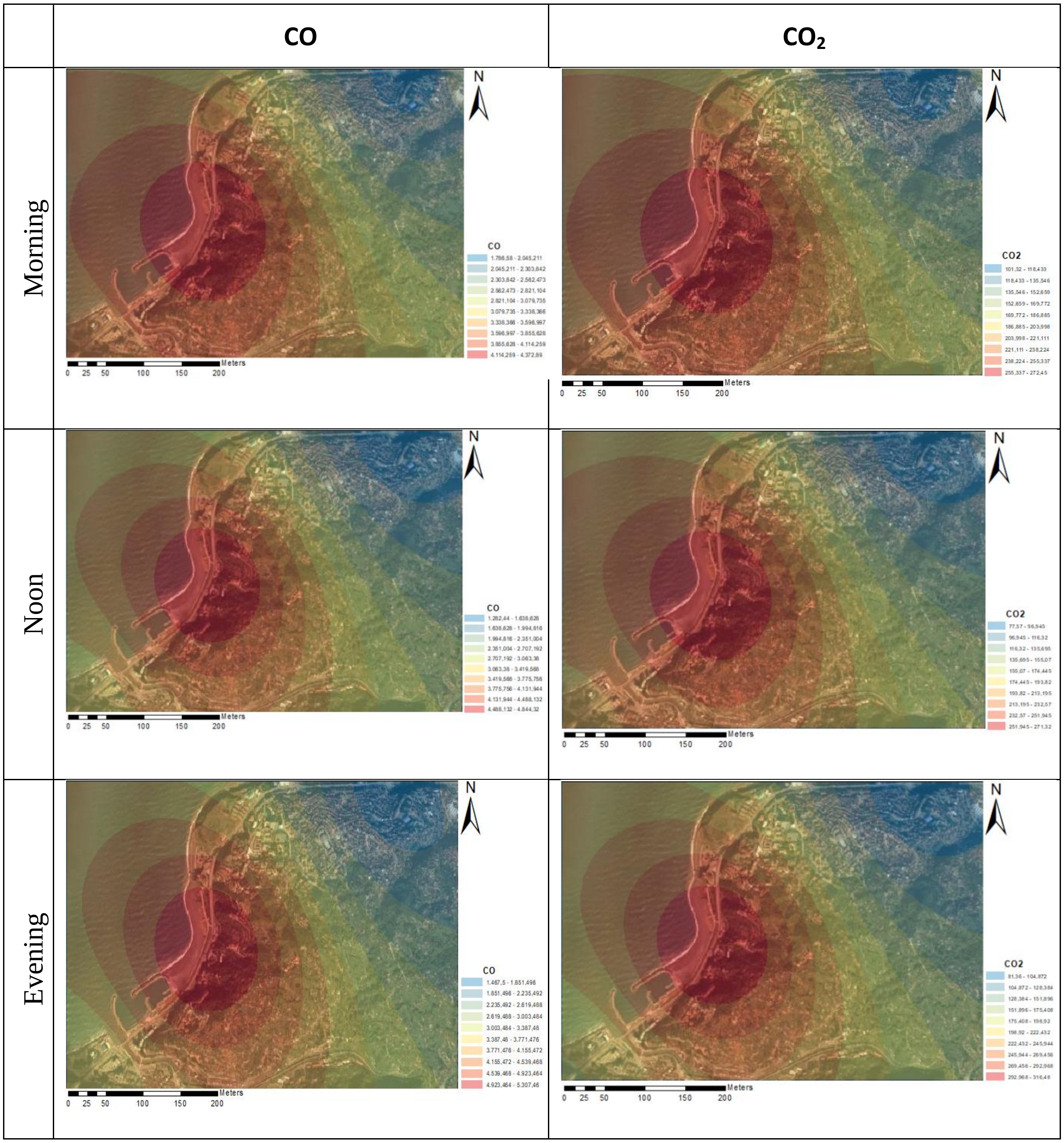

Figure 2: Emissions of *CO and CO_2 at D010 highway in the morning, noon and evening.*

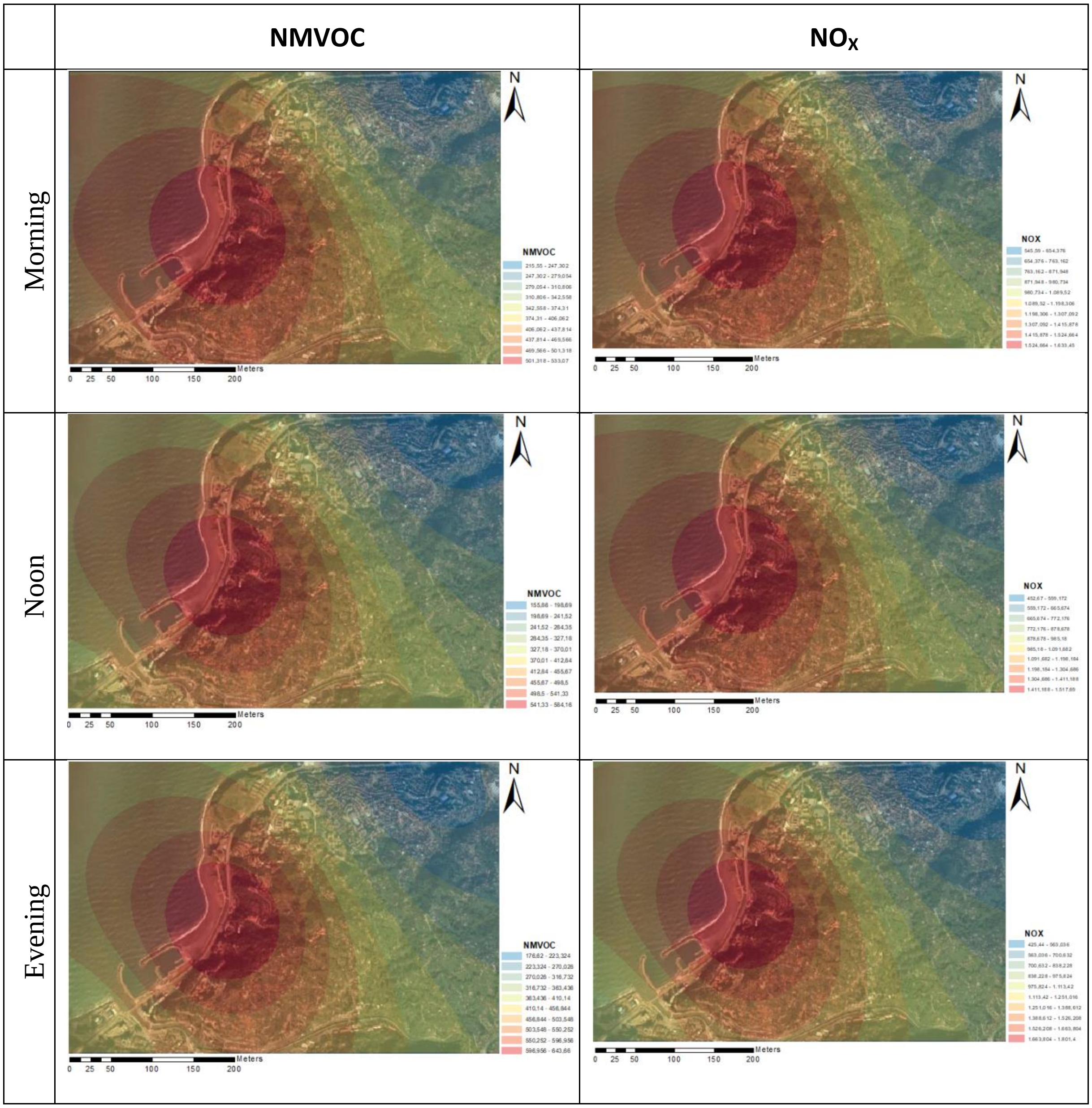

Figure 3: Emissions of *NMVOC and NO_X at D010 highway in the morning, noon and evening.*

Contribution of transport related emissions to total air quality in urban areas is important because traffic emission is one of the most important pollutant source. Zonguldak is a small city with a population of 126404. Coal has been used in the city for domestic heating for long years. Because of heavy use of coal, coal related emissions are significantly high and therefore the air quality is very low. According to national and international air quality standards Zonguldak is an alarming city. Especially SO_2 and NO_X emissions are used to be very high. Starting from 2015 natural gas is being used in the city center and in some other parts of the city. Along with the start of the use of natural gas, the use of coal has been decreased considerably. By eliminating the emissions from coal burning, traffic related emissions have gain more importance in city center.

Regulation of traffic-related emissions is important for improving the air quality in cities. Researches have noted that, signalization and geometric arrangements have significant effects in reducing the emissions in city centers.

6. Conclusions

This study was conducted to determine traffic related emissions in Zonguldak city center by Tier 1 calculation method based on vehicle numbers, vehicle types and fuel types. Tier 1 is the basic method to calculate emissions which only based on vehicle numbers and fuel types. But in reality, a more complex classification should be done to get more accurate results. Vehicle technology, driver habits, country specific carbon contents and many other variables should be of concern while dealing with traffic emissions. Unfortunately in Turkey we have very limited data. For that reason the simplest empirical formula was used. By considering a more detailed data and by enlarging study area a more detailed study can be conducted. Also vehicle counts done for different air conditions and seasons would improve the value of the study.

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