Journal of Air Pollution and Health (Winter 2025); 10(1): 93-114

Original Article

Available online at http://japh.tums.ac.ir

Econometric analysis of the effect of weather on air pollution

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ARTICLE INFORMATION

Article Chronology:
Received 26 July 2024
Revised 02 January 2025
Accepted 05 February 2025
Published 29 March 2025

Keywords:
Data analysis; Air pollution; Econometric

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ABSTRACT

Introduction: Air pollution is one of the world's major global issues. In this research we aimed to calculate the impact of weather factors on air pollution and show the results by using the econometric method of data analysis. After that, we also studied the effect of car exhaust on air pollution in relation to urban congestion and car age.
Materials and methods: Data cleaning methods used in this research include as correcting structural errors, dealing with missing data and sorting data. For calculation, correlation analysis was used to find the relationship of the time series dataset, and then used panel model for the test results, which are estimated by least squares method. In correlation analysis, used air quality and weather's data of Ulaanbaatar city's last 3 years.
Results: As a result of the research, we found that the amount of air pollutant depends on weather factors, that is, location and wind speed have the greatest influence on air pollution. Also the decrease in the amount of sulfur dioxide is due to the ban on burning raw coal in the capital. Our findings indicate that the nitrogen dioxide level in the residential area is high even in the warm season, which is due to congestion and age of vehicles.
Conclusion: The most important weather factors affecting air pollution are location and wind direction. In the future, with comprehensive data collection, future research could better identify sources of air pollution and develop effective mitigation strategies.

Introduction

Air pollution is one of the greatest environmental health risks. It is so widespread and it represents one of the main problems of the worldwide, especially because it is emitted by so many different types of sources [1]. The human exposure to air pollutant depends on geographical features. Citizens in Africa, Asia or the Middle East

Please cite this article as: Ganchimeg G, Jargal E, Choi J. Econometric analysis of the effect of weather on air pollution. Journal of Air Pollution and Health. 2025;10(1): 93-114.

breathe much higher levels of air pollutant than those who live in other parts of the world [2]. On the other hand, although air pollution is a global problem, it affects people living in developing countries, especially women, children and the most vulnerable groups. Every time we breathe, we inhale tiny particles that can damage the lungs, heart, and brain and cause many health problems. Of these particles, which can be anything from soot, soil dust, and sulfates, the most dangerous are fine particles with a diameter of 2.5 µm or less, abbreviated as $PM_{2.5}$ [1-2]. The territory of Mongolia is far from foreign seas, surrounded by high mountains on all sides in the central part of the Eurasian continent, with an average height of one and a half kilometers above sea level, so it has a hypercontinental climate. Average annual winter temperature in Mongolia -10°-38°C (14°-36.4°F) [3].

With its vast territory and semi-nomadic population, Mongolia may seem to be immune to air pollution, but Ulaanbaatar is the city most affected by air pollution in the region. Ulaanbaatar's air pollution is caused by the burning of raw coal by the expanding ger communities to keep their homes warm during the bitter winter months. While this traditional lifestyle is possible in rural areas, it is not suitable for densely populated urban areas. Therefore, Ulaanbaatar, home to almost half of Mongolia's population, is one of the most polluted capital cities in the world [4]. In addition, in our country, research on the impact of human activities on air pollution is intensively conducted, and the government is taking step-by-step measures to reduce air pollution, but the amount of PM_{10}, $PM_{2.5}$ particles, SO_2 sulfur dioxide, and CO carbon monoxide in the air of the capital city pollution is still higher than the air quality standards of the World Health Organization (WHO) and Mongolia [5]. As of February 20, 2024, Ulaanbaatar was ranked 8^{th} out of 122 cities in the world with high smoke pollution, and 40th as of April 20, 2024. Fig. 1 shows the appearance of the environment in Ulaanbaatar during periods of high air pollution, Dec 2024. In addition, Fig. 2 shows the ranking of the most polluted major cities: Air pollution in Ulaanbaatar city as of November 8, 2024, and December 29, 2024 [6]. However, there were cases where Ulaanbaatar was ranked in the first three places with very poor air quality in winter between December and January.

Fig. 1. The appearance of the environment in Ulaanbaatar during periods of high air pollution, Dec 2024 [6]

The main source of air pollution in our country is about 80% of exhaust fumes from homes and heating boilers, 10% from vehicle exhaust, and 6% from thermal power plants. More than 70% of the total population of Ulaanbaatar city lives in ger districts [5]. This is influenced by the fact that the residential area surrounds the housing area, and 70-80% of them are located in the north of the capital city. Because in our country, the prevailing winds are from the west and north, so the direction of the wind means that the smoke generated in the neighborhood will reach other parts of the city. In December, the coldest months of the year, the daily average of $PM_{2.5}$ pollution reaches 687µg/m3, which is 27 times higher than the safe level recommended by WHO [4, 7]. Fig. 3 shows the residentialger area of Ulaanbaatar city [8-10].

AQI⁺ US legend

0-50	51-100	101-150	151-200	201-300	301+
Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous

Rank	Major city, country/region	AQI⁺ US	Followers
1	Lahore, Pakistan	840	442.8K followers
2	Delhi, India	486	2.8M followers
3	Sarajevo, Bosnia Herzegovina	189	66.3K followers
4	Ulaanbaatar, Mongolia	187	59.2K followers
5	Beijing, China	181	8.1M followers

Fig. 2. The ranking of the most polluted major cities: Air pollution in Ulaanbaatar city as of November 8, 2024 [6]

Fig. 3. Residential ger area of Ulaanbaatar city [8-10]

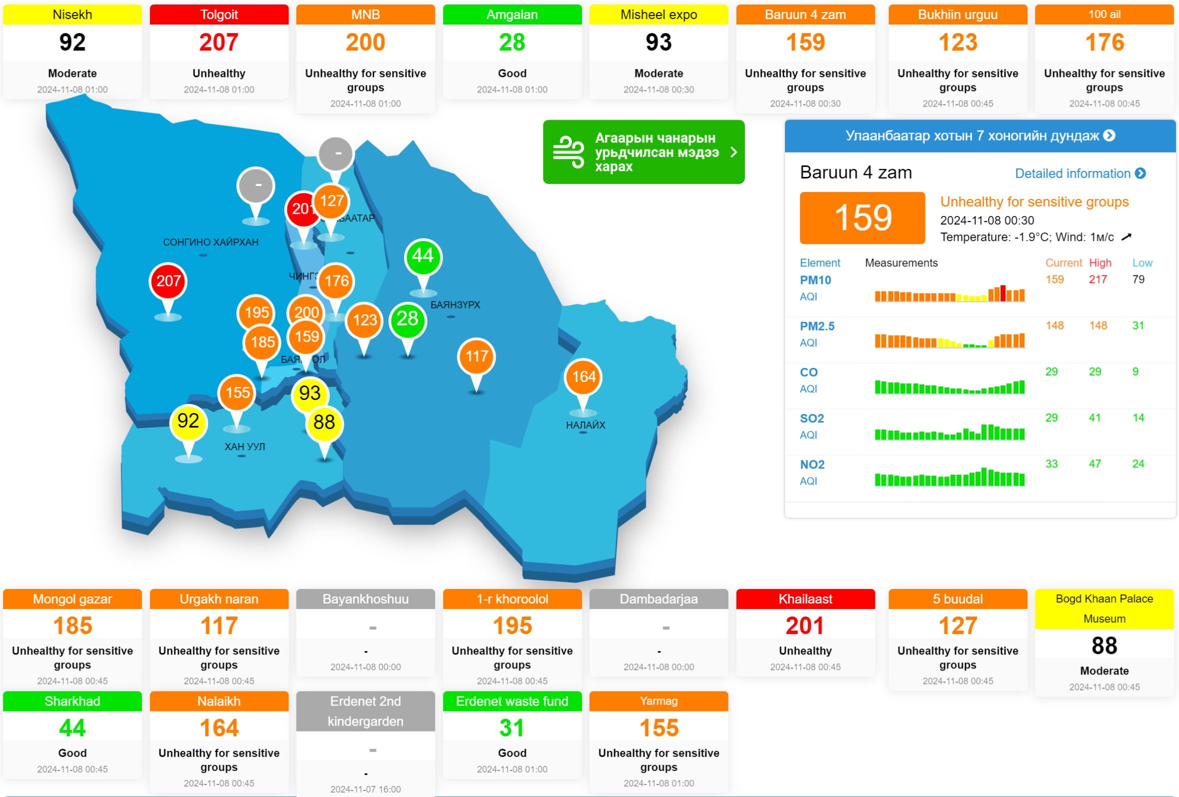


Fig. 4. Air quality monitoring data from 18 locations in Ulaanbaatar as of December 29, 2024 [11]

In most countries, air pollution is controlled by 6-8 parameters such as sulfur dioxide, nitrogen dioxide, ozone, particulate matter, and carbon monoxide. However, in Mongolia, the air pollution of the capital city and the centers of 21 provinces is measured only by sulfur dioxide and nitrogen dioxide. Air quality index refers to a numerical indicator comparing the concentration of pollutants in the atmosphere of urban areas with the concentration value of that pollutant that can adversely affect human health. In other words, it is indexing for daily air quality reporting. In accordance with Article 1.4 of the "Procedure for evaluating and reporting air quality by air quality index", the air quality index is determined by taking into account the monitoring program of air quality parameters widely distributed in the air in at least 3 main types. The air quality index is calculated taking into account indicators of 4-9 types of main pollutants at 18 control points of the capital. The corresponding values for air quality index calculations are calculated as follows. Includes:

- Up To 50 - Clean
- 51-100 - Normal
- 101-200 - Low Pollution
- 201-300 - Pollution
- 301-400 - Heavy Pollution
- 401-500 - Very Pollution

12 out of 18 control points located in the capital are under the responsibility of the Department of Weather and Environmental Analysis, the Department of Air Pollution Reduction, and 6 points respectively. Fig. 4 shows air quality monitoring data from 18 locations in Ulaanbaatar as of December 29, 2024 [11].

After 2021, or within the last 3 years, research on how international weather factors affect air pollution has been conducted in China, Africa, Belarus, Italy, and Poland. Their research in Delhi and West Africa identified the relationship between selected weather factors such as air humidity and temperature [12]. Studies conducted in Italy and Poland determined the relationship between air pressure, air humidity, and temperature to the size of particles [13], while a study conducted in China, which is more similar to our country in terms of weather, identified 5 factors: wind speed, air temperature, air pressure, precipitation, and air humidity. exposure to air pollution impact is calculated [14-16]. Correlation and regression analysis were used to make the calculations, and location relationships were visualized using ArcGIS.

For Mongolia, in 2022, many researchers conducted a study of the impact of climate parameters on the content of $PM_{2.5}$ particles in the air using quantile regression analysis. It was concluded that when pollution decreases and air humidity is high, if the distribution variance of $PM_{2.5}$ particles is high, the effect of air pressure on the content of $PM_{2.5}$ particles in the air is small.

According to the international research on the influence of weather factors on air pollution, wind speed and air humidity affect air pollution, especially the amount of particulate matter [17]. It has been concluded that there is a need to further investigate the relationship between steam conditions. Traditional methods of determining air quality use mathematical and statistical methods. These methods have several disadvantages, and the use of machine learning and big data processing techniques will allow for more detailed calculations [18-22]. It is also necessary to use computer intelligence and big data processing to research and identify other ways to reduce air pollution. Therefore, the effect of weather factors on air pollution in Ulaanbaatar city was calculated by the econometric method of big data analysis.

Chimney and smoke from vehicles

In the early 1990s, the population of Ulaanbaatar was 548.3 thousand and the number of households was 108.1 thousand. In 2007, there were 235.0 thousand households. In the last 16 years, the migration from rural areas to the city increased from 235.0 thousand to 465.0 thousand or increased by more than 197%. More than 60% of them, or more than 280,000 families, live in ger district. About 55% of the households living in the residential area live in houses, and the remaining 45% live in ger. Although most households live in apartments and have electric heaters, more than 90% of these households are built without engineering studies, so they are prone to fire, heat loss is high, and quality control is difficult [5-11]. Therefore, the higher the fuel consumption in winter, the more air pollution is caused. The migration flow from rural areas to the capital city continues unabated, and because people cannot afford to buy a house depending on their income level, they are expanding the size of the ger district. Accordingly, the amount of smoke from ger stoves, which contributes to air pollution, is also increasing.

According to a survey by the Ministry of Environment and Tourism, there are currently 122,301 stoves in Ulaanbaatar, 56% of which are improved stoves and the remaining 44% are simple stoves.

The air has the highest concentration of SO_2 or sulfur dioxide, which is 2-6 times more than the international standard in the home area in winter. It has a negative effect on young children and the elderly with chronic respiratory diseases and poor lung development. The main symptoms in the human body are narrowing of the airways, which include nasal congestion and shortness of breath. By constantly breathing air with sulfur dioxide it will increase the incidence of respiratory diseases, reduce the protective mechanism of the lungs, and cause chronic cardiovascular diseases.

Motor vehicles and congestion

Vehicle exhaust contains large amounts of NO_2, the nitrogen dioxide in the air. This gas is a colorless, odorless gas and gives the atmosphere a brownish color. Nitrogen dioxide irritates human lung tissue and increases susceptibility to respiratory infections. Nitrogen dioxide has negative effects, such as increasing the likelihood of respiratory diseases, increasing the sensitivity of people with bronchial asthma and inflammation, reducing the self-defense mechanism of the lungs, and provoking chronic cardiovascular diseases [23]. People with chronic cardiovascular and lung diseases, as well as young children and the elderly are more susceptible to adverse effects.

Since there are no car factories in Mongolia, cars are purchased from abroad. Of the 89,063 passenger cars imported to Mongolia in 2022, 6.8% were 0-3 years old, 10.1% were 4-6 years old, 48.5% were 7-9 years old, and 34.7% were more than 10 years old. As of December 31, 2023, 1,731 public transport vehicles, 73,556 passenger cars, and 21,361 trucks, a total of 96,648 vehicles, were imported to Mongolia [8, 24]. This trend is expected to continue to increase in Figs. 5 and 6.

Fig. 5 shows the number of vehicles in Ulaanbaatar city, by type, over the past five years. When calculating the future Trendline, R^2=0.82 indicates that the number of vehicles will continue to grow steadily. Fig. 6 shows the age of registered vehicles in Ulaanbaatar city over the past five years. In addition, when calculating the future trend line, R^2=1 indicates that the number of used cars imported into our country will continue to grow steadily.

In addition, 67,843 passenger cars were imported from Japan in 2023 [8]. Because they are cheap and consume less fuel, Toyota's Prius and Aqua brand cars are the main consumption of Mongolians. As of 2020-2023, more than 170,000 Prius cars are on the road in Mongolia. The fact that 85-90% of cars imported from Japan are old is a problem. In particular, it is important to note that how damaged car batteries and accumulators are disposed of in Mongolia is of great interest to citizens. Car batteries contain heavy metals such as lead, sulfuric acid, antimony, cadmium, and arsenic. The Prius car, which is imported and sold in the largest number in Mongolia, contains more than 20 types of substances in one battery. While the Japanese replace the battery in a package, in Mongolia they disassemble the battery and replace it in parts. This is dangerous and creates waste of harmful elements to the environment and humans. In addition, in the last three years, 39,517 kg of coal exhaust substances have been exported across the border of Mongolia. For example, if there is an average of 500-700 g of substances per car, it is clear how many car exhaust substances have been exported across the border [25]. On the other hand, there are many cases where citizens themselves sell car exhaust substances to make money. Studies have shown that an average of 200-200 tons of toxic chemicals are emitted from a single car without a carbon exhaust. However, more than 2,500 vehicles without carbon exhaust and found to have violations by the diagnostic department are participating in city traffic, causing a certain amount of damage to air pollution.

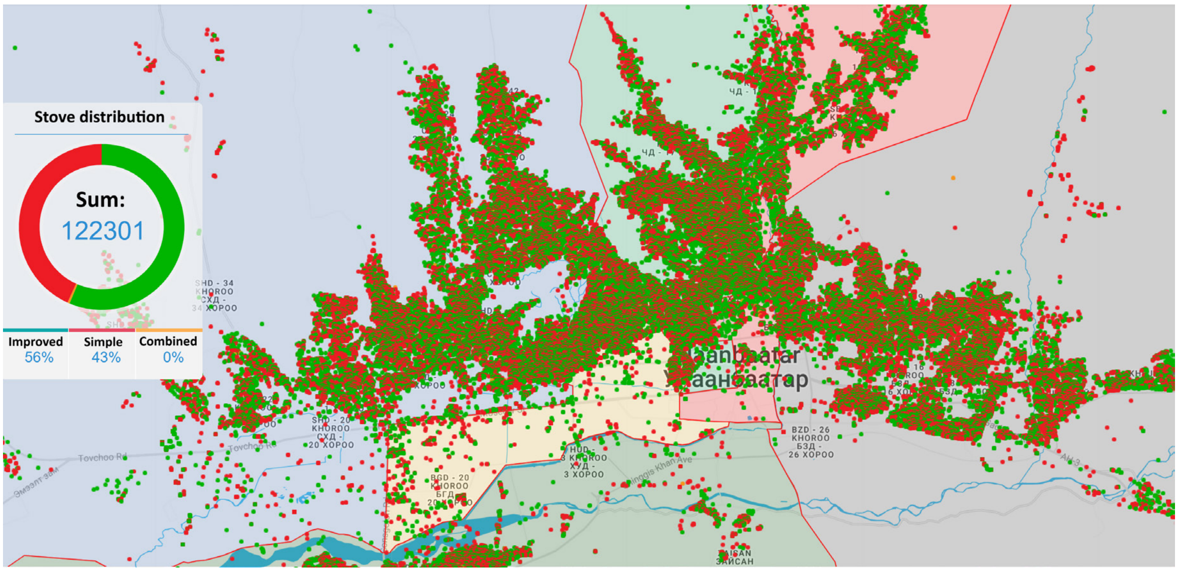


Fig. 5. Number and location of stoves in Ulaanbaatar city as of November 8, 2024 [11]

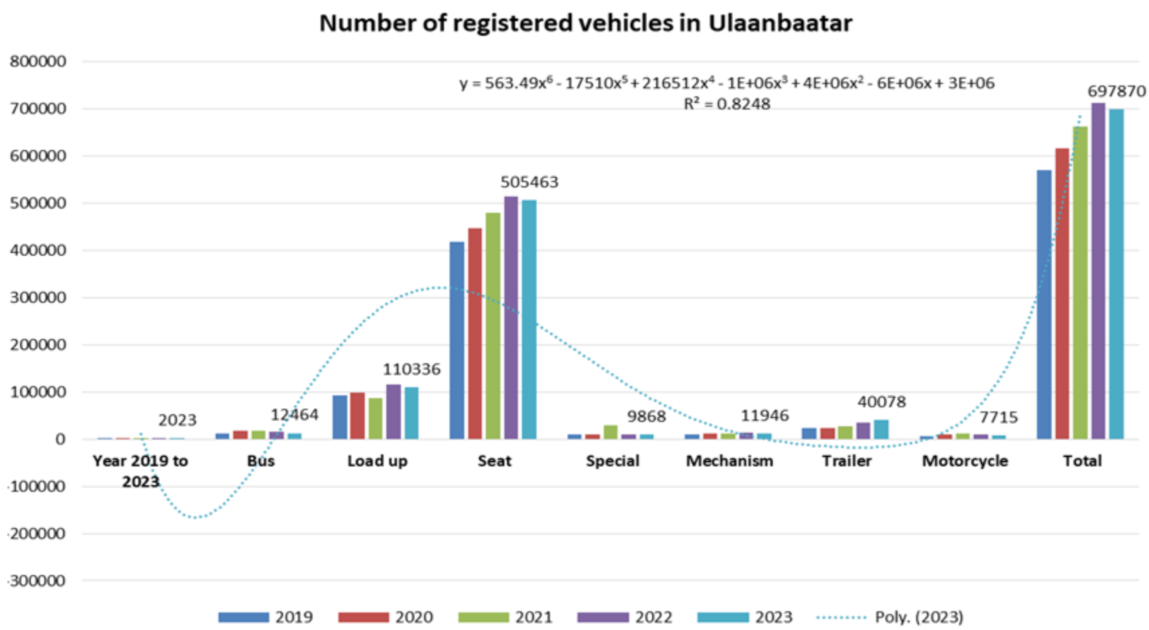


Fig. 6. Future trends in vehicle growth in Ulaanbaatar city based on data from 2019 to 2023 [24]

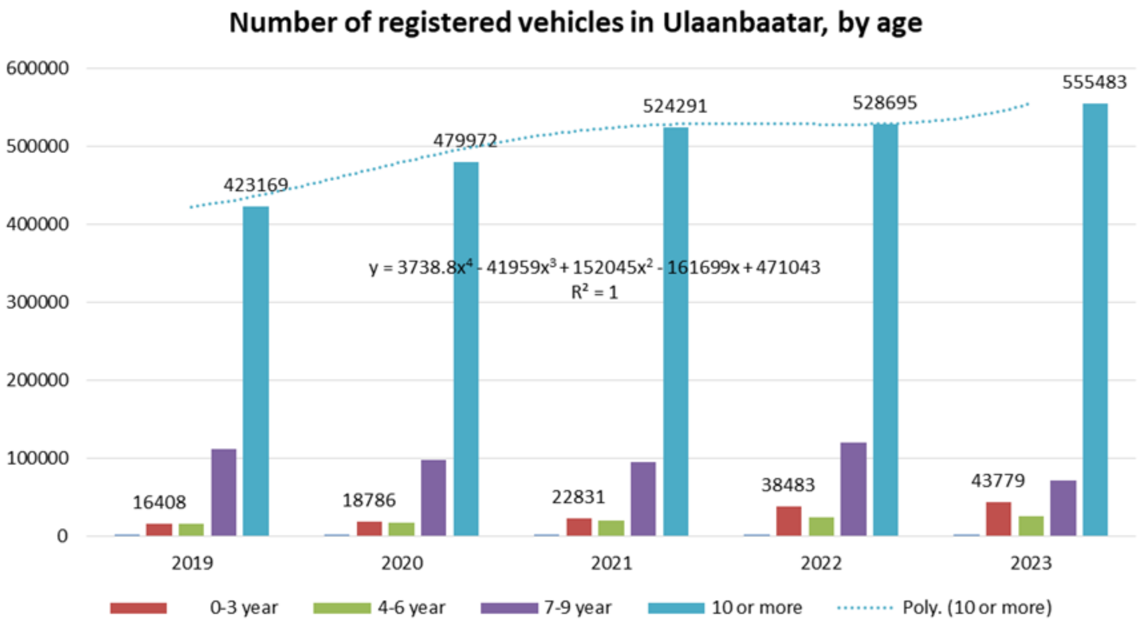
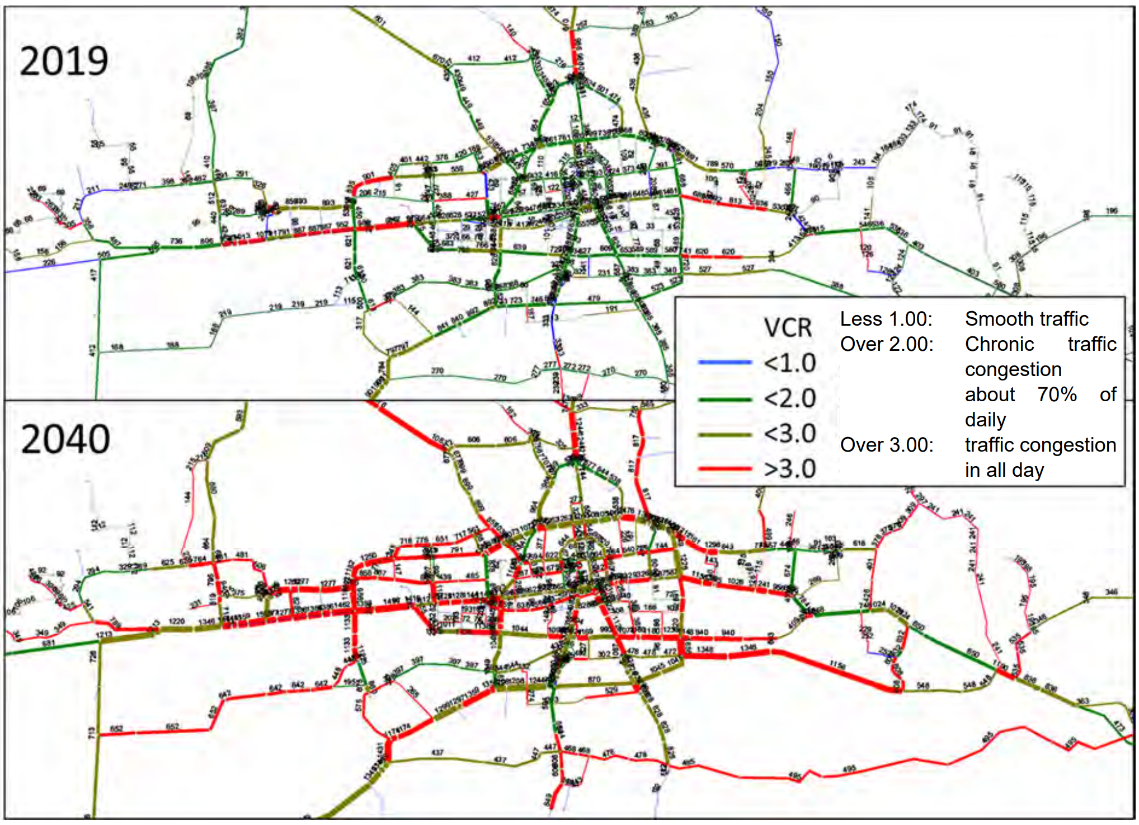


Fig. 7. Transport in Ulaanbaatar in the last 5 years by number and age of instruments [24]



Source: JICA Study Team

Fig. 8. Ulaanbaatar demand forecast until 2040, as of 2019

ALMEK Corporation, CTI Engineering International LLC, in cooperation with JICA, Japan International Cooperation Organization, calculated the circulation forecast for the basic study to strengthen the road transport infrastructure of Ulaanbaatar, Mongolia in 2022, using a four-step simulation. The result is that by 2040, traffic congestion will be much worse than it is now, and there

will be traffic jams all day long [26, 27]. In 2019, considering the congestion near the 2 guard points on which this study was based, the congestion around Khailaast and Bogd Khan Museum has a 2+ index. It is estimated that it is chronically congested, 70% of 12 h a day, or 8-9 h. Fig. 7 shows Transport in Ulaanbaatar in the last 5 years by number and age of instruments.

Every year, the number of stoves in homes and the number of cars that have been around for many years are increasing, which will affect the air pollution in Ulaanbaatar, and if measures are not taken, air pollution will continue to increase regardless of the season. It may eventually affect the neighboring countries as well. In our country, air cleanliness, air temperature it begins to deteriorate after the weather starts to fall to minus degrees, that is, from the end of 10 months. Since the emergence of the problem of air pollution, respiratory diseases have increased rapidly among the residents of Ulaanbaatar, and 10,000 people cases of respiratory infections increased 2.7 times per year [28]. It has also been determined that children are the most affected by air pollution in the past 10 years [29].

Car exhaust is the most harmful to human health because it is emitted at the level of human breathing, about 1-2 m from the ground. Especially in winter, due to the cold temperature, the air is denser, so the smoke from vehicles cannot rise up and accumulates in the environment [30]. Here are some of the negative effects of some substances in car exhaust on the human body:

- Carbon monoxide-CO enters the body together with the air we breathe and impairs the ability to participate in the metabolism of red blood cells, affecting the functioning of the central nervous system and causing negative effects such as weakness, headache, vomiting and nausea.

- Nitric oxide-NO irritates the mucous membrane of the nose and eyes, forms nitrogen nitrites due to the humidification of the upper respiratory tract and damages the lungs, while sulfur gas affects the lungs by disrupting human protein metabolism and hormone function.

The main causes of air pollution in Ulaanbaatar are extreme climate of our country, urban planning, location and size of neighborhoods, their fuel solutions, substandard and even old vehicles without filters, highway network solutions and congestion. By 2023, the number of lung cancer patients will increase 2.0 times from 2019, while the number of deaths in Ulaanbaatar increased by 26 %in the last 8 years, and decreased by 4.5-15.5% in the eastern and western regions [28]. Fig. 8 shows the Ulaanbaatar demand forecast until 2040, as of 2019 and Fig. 9 shows the graph of cancer incidence in Mongolians in the last 5 years.

Materials and methods

Quantitative analysis, which is a major branch of data analysis, often uses mathematical modeling, statistical analysis, and econometric analysis. In this study, the raw values of air pollution measurements of Ulaanbaatar city from January 1, 2021 to January 1, 2024 were obtained from the National Institute of Statistics, and experiments were conducted on manually sampled data from [11]. Three years of data were used because Mongolia only started collecting raw air pollution data three years ago. Which is conducts by Ministry of Environment and Climate Change. Also, the weather data of Ulaanbaatar city, was obtained from the National Agency Meteorology and the Enviromental Monitoring. We based on classical linear regression analysis and correlation analysis, which is one of the main methods of quantitative analysis of data science and econometric analysis of statistics, we calculated the impact of weather factors on air pollution using data analysis tools of Stata program. In order to further confirm the results of that analysis, a panel model was developed and the method of least squares was used. Visualization of the analysis results is shown using the tools of the Polymer search electronic platform.

Correcting structural errors

Errors in measurement, data transmission, etc. are called structural errors. If a large amount of data has structural errors, the results will be of poor quality. Our big data structure is purely numeric data and because the data collected by the Department of Meteorology and Environmental Analysis was sent as an MS Excel file, there were almost no structural errors. We corrected data type errors where necessary to ensure data consistency.

Dealing with missing data

Data cannot be deleted before it is confirmed that the data is not needed for the analysis, but the 2 points we have chosen for air quality data, $PM_{2.5}$ particle data was missing because it had too many gaps, so excluded from the analysis. Average the values before and after other data gaps filled up by comparing with the value of the year.

Sorting the data

After averaging the hourly air quality data into daily data for analysis, the weather and air quality data were combined by date and location.

A. Materials used in the research

In Ulaanbaatar, the air quality index is determined every hour by taking air samples every 10 min at a total of 21 stations, but except fot the 2 stations selected to be used inthe study, the data was intermittent and incomplete. We cleaned data before used it because dirty data will affect the accuracy of prediction result [15]. In this research, the air quality data (NO_2-nitrogen dioxide, PM_{10}-particles, CO-carbon monoxide, SO_2-sulfur dioxide) of the air pollution sampling stations around Khailaast and Bogd Kan Museum, and the weather data (temperature, precipitation, wind direction, wind speed, cloudiness, air humidity) of Ulaanbaatar city were used. Timeline was total of 1095 days from 01.01.2021-31.12.2023. Variables used in the analysis are4 shown in Table 1.

B. Methodology

Air quality reports are available hourly, while weather reports are available daily so, to perform the analysis, 24- h air quality data were averaged and daily indicators were obtained. Correlation and autocorrelation are appropriate tools for measuring the relationships between variables and lagged values of time-series data, respectively [16-17].

Factors affecting air pollution are determined by the following indicators, including:

- Location
- Temperature
- Precipitation
- Wind speed
- Wind direction
- Cloudiness
- Air humidity

Location is not weather factor but we chose the location as a one of factors because of Ulaanbaatar city's structure and distribution of air pollutants.

Table 1. Variables used in the analysis

No	Variables	Name
1	CO	Carbon monoxide
2	NO_2	Nitrogen dioxide
3	PM_{10}	Particles
4	SO_2	Sulfur dioxide
5	Loc	Location (1=Khailaast, 0=Bogd Khan Museum)*
6	TEM	Temperature
7	PRE	Precipitation
8	WS	Wind speed
9	WD	Wind direction
10	CF	Cloudiness
11	RH	Air humidity

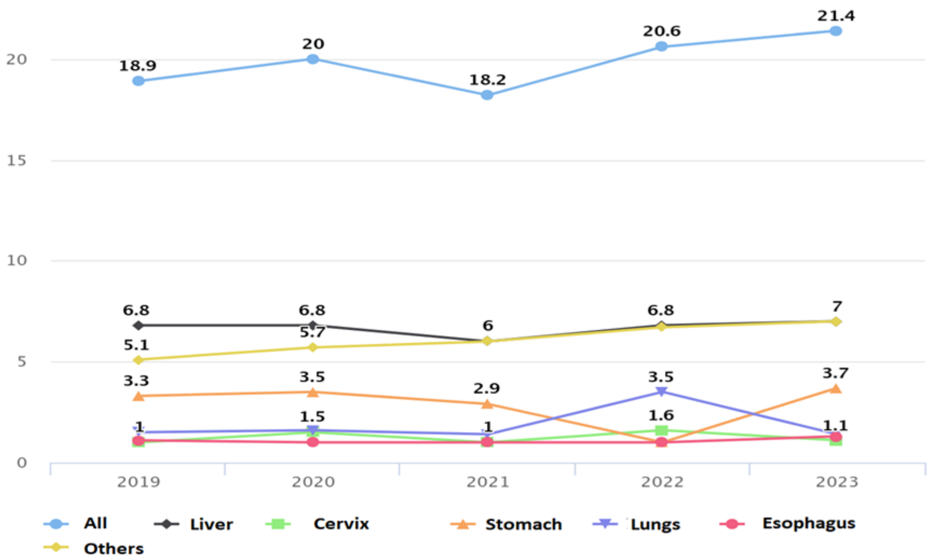


Fig. 9. The proportion of new cancer cases per 10,000 population in Mongolia by cancer type, 2019–2023 [29–30]

Results and discussion

Comparing the amount of air pollution in the last 3 years of Ulaanbaatar city, the air pollution levels were highest in January, and the air pollution was 1.2-2.3 times higher in ger areas than in residential areas. In winter, particulate matter is very high regardless of location. Figs. 10 to 12 show monthly and hourly air quality indice for the locations used inthe study.

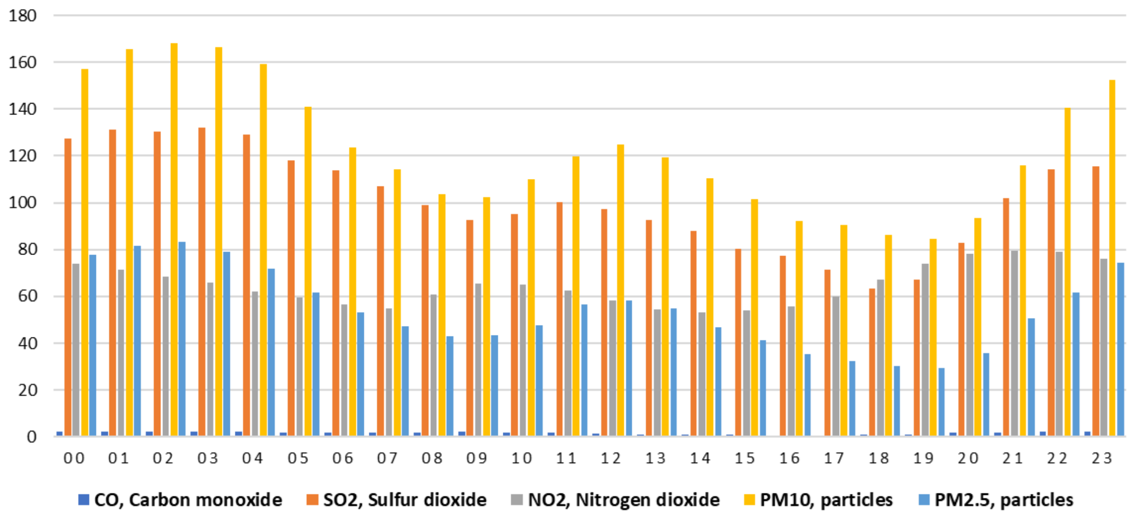


Fig. 10. Air quality index around Bogd Khan Museum, in January, by hour

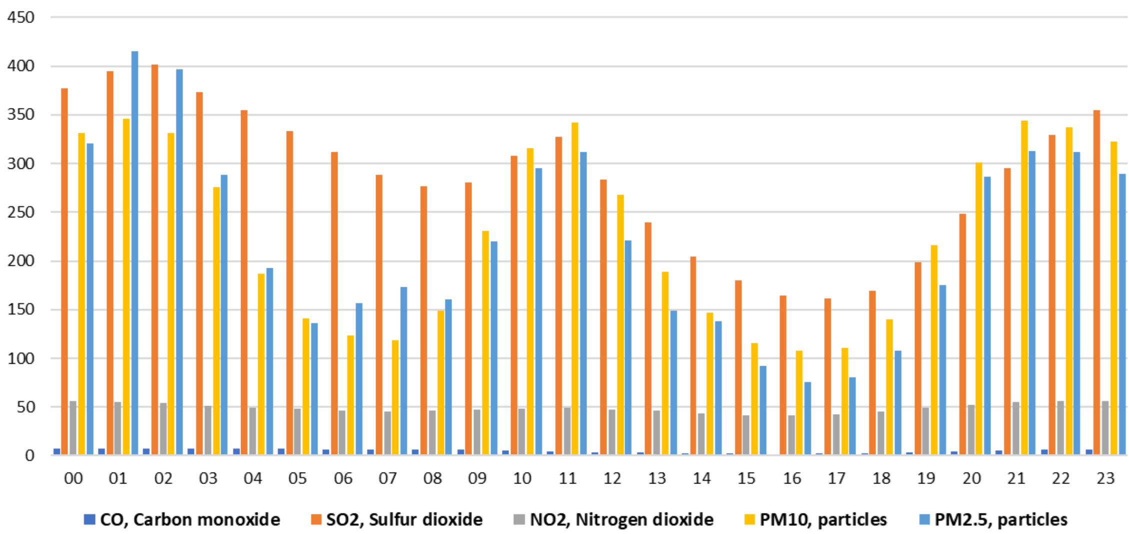


Fig. 11. Air quality index around Khailaast, in January, by hour

In June and July, which are the least polluted months of the year, due to their location, $PM_{2.5}$ and PM_{10} dust levels are higher in residential areas than in ger areas.

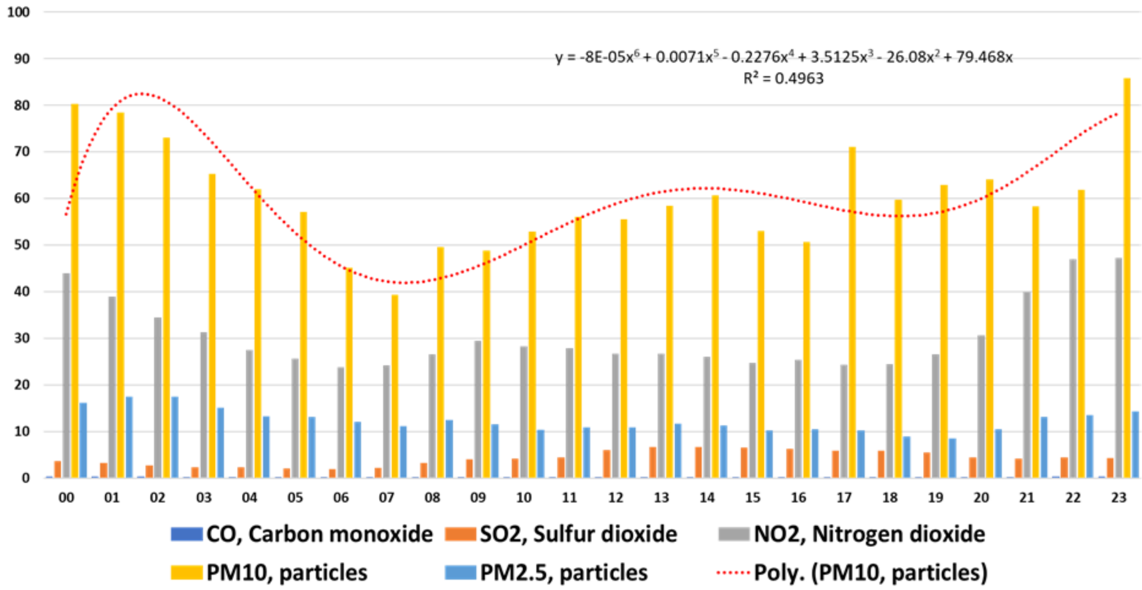


Fig. 12. Air quality index around Bogd Khan Museum, in June, by hour

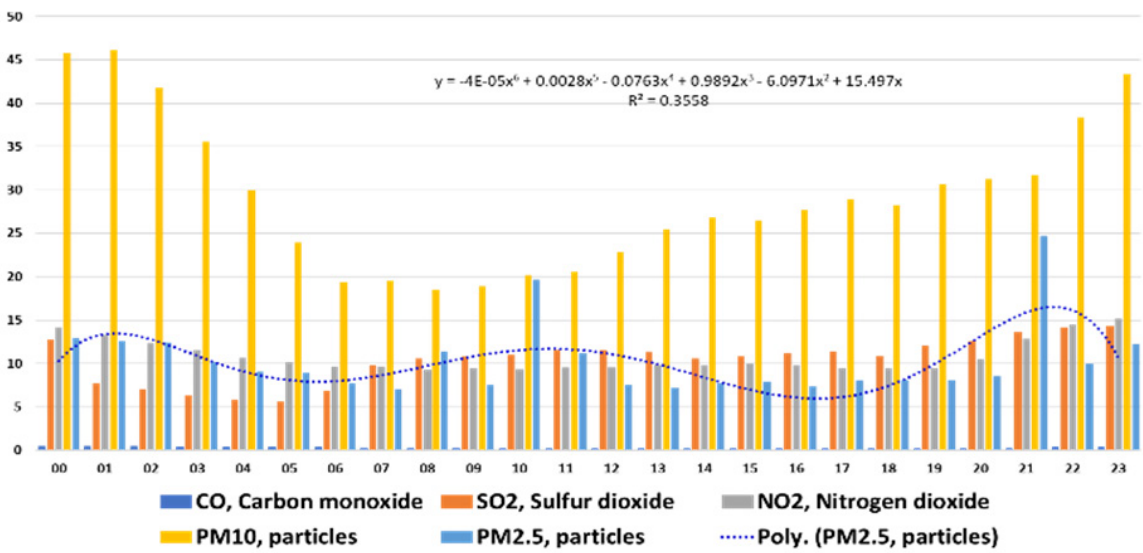


Fig. 13. Air quality index around Khailaast, in June, by hour

However, regardless of the season, sulfur dioxide levels are high in ger areas, and nitrogen dioxide levels are high in residential area. Across all locations and seasons, air pollution is lowest between 15:00 and 18:00 daily. The relationship between the variables determining air pollution was found by correlation analysis and shown in Table 2.

Table 2 shows that CO-carbon monoxide, PM_{10}-particles, and SO_2-sulfur dioxide are moderately correlated with location in Khailaast, while NO_2-nitrogen dioxide is weakly correlated with location in Bogd Khan Museum. Fig. 13 shows air quality index around Khailaast, in June, by hour. Fig. 14 shows Correlation between variables determining air pollution

Table 2. Correlation between air pollution determinants

Variables	CO	NO_2	PM_{10}	SO_2
loc	0.489	-0.27	0.354	0.305
TEM	-0.545	-0.671	-0.518	-0.472
PRE	-0.169	-0.237	-0.2	-0.112
WS	-0.432	-0.59	-0.439	-0.352
WD	-0.368	-0.468	0.397	-0.306
CF	-0.43	-0.566	-0.47	-0.319
RH	0.099	0.087	-0.0007	0.099

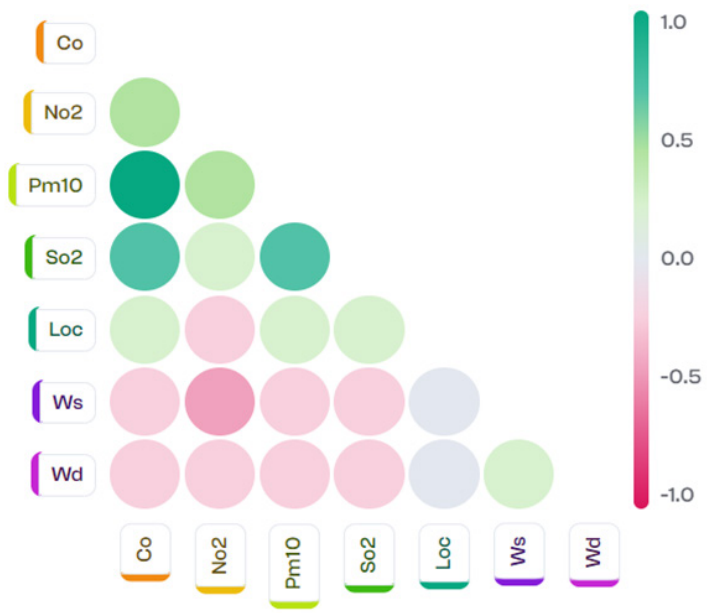


Fig. 14. Correlation between variables determining air pollution

NO_2-nitrogen dioxide, PM_{10}-particles, CO-carbon monoxide, SO_2-sulfur dioxide are moderately inversely related to air temperature, wind speed and direction, and cloudiness, while they are weakly related to air humidity and precipitation. Therefore, the method of determining the relationship has been redefined. Used fulled panel model. This study used a panel model and least square method to determine relationships between variables because fixed and random effects panel models were ineffective. Including Eqs. 1-4:

$$CO=18.287+1.628\cdot Loc-0.045\cdot TEM+0.012\cdot PRE-0.095\cdot WS-0.005\cdot WD-0.068\cdot CF-0.007\cdot RH \quad (1)$$

$$NO2=69.280-8.125\cdot Loc-0.480\cdot TEM+0.124\cdot PRE-1.584\cdot WS-0.049\cdot WD-0.714\cdot CF-0.137\cdot RH \quad (2)$$

$$PM10=206.802+48.522\cdot Loc-1.727\cdot TEM+0.434\cdot PRE-4.736\cdot WS-0.230\cdot WD-3.066\cdot CF-0.777\cdot RH \quad (3)$$

$$SO2=140.560+51.077\cdot Loc-0.249\cdot TEM+1.264\cdot PRE-4.419\cdot WS-0.230\cdot WD-0.388\cdot CF-0.448\cdot RH \quad (4)$$

Table 3. Correlation between variables calculated by the method of least squares

Variables	CO	NO_2	PM_{10}	SO_2
loc	1.628	-8.125	48.522	51.077
TEM	-0.045	-0.480	-1.727	-0.249
PRE	0.012*	0.124*	0.434*	1.264
WS	-0.095	-1.584	-4.736	-4.419
WD	-0.005	-0.049	-0.230	-0.195
CF	-0.068	-0.714	-3.066	-0.388*
RH	-0.007	-0.137	-0.777	-0.448
Constant parameter	18.287	69.280	206.802	140.560
Number of observations	2190	2190	2190	2189
R^2	0.605	0.673	0.510	0.353

*In here: *Not confident at the 95% significance level*

From the test results, 4 regression models were found to be significant, and it can be seen that the amount of air pollutants depends on weather conditions. Precipitation an cloudiness were not confident at the 95% significance level so precipitation has minimal impact on pollution levels. Location and wind direction appear to have the greatest effect.

In addition, other factors such as weather, traffic, and air pollutants should also be taken into account for the variables related to air pollution. Also, the number of self-driving cars and scooters has increased dramatically, and the study found that traffic air pollution is the main component of total air pollution. CO, NOx, and SO_2 emissions from automobiles are important sources of $PM_{2.5}$ parameters. Therefore, in our country, the increase in the number of self-driving vehicles in the warm season is considered to be one of the reasons for the increase in the concentration of $PM_{2.5}$ particles in the warm season. It is also important to consider Average Daily Traffic (ADT), carbon monoxide emissions and other variables for each road segment to predict air levels [29, 30].

Table 3 shows the correlation between variables calculated by the method of least squares.

A case study

50% of the tested vehicles exceed the maximum permissible emission levels when measuring the emissions of gasoline, diesel, and liquefied petroleum gas vehicles, which has a negative impact on air pollution and air pollution in Ulaanbaatar. If the exhaust filter in the car exhaust meets the requirements of Euro 5 or higher standards, the emission of harmful emissions is low. According to a study released in 2022 by the "Center for Research, Development and Quality Management of the National Center for Motor Transport": 33.5% of all vehicles have Euro 5 and Euro 6 emissions standards and it says it has a filter. When calculating the number of vehicles deemed necessary in our country, there are a total of 409,158 vehicles that require the installation of smoke filters that meet the standards of which smoke filters, 196,395 or 48% of which are located in Ulaanbaatar, and 212,763 or 52% of which are located in local areas [25]. As for our country, which does not produce automobiles, it imports and uses a lot of old cars, so as the number of old cars increases, the air pollution and greenhouse gas emissions caused by vehicles continue to deteriorate the living environment and health. Carbon dioxide emissions are estimated to be 1 g/mile at 55 mph, and 7 g/mile at 20 mph. In other words, the instability of the vehicle's speed (stop-go-stop), such as switching between car parts and applying the brakes, burns more fuel and emits more pollutants into the air than driving at an average speed [31]. Table 4 shows the amount of toxic substances released when a car burns one liter of gasoline.

Table 4. Toxic substances released by burning one liter of gasoline size [31]

Type/substance	Carbon monoxide, CO	Nitrogen dioxide, NO_2	Hydrocarbon, CH	Sulfur dioxide, SO_2	Aldehyde CHO	Soot
Petrol car	225	55	20	1.5-2	0.8-1	1-1.5

In order to determine how traffic fumes affect air quality, the data used in this study were used to determine the location of 2 checkpoints, the surrounding road network, and the amount of congestion, and the amount of toxic fumes emitted during congestion. It includes:

500m around the guard point of Khailaast area in the 15th district of Chingeltei district, the main asphalt road has 2 lanes, and the dirt roads between the other streets, which are congested at 8-9 o'clock a day, are normal and free of congestion. If it is blocked, 250-350 cars will emit smoke on that part of the road. 0.8 per car per hour in traffic jams 300 cars consume 2040 liters of gasoline in 8.5 h [8], and if it is assumed that 15-16 h without traffic jams, 5 times fewer cars will drive than when there is no traffic jam, the amount of smoke shown in Table 5 will be released into the air 229,500-382,500 tons pollute the air during congestion. Fig. 15 shows the traffic congestion in the Hailaast area.

Fig. 15. Traffic congestion in the Hailaast area [9]

Located in the 15th district of Khan-Uul district, around the guard point of the Bogd Khan Museum, 500 m away, it is surrounded by 4-6 lanes of asphalt main road on 3 sides, north, south and east. There are 6 parking spaces for 15-110 cars in the front, and in terms of congestion, it has the same chronic congestion as the other point, or 70% of the 12 hs a day. If there is a traffic jam in this area, 1,300-2,000 cars will stand and emit smoke as shown in Table 6 per day. Fig. 16 shows traffic congestion in the Bogd Khan Museum area.

Table 5. Vehicle emissions per day in Khailaast area size

Type/substance	Carbon monoxide, CO	Nitrogen dioxide, NO_2	Hydrocarbon, CH	Sulfur dioxide, SO_2	Aldehyde CHO	Soot
During traffic, 8.5 h	459000	112200	40800	3060-4080	1632-2040	2040-3060
Non-congestion period, 15.5 h	62775	15345	5580	418.5-554	223-279	279-418.5
Total, 24 h	521775	127545	46380	3478-4638	1855-2319	2319-3478

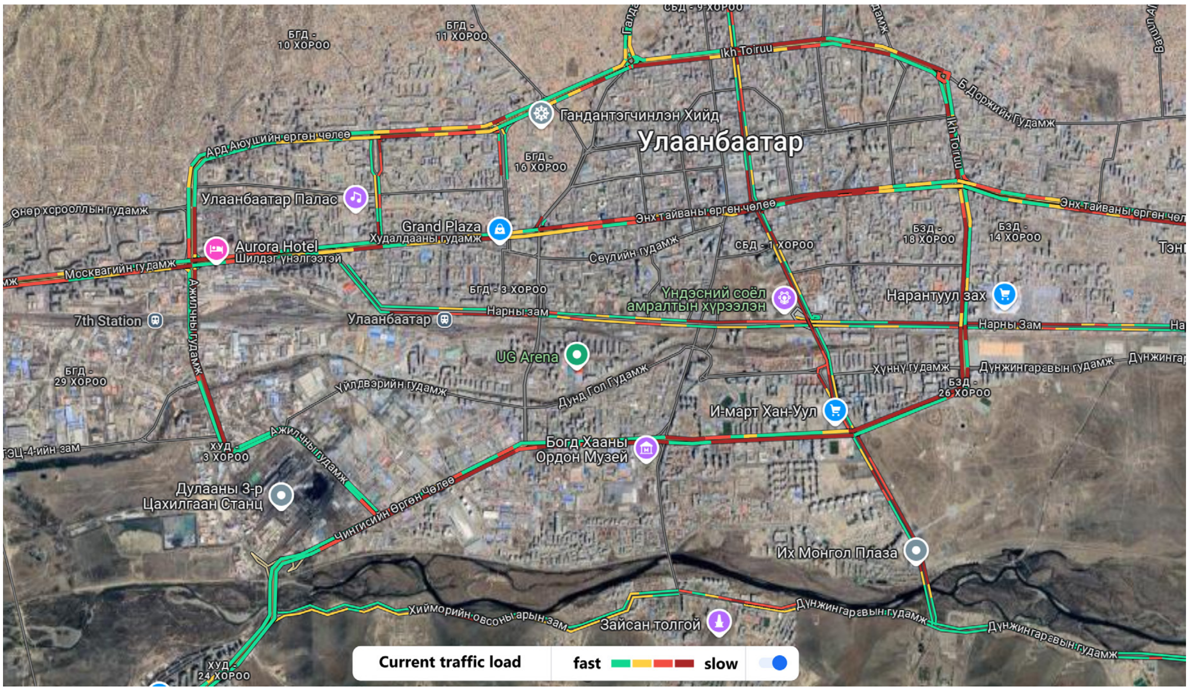


Fig. 16. Traffic congestion in the Bogd Khan Museum area [10]

Looking at the annual average of air pollution levels for 2021-2023, the following conclusions are drawn. It includes:

- The amount of sulfur dioxide decreased by 45% in the residential area and by 32.5% in the residential area, regardless of location.
- Carbon dioxide decreased by 11.5% in residential areas, and increased by 14% in 2022 and 7% in 2023.
- Total air pollution in residential areas in 2022 was 2-8% higher than in the 2 years of the study.
- The amount of $PM_{2.5}$ particles decreased by 36% in residential areas within 3 years, while it increased by 7% in residential areas in 2022 and decreased by 14% in 2023.
- Nitrogen dioxide was 2-9% higher in 2022, and decreased by 2-16% in 2023, regardless of location.
- PM_{10} particles increased by 2-10% in 2022 and decreased by 5-7% in 2023, regardless of location. In doing so, the height increased and decreased slightly in the residential area, while it increased by a small percentage and decreased by a large percentage in the residential area.

Table 6. Daily emissions of cars around Bogd Khan Museum amount of smoke

Type/substance	Carbon monoxide, CO	Nitrogen dioxide, NO_2	Hydrocarbon, CH	Sulfur dioxide, SO_2	Aldehyde CHO	Soot
During traffic, 8.5 h	2524500	617100	224400	46830-22440	8976-11220	11220-16830
Non-congestion period, 15.5 h	345262	84397	30690	2301-3069	1227-1534	1534-2302
Total, 24 h	2869763	701497	255090	19132-25509	10203-127754	12754-19132

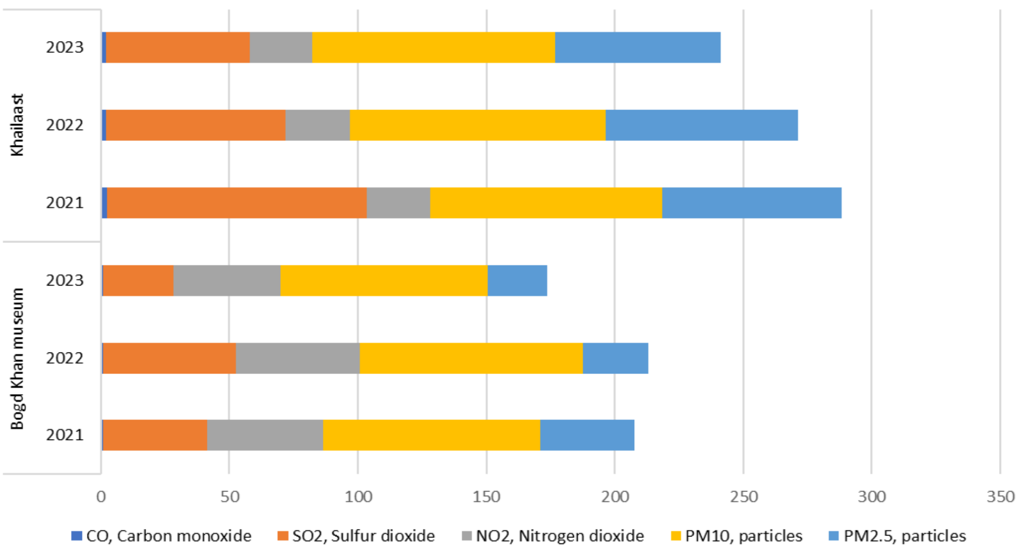


Fig. 17. Air pollution in 2021-2023, annual average

The decrease in the amount of sulfur dioxide is due to the ban on burning raw coal in the capital. Our findings indicate that the nitrogen dioxide level in the residential area is high even in the warm season, which is due to congestion and age of vehicles. The cleanest air time is between 15-17 h, which is due to the fact that those hours are the warmest hours of the day, in addition to the fact that there is less traffic during those hours, and outdoor cleaning services do not create mechanical dust. But our findings indicate that the high level of dust in the air pollution between 4-6 am is due to the fact that large vehicles travel a lot in the city at night and environmental cleaning services create dust it is possible. Fig. 17 shows air pollution in 2021-2023, annual average

Conclusion

More than 92% of the world's population lives in areas where air quality levels are above normal. Therefore, it is necessary to study the factors affecting air pollution and all kinds of ways to reduce pollution. One of the main problems facing our country is creating favorable living conditions in urban areas by reducing air pollution. In this research work, the influence of weather factors on air pollution in Ulaanbaatar city, as well as the main factors that pollute the air, were studied. The big data analysis led to the following conclusions. It includes:

- The most important weather factors affecting air pollution are location and wind direction.
- The amount of PM_{10} particles in the air is high even in summer.
- By banning the burning of raw coal in the capital, the amount of sulfur dioxide in air pollution has decreased by 32-45% since 2021. This is a great achievement and now it is necessary to identify other causes of air pollution and reduce the amount of other pollutants.
- The impact of air pollution on cancer incidence, particularly lung cancer, is growing.
- If the necessary data can be collected by proper sampling and prepared with gaps in the time series, the results of the analysis can be clearly defined more accurately.
- In the future, the quality of raw data should be improved using big data sampling methods.

We will continue with detailed data mining and analysis, as there are important useful values hidden in big data that can only emerge through very careful mining and analysis. Identifying the contributing factors to PM_{10} pollution, particularly in warmer months, may enable preventive actions, thereby promoting public health.

To further reduce air pollution, it is necessary to reduce the use of older cars and introduce methods to reduce traffic congestion in Ulaanbaatar city. It is also necessary to create conditions for the use of solar and non-burning power sources for housing in ger districts.

In addition, there is research that shows that the level of air pollution is tolerable when the pedestrian path is directly adjacent to the road and is 2.5-4 m away, or when there is grass or bushes. Therefore, to reduce the risk of children being more exposed to air pollution, street and road planning should be re-designed and more trees should be planted.

In addition, a study has begun collecting image data from cloud remote sensing [32-33] in Ulaanbaatar to estimate the amount of smoke.

Financial supports

This research was funded by the KOICA project “Capacity Building Project of School of ICT at MUST in Mongolia”.

Competing interests

The writers say they have no known conflicts of interest.

Acknowledgements

We would like to thank KOICA and the Weather and Environmental Numerical Modeling and Research Department of the Mongolian Meteorological and Environmental Analysis Department for their cooperation in providing research data.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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