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ARTICLE

Promoting Pedestrian Transportation to Reducing Air Pollution from Urban Transport

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ABSTRACT

Increasing air pollution around the world causes many problems, especially in the field of health. Air pollution affects not only human health but also other living things' health. The factors that cause air pollution the most are heating, industry, and transportation. Many countries in the world carry out various studies to reduce the effect of these factors on air pollution. Especially in the field of transportation, studies have been done quite a lot in recent years. In this study, air pollution caused by transportation in Erzurum, Turkey has been investigated. Emission amounts of NO_X, PM_{10}, and SO_2 values have been calculated according to the types of vehicles in the city. Then, the amount of emissions from transportation in the total sector has been revealed. The transportation structure of the city has examined in general terms and the missing aspects in terms of pedestrian transportation have been revealed. Finally, some solution proposals aiming to encourage the use of pedestrian transportation and micro mobility vehicles in order to reduce motor land vehicles are presented.

1. Introduction

Air pollution is the presence of foreign substances in the air in the form of solids, liquids and gas in the atmosphere in an amount, density and for a long time that will harm human health, living life and ecological balance. The air layer is polluted with the wastes generated during the production and consumption activities that occur as a result of various activities of people, negatively affecting the living life on earth. There are natural and artificial factors affecting air pollution. While natural factors usually occur with natural events, artificial factors emerge with the effect of humans. The three biggest artificial factors affecting air pollution are heating, industry and transportation sectors [1].

Air pollution originating from these sectors may differ according to the region. In regions where industrial facilities are very concentrated, air pollution originating from

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the industrial sector is high. Air pollution in the heating sector is high in regions where the winter period is long and coal-derived fuels are used frequently. In areas where road vehicles using fossil fuels are heavily used, air pollution from transportation is higher [2,3].

Air pollution from transportation is affected by driving patterns, speed and traffic congestion, altitude, meteorological conditions, vehicle type, size, age, technical inspection, exhaust inspection and most importantly, emission control equipment and its maintenance. Especially old motor vehicles, vehicles that do not have periodic maintenance and repair, vehicles with carburetors, vehicles carrying loads above the limit, bad roads and traffic congestion cause an increase in air pollution [4,5].

Due to the increase in air pollution caused by transportation in the world, many studies are carried out in this field. A significant part of the studies carried out by considering the effect of the transportation sector on air pollution reveals the necessity of making some changes in this sector [6-8]. Some studies examine the negative effects of air pollution from transportation on human health and the environment [9,10]. Harmful gases in the air can significantly damage people's respiratory systems [11]. Problems that occur in the respiratory system can progress seriously enough to cause cancer later on. Harmful gases in the air can adversely affect animals and plants as well as humans. In areas with intense air pollution, some animal species may become uninhabitable. Similarly, intense air pollution can cause vegetation to change [12,13].

Especially in the city centers, the high number of road vehicles and the traffic jams in these regions increase the air pollution that may occur. Therefore, in studies dealing with transportation-related air pollution, city centers are generally examined. For example, due to the COVID-19 epidemic, which has been affecting the world since 2019, lockdowns occurred at certain times in various parts of the world. In these periods, it has been observed from the studies that air pollution has decreased significantly, especially in urban centers. Because in these periods, people did not feel the need to go to work or school because they stayed at home. For this reason, since they do not provide transportation to any place by vehicles, harmful gas emissions in cities have decreased [14-16].

Some of the studies affecting the air pollution of transportation deal with the economic costs caused by this air pollution. Because it is necessary to apply some treatments in order to improve the health problems caused by air pollution. These treatments can also be provided with serious costs. In addition, the cleaning of particles released from transportation incurs certain costs [17,18].

There are many studies examining the transportation sector and air pollution [19,20]. These studies provide readers with important information to reduce air pollution. In addition, the results obtained from these studies can offer important ideas to policy makers or local governments. In addition to the existing studies in this field, new studies are being conducted every day that examine the relationship between transportation and air pollution.

In this study, motor road vehicles in Erzurum province have been examined separately according to their types and fuel types. Annually released NO_X, PM_{10} and SO_2 gas amounts have been calculated for each species. Then, the gas emissions from the transportation sector and the gas emissions from the industry and heating have been compared and the share of transportation in air pollution has been revealed. Finally, some suggestions have been made to reduce air pollution caused by transportation in the city. It has stated that some studies should be prioritized especially in order to encourage pedestrian transportation.

2. Materials and Methods

2.1 Study Area

The city of Erzurum, used as the study area, is located at an altitude of 1900 meters above sea level and in the eastern part of Turkey. The population of the city is approximately 750 thousand as of 2021. Road vehicles are used in urban transportation. The total number of motor road vehicles in the city is approximately 117 thousand. Cars and trucks cover a large part of this number of vehicles [21,22]. The location of Erzurum, the study area, is shown in Figure 1.

2.2 Data Processing

Most of the data used in the study have been obtained from the reports of the Provincial Directorate of Environment and Urbanization [23]. An inventory of traffic activity data has been created by the staff of the Provincial Directorate of Environment and Urbanization, in written and one-on-one interviews with the institutions. The length of roads and vehicle counts in Erzurum Province have been obtained from the Erzurum Metropolitan Municipality Presidency (Directorate of Transportation and Urban Planning), and the number of vehicles according to the motor types and fuel types in the traffic in the city have been obtained by the Turkish Statistical Institute and the Provincial Police Department (Traffic Registration Branch Directorate) [24-27]. From the records of Vehicle Maintenance Services operating in Erzurum province, the average annual fuel consumption and annual road distances have been determined according to vehicle types. Annual fuel amounts sold in Erzurum have been also obtained from the Energy Market Regulatory Authority and compared

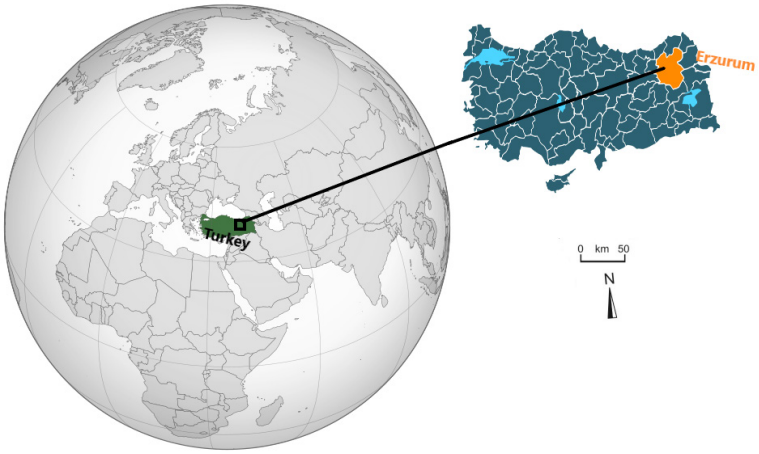

Figure 1. Location of study area.

with the fuel consumed by the vehicles. Defined fuel and vehicle subcategories: Air pollutant emissions can reach significant levels around main streets, intersections and highways where traffic is intense.

Table 1 below shows the statistics including the types of vehicles in Erzurum and the types of fuel they use.

The main emissions from vehicles are NO_2, CO, HC, SO_2, PM and lead in PM. Although PM emissions from exhaust gases are low, they should be carefully examined in terms of threatening human health and nature due to the lead they contain. These emissions from vehicles depend on parameters such as vehicle age, engine operating speed, operating temperature, ambient temperature, ambient pressure, fuel type and quality. In the study, different emission factors have been used according to each vehicle type and fuel type. These factors have been determined by the Ministry of Environment and Urbanization. Emission factors determined according to vehicle types are given in Table 2.

Table 1. Number of vehicles in Erzurum province.

Type of vehicle	Gasoline	Diesel	LPG	Total
Truck		5,878		5,878
Small truck		26,645		26,645
Minibus		2,990		2,990
Motorcycle	2,662			2,662
Bus		1,159		1,159
Automobile	15,031	20,917	22,318	58,266
Tractor		19,663		19,663
Total	17,693	77,252	22,318	117,263

Table 2. Emission factors determined by vehicle type.

Type of vehicle	Types of Fuel	Emission Factor (NO_X)	Emission Factor (PM_{10})	Emission Factor (SO_2)
Automobile	Gasoline	14.5	0.03	0.02
Automobile	Diesel	11	1.1	0.02
Automobile	LPG	15.5	0	0.1
Light Vehicle	Gasoline	24	0.02	0.02
Light Vehicle	Diesel	15	1.52	0.02
Light Vehicle	LPG	16	0	0.1
Heavy Vehicle	Gasoline	6.6	0	0.02
Heavy Vehicle	Diesel	37	0.94	0.02
Heavy Vehicle	CNG (Bus)	13	0.02	0.1
Motorcycle	Gasoline	9.5	2.2	0.02

*CNG: compressed natural gas.

3. Results

In order to calculate the amount of emissions from road vehicles in a year, the emission coefficient of each type of vehicle and the amount of fuel used in a year must be taken into account. Total NO_X, PM_{10} and SO_2 gas emissions in a year are given in Tables 3-5, respectively.

When all three tables are examined, the total NO_X emission amount in a year is 4,843.95 tons, the total PM_{10} emission amount is 212.87 tons and the total SO_2 emission amount is 7.70 tons. It is seen that NO_X emission amount is quite higher than PM_{10} and SO_2 emission amount. The reason for this is that the emission coefficient of NO_X is quite high. In order to determine the share of these three emission values in the city's air pollution, it is necessary to compare them with the emission values in the heating and industry sectors. The graph in Figure 2 below shows the sectoral distribution of one-year NO_X, PM_{10} and SO_2 emission values in Erzurum.

Table 3. Total NO_X emission amount in a year.

Traffic Total Emissions (NO_X)				
Type of vehicle	**Types of fuel**	**Emission factor (A)**	**Total fuel (Tons) (B)**	**Total emission (tons/year) (A)*(B)/1000**
Automobile	Gasoline	14.5	13,527.9	196.15
Automobile	Diesel	11	14,641.9	161.06
Automobile	LPG	15.5	40,172.4	622.67
Light Vehicle	Gasoline	24	0	0.00
Light Vehicle	Diesel	15	85,449.5	1,281.74
Light Vehicle	LPG	16	0	0.00
Heavy Vehicle	Gasoline	6.6	0	0.00
Heavy Vehicle	Diesel	37	69,781.84	2,581.93
Heavy Vehicle	CNG (Bus)	13	0	0.00
Motorcycle	Gasoline	9.5	399.3	0.40
Total			223,972.84	4,843.95

Table 4. Total PM_{10} emission amount in a year.

Traffic Total Emissions (PM_{10})				
Type of vehicle	**Types of Fuel**	**Emission Factor (A)**	**Total fuel (Tons) (B)**	**Total emission (tons/year) (A)*(B)/1000**
Automobile	Gasoline	0.03	13,527.9	0.41
Automobile	Diesel	1.1	14,641.9	16.11
Automobile	LPG	0	40,172.4	0.00
Light Vehicle	Gasoline	0.02	0	0.00
Light Vehicle	Diesel	1.52	85,449.5	129.88
Light Vehicle	LPG	0	0	0.00
Heavy Vehicle	Gasoline	0	0	0.00
Heavy Vehicle	Diesel	0.94	69,781.84	65.59
Heavy Vehicle	CNG (Bus)	0.02	0	0.00
Motorcycle	Gasoline	2.2	399.3	0.88
Total			223,972.84	212.87

Table 5. Total SO_2 emission amount in a year.

Traffic Total Emissions (SO_2)				
Type of vehicle	**Types of Fuel**	**Emission Factor (A)**	**Total fuel (Tons) (B)**	**Total emission (tons/year) (A)*(B)/1000**
All vehicles	Gasoline	0.02	13,927.2	0.28
All vehicles	Diesel	0.02	169,873.24	3.40
All vehicles	LPG	0.10	40,172.4	4.02
Total			223,972.84	7.70

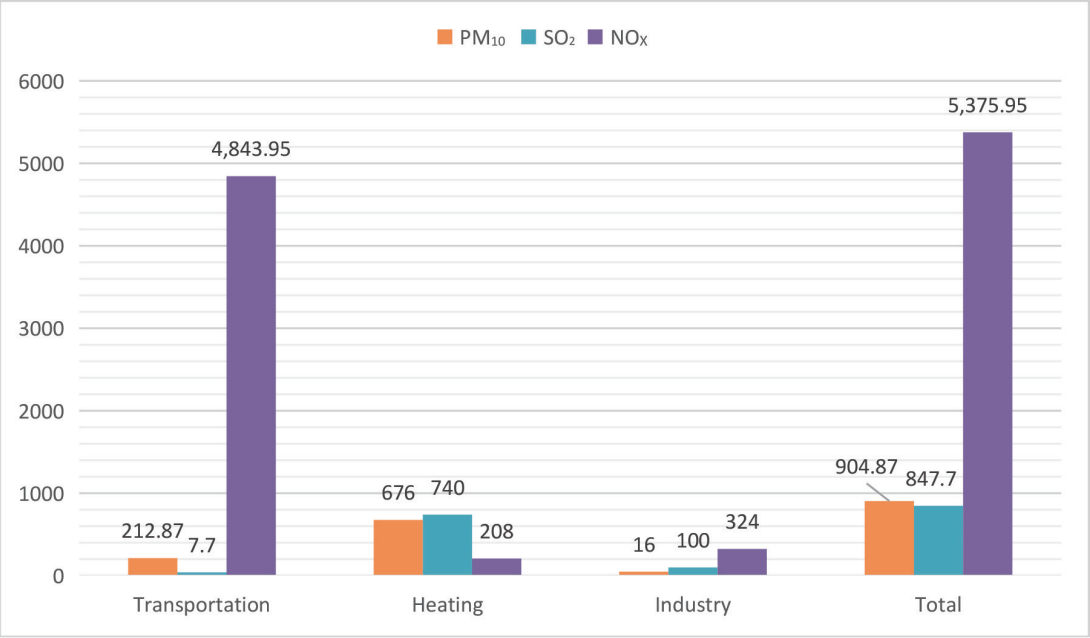

Figure 2. Sectoral distribution chart of NO_X, PM_{10}, SO_2 emissions.

When the sectoral distribution of emission values in the city is examined, it is seen that the transportation sector covers approximately 70% of the total emission values. A very large part of this amount is due to NO_X emissions. In addition to this situation, in the study, it has been determined that motor vehicles on the road increased between 07.00-09.00 in the morning and 17.00-20.00 in the evening. Particulate matter and emissions from motor vehicles reach significant levels, especially around main streets, intersections and highways. The amount of these emissions from vehicles depends on parameters such as the age of the vehicle, the operating speed of the engine, operating temperature, ambient temperature, ambient pressure, fuel type and quality. Although air pollution caused by heating occurs in the city due to cold weather, air pollution caused by transportation is much higher. It is seen that the share of the industrial sector in air pollution in the city is much lower. The reason for this is that the city is not an industrial city and the industrial facilities are generally located far from the city.

4. Discussion

The fact that the share of the transportation sector in the air pollution in the city is too high is an important problem. Because while interventions to air pollution originating from the heating and industry sector are quite difficult, it is easier to intervene in air pollution related to the transportation sector. For this reason, it is possible to significantly reduce air pollution related to the transportation sector with some regulations.

Although the use of hybrid and electric vehicles in the transportation sector is increasing day by day, air pollution caused by transportation is very high as the demands of individuals for automobile ownership are higher. In addition, although the province of Erzurum, which has been chosen as the study area, has a cold climate, the air

pollution caused by the heating of houses and workplaces is almost one third of the air pollution caused by transportation.

In this study, when the urban transportation structure is examined, it has been determined that individuals prefer individual automobile use rather than public transportation. In addition, it is seen that individuals travel by automobile even for very short distances. In order to prevent these and similar problems and to prevent air pollution in the city, some suggestions are presented below.

- Within the framework of the Transportation Master Plan, the pedestrian roads should be redesigned to reduce the traffic density in the city center.
- It is necessary that the pedestrian roads provide a connection between the important points of the city and the pedestrian crossings should be made suitable for this.
- A minimum number of safe pedestrian crossings are required, rather than a large number of pedestrian crossings. In this way, safe passage can be provided for pedestrians. In addition, air pollution can be reduced by reducing stops on the road.
- In order to reduce the use of individual vehicles, it is necessary to carry out studies to make public transportation services attractive.
- For the planning and management of traffic, green wave, smart signaling systems, traffic congestion pricing, different parking fees need to be implemented.
- It is necessary to limit the use of vehicles in the hours and regions where the traffic density increases and individuals should be directed to public transportation vehicles or pedestrian transportation.
- In order to increase micromobility in the city, bicycle lanes and similar alternative transportation should be increased and encouraged.

5. Conclusions

In this study, the problems caused by the increasing air pollution in the world have been mentioned. The transportation sector, which is one of the most important factors causing air pollution, has been discussed. For this reason, the air pollution caused by transportation has calculated for the province of Erzurum, which has determined as the study area. Emission factors determined for each vehicle type and each fuel type have been taken into account in the calculation process. NO_X, PM_{10} and SO_2 emissions have been calculated by taking into account the amount of vehicle fuel used in the city in a year. As a result of the calculations, it has been determined that the NO_X emission is particularly high. Accordingly, the amount of emissions originating from transportation and the amount of emissions originating from heating and industry have been compared. It has been determined that approximately 70% of the total amount of emissions in the city originates from transportation. In the discussion part, this situation has been examined and some suggestions have been made in order to reduce the use of vehicles in the city. In particular, the preference for public transportation vehicles, the increase in bicycle paths and the increase in pedestrian transportation have been mentioned. It has been mentioned that in order to spread pedestrian transportation, the pedestrian ways should be designed to connect the important points in the city, the pedestrian ways should be made more usable and the pedestrian crossings should be designed safely. In this direction, cleaner and healthier living conditions will be provided for living things.

This study revealed the effect of transportation on air pollution in cities. In order to reduce this air pollution, it has been stated that the use of motor vehicles should be reduced and measures should be taken to increase pedestrian transportation. Future studies can optimize the design of pedestrian roads that increase pedestrian access and public transport systems that will reduce the preference for motor vehicles.

Author Contributions

Emre Kuşkapan: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Validation; Visualization; Writing - original draft. Muhammed Yasin Çodur: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Validation; Visualization; Writing - original draft.

Conflict of Interest

There is no conflict of interest in this study.

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