The present work was submitted to the Faculty of Engineering

Temporal characteristics of air quality in Ulaanbaatar and its relationship with weather parameters

Bachelor Thesis

by

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Statutory Declaration

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

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I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Nalaikh, May 16,2022
Place, Date

Signature

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Acknowledgement

The educational opportunity I received at the German Mongolian Institute for Resources and Technology provided me with the opportunity to learn and enhance my profession. Not only did I receive a lot of skills and information from the study program, but I was also faced with the difficulty of living on my own and got a lot of insights, from which I learned more than I imagined.

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Abstract

Over the previous few decades, Mongolia has faced a significant increase in population growth, urbanization, and industrialization, as well as a significant increase in mining and automobile use. As a result, the types and number of air pollution emission sources have increased significantly, particularly in cities. During the winter season, Ulaanbaatar, the capital of Mongolia, has the greatest amount of air pollution in the world. However, due to a lack of air quality control, the city's air quality is deteriorating. In this study, the temporal characteristics of air quality during the recent seven years, from January 2014 to December 2020, and its relationship with weather parameters were studied by assessing and processing the hourly data. The average concentrations of CO, NO_2, PM10, PM2.5, SO_2, and O_3 pollutants have illustrated different variations during the study period. The Air Quality Index is calculated by using the Air Quality Assessment and Regulation of Mongolia. The mean AQI clearly showed a decreasing trend from 2017 to 2020. Although air quality has steadily improved over the last four years, further steps must be taken in order to protect the health of inhabitants and future generations.

1. Introduction

1.1. Background

The Mongolian region encompasses northeast and central Asia and has an area of 1,564,120 square kilometers [1]. The country has a population of around 3.279 million people and Ulaanbaatar city has a population of 1,639,172 people [2]. Ger (traditional dwelling) neighborhoods, where coal and wood are burnt for heat, have seen the most population development. These ger areas are thought to be Ulaanbaatar's primary source of particulate matter (PM) pollution. Vehicles are another source of air pollution in Ulaanbaatar, posing a significant threat to air quality.

Figure 1. Air Pollution in Ulaanbaatar city, 2022.

They have an impact on the urban environment not just through emissions, but also through displacing the soil and causing floating dust along highways, particularly unpaved roads. In the winter season, 60% of its population lives in ger regions, which often use raw coal and wood for heating and cooking [3]. Pollutants are released by a variety of sources, including over 200,000 ger households (most of which use small stoves), 3000 heat-only boilers (HOBs), four power plants, over 500 thousand cars, and other sources.

A substantial number of studies have indicated that meteorological circumstances impact atmospheric pollution in a variety of ways [4]. It was discovered that there were apparent seasonal and weekly variable features related to weather conditions for the concentration of air pollution. Meteorology's most essential purpose is to influence the dispersion, transformation, and removal of atmospheric pollutants from the atmosphere, which in turn impacts the temporal features and pollution levels of atmospheric pollutants.

A person's health is influenced by a variety of factors, including their lifestyle, diet, and environment. Various studies have shown that environmental air pollution has an impact on human health. Living in an environment with high levels of air pollution is harmful to the health of the population, particularly children.

According to the United Nations and the World Health Organization, 9 out of 10 people on the earth breathe polluted air, which kills 7 million people each year (World Air Quality Report 2021), 800 people every hour, and 13 people every minute [5]. This is three times the entire number of deaths caused by tuberculosis, HIV, AIDS, and malaria combined. Pneumonia, bronchitis, and chronic respiratory diseases are all caused by air pollution. Many diseases that are related to each other can be named here. Complications such as reduced lung function may arise as children grow older.

Outdoor air pollution is responsible for 29% of cardiovascular fatalities and 40% of lung cancer deaths in Ulaanbaatar city. These fatalities account for about 10% of overall mortality in the city [6].

The National Agency for Meteorology and Environmental Monitoring (NAMEM) and the Agency Against Air Pollution (AAAP) of the Municipality started evaluating air quality by using the air quality index (AQI), which is calculated based on ground monitoring of 24-hour average concentrations of pollutants. The air quality index (AQI) is a scale that goes from 0 to 500, with higher numbers indicating poorer air quality. Moreover, AQI is classified into six levels depending on specific scores: clean, satisfactory, less polluted, polluted, highly polluted, and very highly polluted. Since 2014, NAMEM has published daily AQI on a web platform (www.agaar.mn), offering a useful tool for the public, stakeholders, and researchers to evaluate the variance and temporal and spatial patterns of Ulaanbaatar city's air quality.

1.2. Aims of the study

In this bachelor thesis, daily air monitoring data from 14 air quality monitoring sites in Ulaanbaatar were gathered from January 2014 to December 2020 to investigate the temporal features of air quality and air pollutants particularly. The objectives of this study are to (1) evaluate the temporal patterns of air quality and air pollutants from 2014 to 2020, and (2) examine the influence of meteorological conditions on air pollution and quality. Detailed goals are as follows:

Goal 1: Describe the current situation

- Document and analyze previous studies regarding the temporal characteristics of air quality in Ulaanbaatar

Goal 2: Compare the air pollution situation in Ulaanbaatar for the last few years.

- Calculate air quality index (AQI)
- Analyze the temporal patterns of the air quality in Ulaanbaatar
- Relate the air quality to weather parameters

Goal 3: Discuss the findings

- Compare the results with previous studies
- Interpretation of the results
- Discuss the reasons for characteristics of temporal variations

2. State of the art

2.1 Air quality in Ulaanbaatar

Ulaanbaatar has risen to the top of the list of the world's most polluted cities. Because of its location, Ulaanbaatar has some specific attributes that make it apart from other polluted cities [7]. Ulaanbaatar is situated in a basin surrounded by mountains, and its latitude results in longer and colder winters than most other global capital cities. In winter, such topographical and geographical characteristics induce positive circumstances for the creation of inversion layers. When an inversion layer is maintained, air pollutants generated at ground level are unable to escape quickly, leading to severe pollution. When the air temperature in Ulaanbaatar initially fell below 0°C, the PM2.5 concentration surged and remained excessive throughout the winter. Although traffic congestion exists throughout the year, serious air pollution occurs only during the winter. As a result, it is mostly caused by particle pollution emitted by coal burning in the city, particularly in ger areas. The wind velocity was low during the winter, especially at night.

Because of the persistence of the Siberian high beyond mid-October, the maximum height of the ABL was less than 1 km, and the presence of a surface inversion layer led to higher PM2.5 concentrations at ground level.

At times, particle matter concentrations were found to be exceedingly high, with maximum PM10 concentrations of 1100 μg/m^3 and several days with concentrations above 300 μg/m^3 [8]. PM10 was dominated by coarse particles, whereas PM2 was high. During the winter months, five values were recorded, with PM2.5 levels frequently exceeding 100 μg/m^3. With such high particulate matter concentrations in the Ulaanbaatar metropolitan region, the exposed population is expected to suffer serious health consequences. During the winter, crustal materials and coal combustion sources dominated the fine fraction, adding significantly to particle concentrations. Crustal matter sources were discovered to be formed both locally (urban dust sources) and transferred to Ulaanbaatar from the west and northwest, especially during the dry and windy spring and fall months.

PM2.5 emissions were dominated by emissions from coal combustion sources, with two distinct source types identified: the first was identified as a high-temperature combustion source originating from power station emissions in Ulaanbaatar's western part, and the second was defined as coal combustion used for domestic heating during the cold season.

Particulate pollution is the most severe, and it is a key pollutant in Mongolian cities, according to this comprehensive evaluation of known research studies [9]. The origins and content of particulate matter in Ulaanbaatar have been thoroughly recorded in studies. A rise in NO_2 is previously known to be linked to an increase in vehicle numbers. Sulfur dioxide (SO_2) emissions are mostly caused by coal combustion and are also influenced by transportation.

2.2 Air Quality Standard

2.2.1. National Ambient Air Quality Standards by EPA

The Clean Air Act, last modified in 1990, mandates the EPA to establish National Ambient Air Quality Standards for six major pollutants that can harm public health (primary standards) and the environment (secondary standards). The standards of six pollutants established by EPA are listed in Table 1.

2.2.2 WHO Air Quality Guidelines

Since 1987, the World Health Organization (WHO) has produced health-based air quality guidelines on a regular basis to help governments and civil society in reducing human exposure to air pollution and its negative impacts. The WHO has produced revised global air quality recommendations, which are not legally enforceable but can be used to improve law and policy in the Member States. The purpose of these guidelines is to assist reduce levels of air pollutants in order to alleviate the significant health burden caused by air pollution exposure globally. In 2021, the WHO adjusted its recommendations on six criteria air pollutants (PM, O_3, NO_2, SO_2, and CO) since 2005. The guidelines are summarized in Table 1.

Table 1. Permissible levels of air pollutants in the National Ambient Air Quality Standards of EPA, USA, and WHO Air Quality guidelines

Pollutant	**Average measurement time**	**The permissible level of pollutant, EPA**	**Air quality guideline, WHO**
Sulfur dioxide (SO_2)	1 hour	196 μg/m^3	-
	24 hours	-	40 μg/m^3
Carbon monoxide (CO)	1 hour	40000 μg/m^3	-
	8 hours	10000 μg/m^3	-
	24 hours	-	4 μg/m^3
Nitrogen dioxide (NO_2)	1 hour	188 μg/m^3	-
	1 year	100 μg/m^3	10 μg/m^3
	24 hours		25 μg/m^3
Ozone (O_3)	8 hours	140 μg/m^3	100 μg/m^3
PM10 particles	24 hours	150 μg/m^3	45 μg/m^3
	1 year		15 μg/m^3
PM2.5 particles	24 hours	35 μg/m^3	15 μg/m^3
	1 year	15 μg/m^3	5 μg/m^3

2.2.3. The Air quality standard of Mongolia

The Mongolian Air quality standard and general technical requirements called “MNS 4585:2016 Air quality. General technical requirements.” were approved in 2016 [4]. The goal of this standard is to establish permissible levels for common pollutants in ambient and indoor air to provide a healthy and safe living environment for people while also maintaining ecological balance. Some important definitions and permissible levels of air pollutants (Table 2) are provided below. The Mongolian standard is way too higher than the permissible levels of EPA and WHO Air Quality guidelines.

Air Quality: Complex physical, chemical, and biological properties of air to indicate compliance with air quality standards.

Ambient air: A gas combination in its natural state that is one of the environment's components.

Air Pollution: Pollutant concentrations directly discharged into the atmosphere or produced as a result of physical or chemical interactions surpass air quality guidelines.

Air Pollutants: Physical, chemical, biological, or radioactive substances and their mixtures that pollute the surrounding air.

PM10 particles: Particles in the air that are fewer than 10 micrometers in aerodynamic equivalent diameter.

PM2.5 particles: Particles in the air that are fewer than 2.5 micrometers in aerodynamic equivalent diameter.

Air quality standard: Tolerable limits for pollutant release into the environment without causing adverse effects on human health or the ecosystem.

Indoor air: Air inside the building, which is structurally isolated from the outside environment.

Table 2. Maximum permissible levels of common pollutants in the air MNS 4585:2016

Pollutant	**Average measurement time**	**Unit**	**Permissible level**
Sulfur dioxide (SO_2)	20 mins	μg/m^3	450
	24 hours		50
	1 year		20
Carbon monoxide (CO)	20 mins	μg/m^3	60000
	1 hour		30000
	8 hours		10000
Nitrogen dioxide (NO_2)	20 mins	μg/m^3	200
	24 hours		50

	1 year		40
Ozone (O_3)	8 hours	μg/m^3	100
Total particles	20 mins	μg/m^3	500
	24 hours		150
	1 year		100
PM10 particles	24 hours	μg/m^3	100
	1 year		50
PM2.5 particles	24 hours	μg/m^3	50
	1 year		25
Lead (Pb)	24 hours	μg/m^3	1
	1 year		0.25
Benzene-a-pyrene ($C_{20}H_{12}$)	24 hours	μg/m^3	0.001

It should be noted that the current Mongolian air quality standard is dedicated to outdoor air quality, but not indoor air quality including some physical parameters and carbon dioxide only. The Mongolian version of the "MNS 4585:2016 Air quality. General technical requirements." standard is attached in Appendix 4.

3. Material and Methods

3.1 Air quality monitoring sites

Through the air quality monitoring network, which consists of the NAMEM and the Air Pollution Reduction Department of Ulaanbaatar (APRD), a total of 14 sites are illustrated in Figure 1. At those monitoring sites, sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, particulate matter (PM10 and PM2.5), and weather parameters are monitored. The number of measurement parameters varies depending on the location. Table 3 shows the air quality monitoring sites' names, locations (longitude, latitude), and classification with measured parameters.

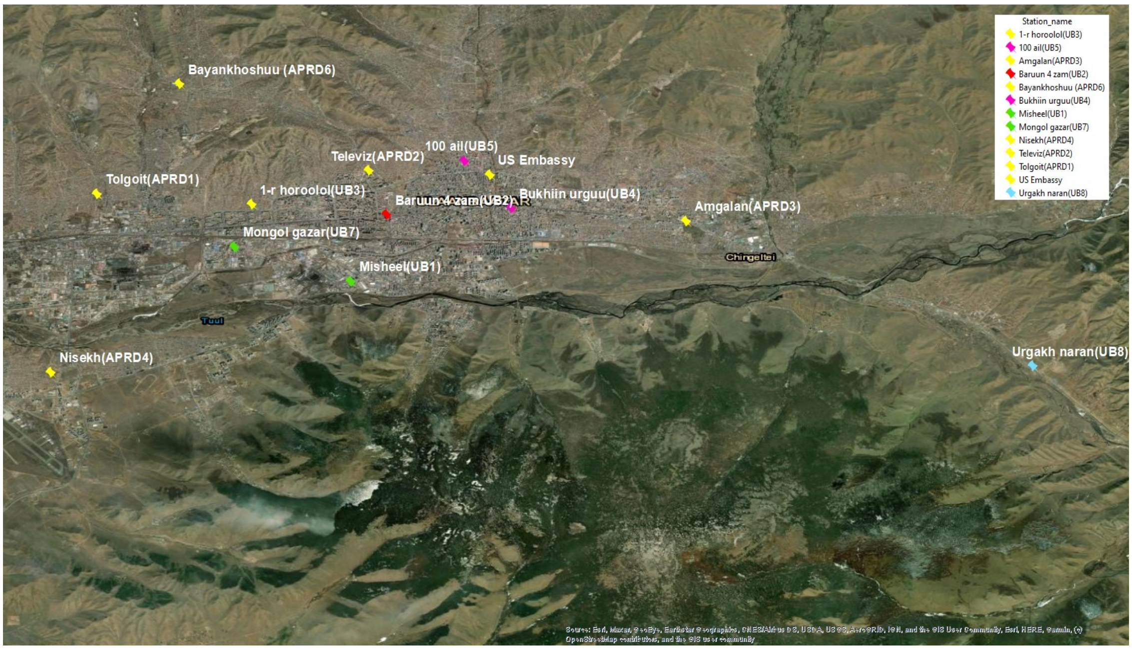


Figure 2. Air Quality monitoring sites in Ulaanbaatar. Yellow marks indicate the sites of the ger area. Green marks indicate the sites of the industrial area. Pink marks indicate the sites of the residential area. The red mark indicates the site of the roadside area. Blue marks indicate the sites of the remote area.

14 air quality monitoring stations are provided and located in various surroundings as below:

- ger (UB3, UB12, APRD1, APRD2, APRD3, APRD4, APRD6, and US Embassy),
- residential (UB4 and UB5),

- industrial (UB1 and UB7),
- roadside (UB2) and
- remote areas (UB8).

Valid data are marked as a dark circle and not valid data are marked as – in Table 3.

Table 3. List of the air quality monitoring sites of Ulaanbaatar with locations, classifications, and measured parameters.

Site name (ID)	Area	Location (longitude N, latitude E)	Measuring parameters						
			Weather parameters	SO_2	NO_2	CO	O_3	$PM2.5$	$PM10$
Michael (UB1)	Industrial	106.8822, 47.894	●	●	●	●	●	-	●
Baruun 4 zam (UB2)	Roadside	106.8945, 47.9155	●	●	●	●	●	-	●
1-r horoolol (UB3)	Ger	106.8478, 47.9188	●	●	●	●	●	-	●
Bukhiin urguu (UB4)	Residential	106.9375, 47.9176	●	●	●	●	●	●	●
100 ail (UB5)	Residential	106.9214, 47.933	●	●	●	●	●	-	●
Mongol gazar (UB7)	Industrial	106.8419, 47.9051	●	●	●	●	-	-	●
Urgakh naran (UB8)	Remote	107.118, 47.8665	●	●	●	●	●	-	●
Selbe (UB12)	Ger		-	●	●	-	-	●	●

Tolgoit (APRD1)	Ger	106.7944, 47.9223	●	●	●	●	●	●	●
Televiz (APRD2)	Ger	106.8883, 47.9298	●	●	●	●	●	●	●
Amgalan (APRD3)	Ger	106.998, 47.9135	●	●	●	●	●	●	●
Nisekh (APRD4)	Ger	106.7783, 47.8644	●	●	●	●	-	●	●
Bayankhoshu u (APRD6)	Ger	106.823, 47.9578	●	-	-	-	-	●	●
US Embassy	Ger	106.9312, 47.9309	-	-	-	-	-	●	-

3.2 Data

The concentrations of all the six pollutants (CO, NO_2, PM10, PM2.5, SO_2, and O_3) were collected from the air quality monitoring stations during the study period. The below values (Figure 3) are averaged over all the air quality monitoring stations in general. The overall trends of the air pollutants' concentrations, maximum, minimum, mean, median, and missing values of each pollutant are shown in this figure. From this figure, PM2.5 and PM10 pollutants shows a decreasing trend from 2017 to 2020. This may be due to the ban on raw coal combustion in ger areas from 2018.

The trends of the pollutants which are classified into the categorization of areas such as ger, industrial (in), remote (rem), residential (res), and roadside (road) are illustrated and attached in Appendix 1.

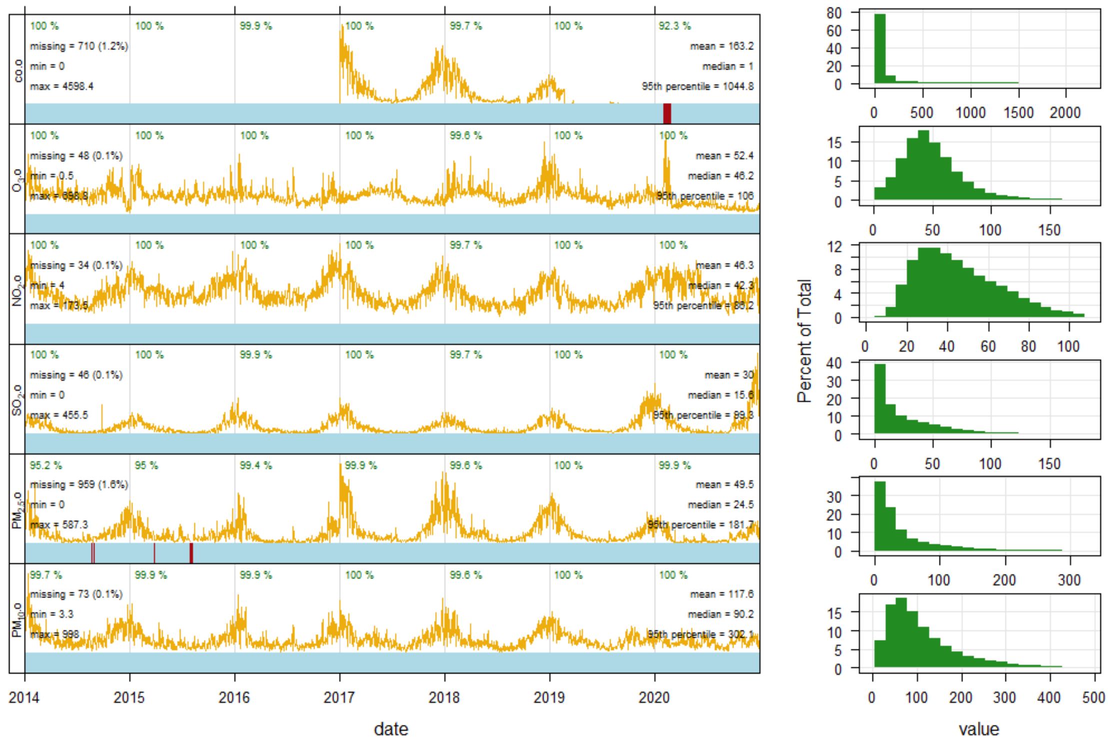


Figure 3. The trends of air pollutants concentration for the study period in Ulaanbaatar city, 2014 to 2020.

Figure 4 shows the trends of weather parameters such as temperature, wind direction and relative humidity for the study period in Ulaanbaatar city from 2014 to 2020. As Figure 3, maximum, minimum, mean, median and missing values are calculated and shown below figure. As for the wind direction figure, the values are missing from 2014, 2015, 2016 and 2020. The existing values are plotted, and the trend doesn't show any increasing or decreasing trend, it only shows the static constant trend. This is because the wind is breezing in any direction at any time, not like the temperature or humidity.

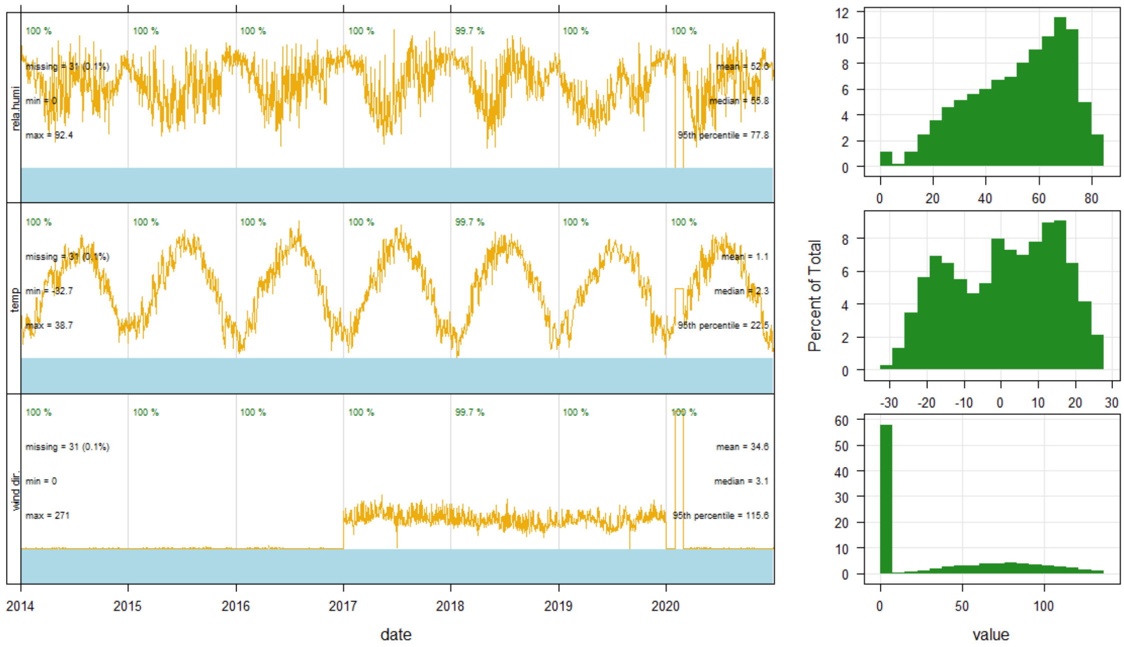


Figure 4. The trends of temperature, wind direction and relative humidity for the study period in Ulaanbaatar city, 2014 to 2020.

3.3 Air quality index (AQI)

The Air quality index has been used in Mongolia since 2011 and updated in 2014 and 2018. The Air Quality Assessment and Reporting regulation (A/387 order by the Minister of Environment and Tourism) of Mongolia was approved in 2018. The purpose of the General Regulation for Assessing and Reporting Air Quality by Air Quality Index is to provide accessible air quality information to the public in compliance with the Law on Air and the standard "MNS4585:2016 Air Quality. General Technical Requirements".

According to this regulation, the air quality index is a quantitative indicator that compares the concentration of pollutants in a metropolitan area's surrounding air to the value of the pollutant concentration that impacts human health. Air quality indexing and reporting will assist in identifying and reporting the impact of air pollutants on the health of the urban population, providing public health advice on air pollution protection, and planning and implementing air pollution preventive measures. The air quality index must be computed for at least three common pollutants in the atmosphere while considering the air quality monitoring program. These include sulfur dioxide, nitrogen dioxide, PM10, PM2.5, carbon monoxide, and ozone.

Air quality is classified into six levels by the Air Quality Index, and Table 4 shows the numerical, color, and human health effects of the corresponding indices for each level.

Table 4 Air Quality Index, health effects

Air Quality Index	**Air Quality Classification**	**Notation (by color)**	**Health effects**
0-50	Clean	Green	No adverse effects on human health.
51-100	Satisfactory	Yellow	Meets air quality standards. However, some hypersensitive people may show signs of respiratory illness.
101-200	Less polluted	Orange	Adverse effects on the health of hypersensitive people. People with chronic cardiovascular and respiratory diseases, especially bronchial asthma, are more likely to be affected.
201-300	Polluted	Red	Adverse effects on human health begin to appear. Adverse effects on the health of hypersensitive people can be severe.
301-400	Highly polluted	Purple	Prolonged outdoor exposure can have significant adverse effects on human health.
401-500	Very highly polluted	Brown	Adverse effects on human health

The air quality index is calculated for each air pollutant using the following formula.

$$I = \frac{I_h - I_l}{C_h - C_l}(C - C_l) + I_l \qquad \text{Eq. (1)}$$

where:

I – AQI,

C – the pollutant concentration,

C_l – the lower concentration breakpoint,

C_h – the higher concentration breakpoint,

I_l – the lower index breakpoint corresponding to C_l,

I_h – the higher index breakpoint corresponding to C_h.

Table 5 shows the upper and lower values of the limits for human health exposure to the 1- and 24-hour average concentrations of each pollutant.

Table 5 Limit values corresponding to the air quality index

AQI	**The limit value of the concentration that affects human health /Breakpoint/**					
	$SO_2, \mu g/m^3$ /1h/	$NO_2, \mu g/m^3$ /1h/	$PM10, \mu g/m^3$ /24h/	$PM2.5, \mu g/m^3$ /24h/	$CO, mg/m^3$ /1h/	O_3, $\mu g/m^3$ /1h/
0-50	0-100	0-100	0-50	0-35	-	-
51-100	101-300	101-200	51-100	36-50	11-30	-
101-200	301-800	201-700	101-300	51-150	31-60	250-400
201-300	801-1600	701-2000	301-420	151-250	61-90	401-800
301-400	1601-2100	2001-3500	421-500	251-350	91-120	801-1000
401-500	2101-2620	3501-3840	501-600, 601<	351-500, 501<	120-150	1001- 2000

The highest numerical value of the index for each pollutant shall be the current air quality index. For example, if the air quality index is 110 for sulfur dioxide, 95 for nitrogen dioxide, and 150 for PM10, the overall air quality index is 150 and the air quality is considered to be slightly polluted.

4. Results and Discussion

4.1. General temporal characteristics of air pollutants in Ulaanbaatar

The time series of the daily mean CO, NO_2, PM10, PM2.5, SO_2 and O_3 concentrations are plotted in Figure 5 for the study period. The concentrations are averaged over the air quality monitoring stations. In general, all the pollutants have shown different characteristics during those 7 years according to this figure. For instance, a clear increase in SO_2 and a clear decrease in CO are observed. As a CO pollutant, data is not observed during 2014-2017 and 2019-2020, the concentrations are clearly higher than other pollutants. The highest was 4500 $\mu g/m^3$ in 2017 and the lowest was 2000 $\mu g/m^3$ in 2019, which shows a clear decrease in CO concentration. As a NO_2 pollutant, the graph is constant during the study period and the values are showing the least values of all the pollutants. As a PM10 pollutant, the concentrations became slightly less from 2014 to 2020 and the ratio is 1.11. As a PM2.5 particle, the mean values showed an increase (approx. 800 $\mu g/m^3$) in 2017 and then decreased to 200 $\mu g/m^3$ in 2020. As an O_3 pollutant, the maximum value is 700 $\mu g/m^3$ in the 2018-2019 winter, the mean concentrations are slightly higher in wintertime.

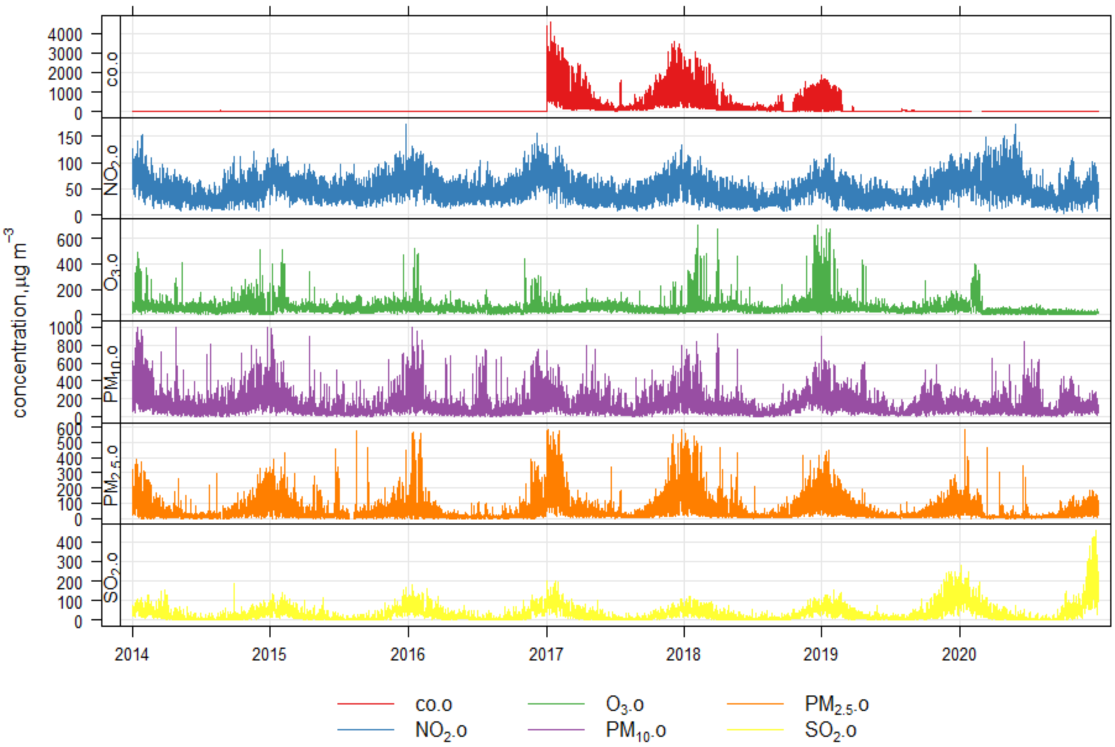


Figure 5 Time series of the daily average CO, NO_2, PM10, PM2.5, SO_2 and O_3 concentrations for the period of January 2014 - December 2020. The concentrations are averaged throughout the air quality monitoring stations.

Figure 6 shows the weekly, hourly, monthly, and daily variations of all the six air pollutant concentrations (CO, NO_2, O_3, PM2.5, PM10, and SO_2) in general. Because of the higher amount of concentrations of CO and PM10 pollutants, Figure 6 is divided into 2 separate figures. From the mean hourly graph, the maximum value is a CO concentration of 225 μg/m^3 at 11 pm and the least value of CO is 70 μg/m^3 at 5 pm, which shows a falling off in the daytime and an increase in the nighttime. The concentrations increased throughout the weekdays, according to the day of the week graph. However, there was a modest decline in weekends. According to the weekly graph, the average maximum value at 9 am on weekdays is between 200-250 μg/m^3, but the average maximum value of this time on weekends is between 150-200 μg/m^3, which indicates a clear decrease. We may conclude that the issue is related to automobile emissions on working days.

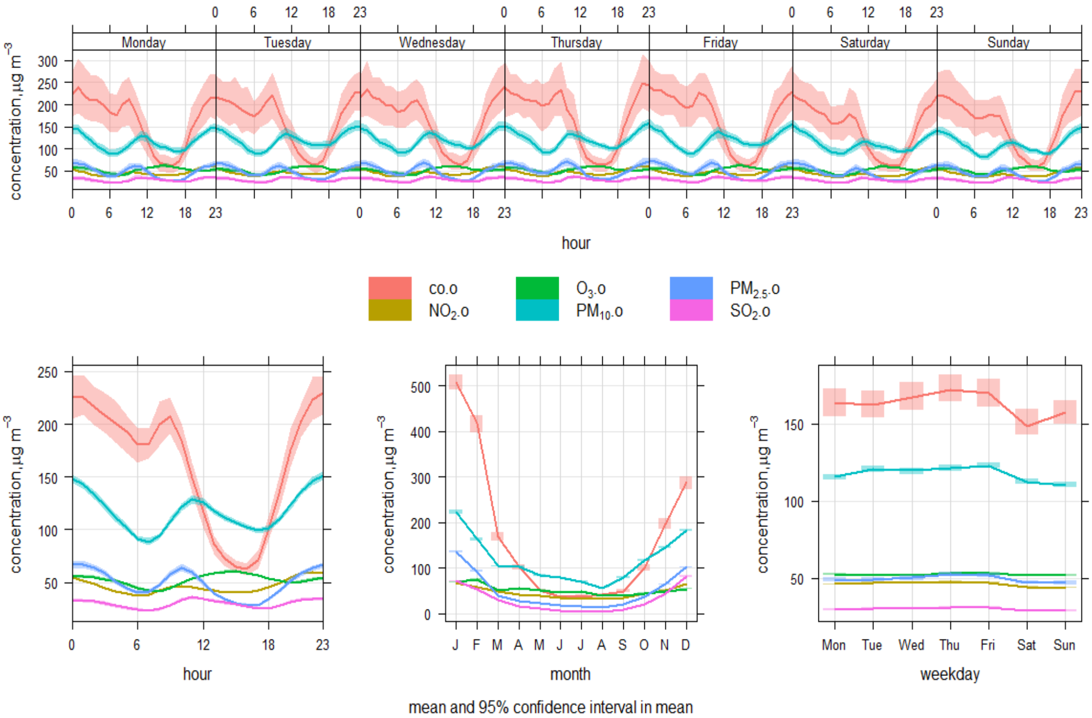


Figure 6. Time series of hourly, daily, monthly mean variations of all the pollutants. (timeVariation)

Figure 7 shows the time series of hourly, daily, and monthly mean variations of the pollutants CO and PM10. Only the concentrations of CO pollutant are higher at 6 am compared to the other pollutants, its maximum value of the day is around 225 μg/m^3 at midnight, and its minimum value of the day is around 60 µg/m^3 from 3 pm to 5 pm and the ratio is 3.75. The mean values are at their maximum in the winter season and their minimum in the summer season. The winter and summer average values of CO pollutants are around 333.3 µg/m^3 and 50 µg/m^3 respectively. The maximum value of PM10 did not exceed 150 µg/m^3 from the hourly and weekly graphs. From the daily graph, both pollutants' mean values are higher on working days and lower at weekends. But, as a pollutant CO, the highest value is on Thursday, the lowest is on Saturday, and the ratio is 1.13. As a pollutant PM10, the highest value is on Friday, the lowest value is on Sunday, and the ratio is around 1.14. The ratio of these 2 pollutants is relatively the same.

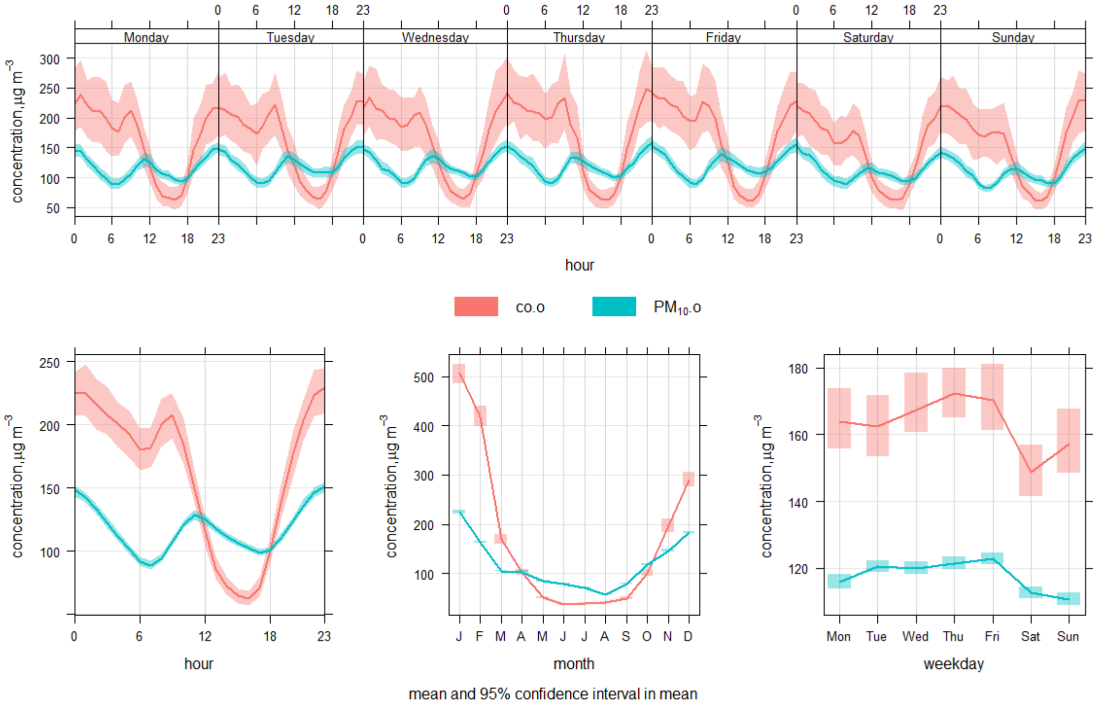


Figure 7. Time series of hourly, daily, weekly mean variations of CO, PM10 pollutants.

Figure 8 depicts the illustration of time series of hourly, daily, and weekly variations of SO_2, PM2.5, O_3, and NO_2. Hourly variations of SO_2, PM2.5, PM10, O_3, and NO_2 show 'W'-like features having two minimums around 6 am and 6 pm, and two maximums around 12 am and 11 am to 2 pm. The mean value of pollutant O_3 seems like the most constant value in general. On the other hand, the mean values of O_3 are highest in a daily mean graph, but it is still constant. SO_2 values are the lowest of all the pollutants in every graph. In general, all the pollutants' mean values are constant during the week except for the PM2.5 pollutant. The maximum value of PM2.5 is around 52.5 µg/m^3, the min value is around 47 µg/m^3, and the ratio is 1.12. The daily mean values of PM2.5 pollutants exceeded the national standards of Mongolia which is 50 µg/m^3 from Wednesday to Friday. The mean values are found to be greater in the winter and lower in the summer. The maximum value is around 150 µg/m^3 in January and the minimum is around 20 µg/m^3 in August, and the ratio is 7.5. The NO_2 concentration figure is the average of them all and it has 2 peaks during 6 am and 6 pm and the maximum value is 60 µg/m^3 around 11 pm in the hourly graph. The average values are constantly rising during working days and then fell off slightly at weekends. But, the difference between these increases and decreases is not that great in a daily graph.

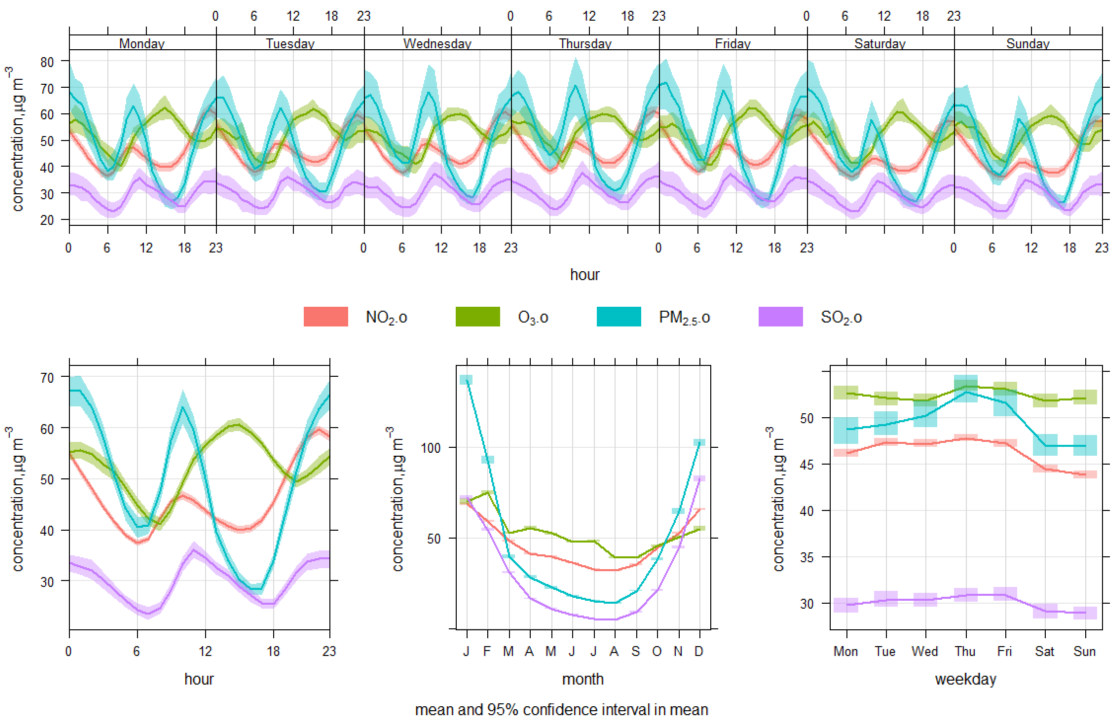


Figure 8. Time series of hourly, daily, and monthly mean variations of the pollutants SO2, NO2, O3, and PM2.5.

4.2 Temporal characteristics of Air Quality

The overall hourly Air Quality Index (AQI) was calculated over the air quality monitoring sites and plotted as time series generally in Figure 9. Equation 1 is used for the calculation of AQI from the air pollutants data. The total AQI reached its highest value during the research period in 2017-2018, indicating the worst air quality in that period. According to the figure, the AQI was the best in the 2016 summer. The AQI clearly shows the seasonal variations.

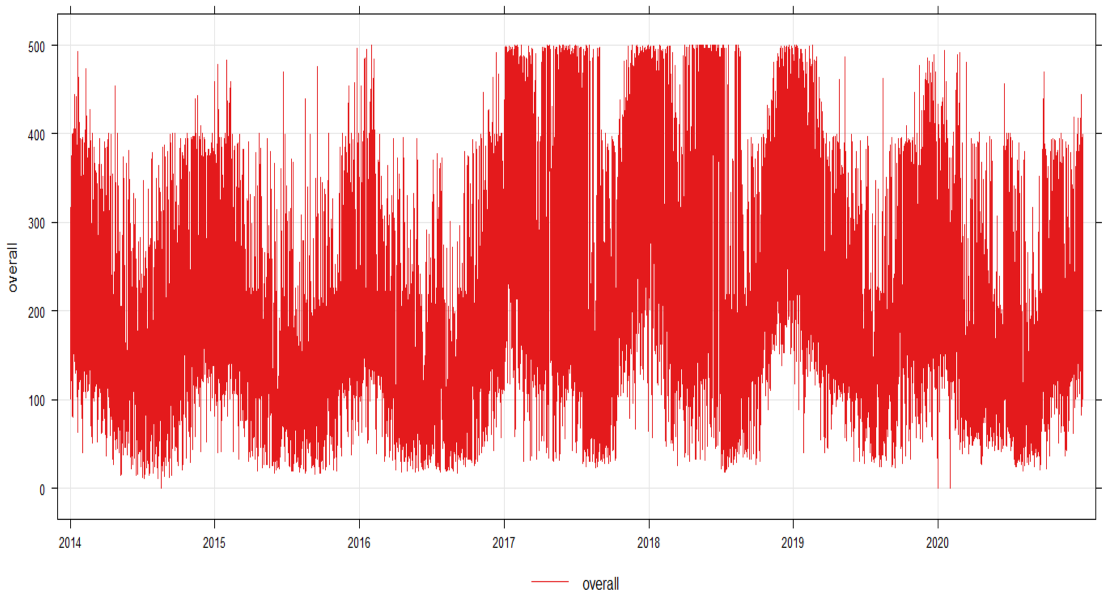


Figure 9. Time series of overall hourly AQI data for the period of 2014-2020. The AQI calculated over the air quality monitoring stations

The time series of overall monthly mean AQI data are shown in Figure 10. The AQI averaged over the air quality monitoring sites monthly. The greatest value is in 2017, when the AQI suddenly climbed from 2016 to 2017, then gradually decreased year by year. However, there is a noticeable decline from 2019 to 2020. Air pollution in Ulaanbaatar city has tended to worsen throughout those years due to raw coal usage [3]. As a result, the AQI has skyrocketed in 2017. To solve this issue, according to Governmental Resolution No. 62 issued in 2018, the use of raw coal in six central districts of Ulaanbaatar has been replaced with the consumption of briquette fuel for the improvement of air quality. The air quality improved significantly once the consumption of raw coal was prohibited. Due to prohibition on this matter, a clear decrease has shown from 2017 to 2020 winter.

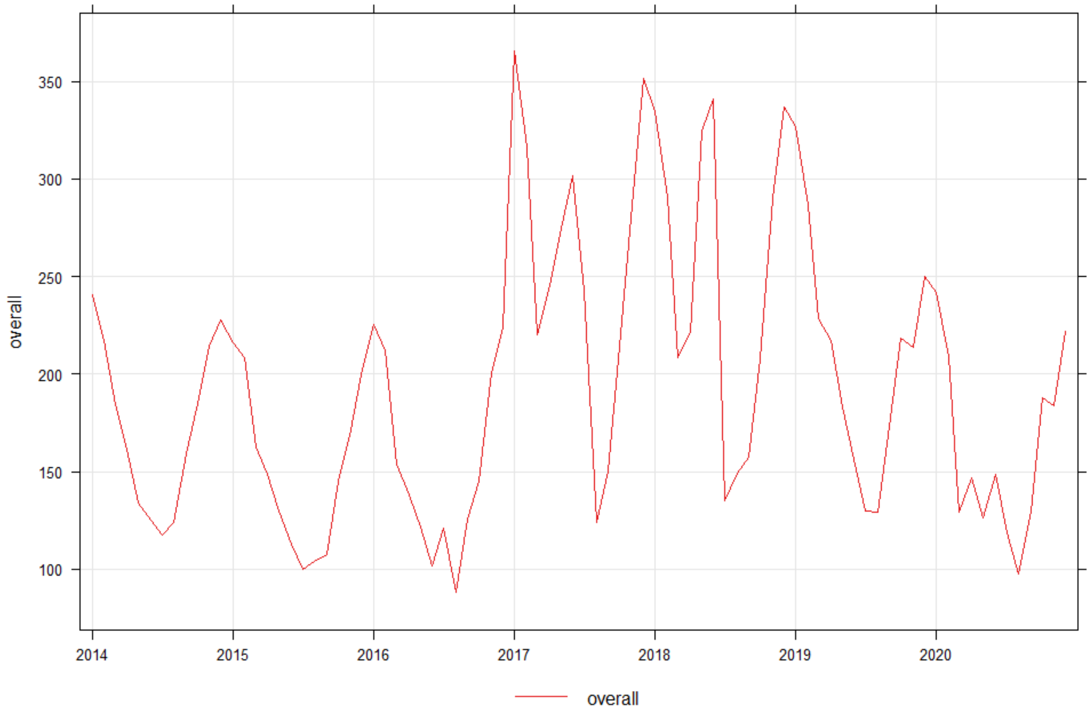


Figure 10. Time series of overall monthly AQI data for the period of 2014-2020. The AQI calculated over the air quality monitoring stations. (timePlot)

Figure 11 depicts a time series plot of hourly, daily, and monthly average fluctuations in overall mean AQI data. The total AQI was measured across all air quality monitoring sites. There is a difference between working days and weekends from the weekly graph, as shown in Figure 6. The maximum occurrence time is 220 μg/m^3 at 11 pm, the minimum occurrence time is 160 μg/m^3 at 6 am, and the ratio is 1.375. This means that the AQI is at its worst at night. In the average monthly graph, the AQI value is greatest in January, steady from March to June, then drops in August and rises in December. It demonstrates that the AQI is rather excellent in the spring, summer, and fall seasons, but significantly worse in the winter. In a day of the week graph, the total AQI value rises steadily from Monday to Friday, then falls drastically on Saturday. As mentioned earlier, this sudden drop is related to vehicle emissions, stoves of gers, and electricity use during nighttime. The electricity cost is much lower at night than during daytime usage which is a discount on nighttime electricity tariff, a part of the air pollution reduction program.

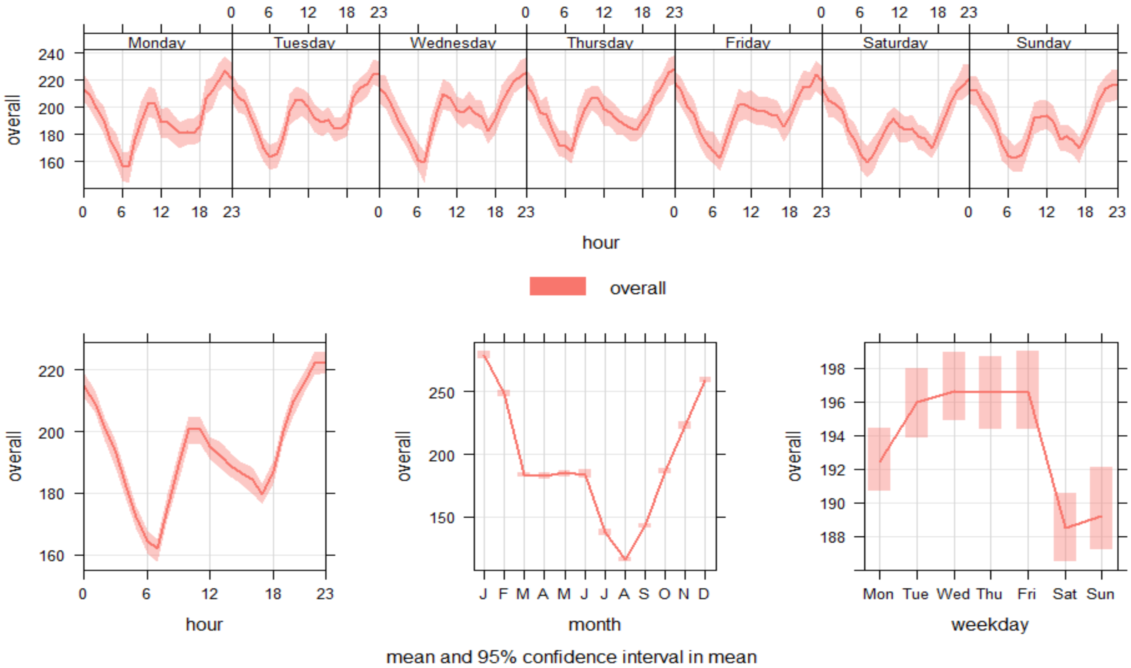


Figure 11. Time series of hourly, daily, monthly mean variations of overall mean AQI. The AQI averaged over the air quality monitoring stations. (timeVariation)

The overall AQI has been categorized by all of those pollutants. This categorization is calculated by using the Air Quality Assessment and Regulation of Mongolia methods, equations, and tables. The percentage of pollutants which determines AQI is illustrated in a bar chart in Figure 12. PM10 makes up the majority (60.8%) followed by PM2.5. The percentage of PM2.5 is nearly 2 times less than PM10 (32.4%) and the other pollutants (SO_2, CO, O_3, and NO_2) account for the remaining percentages. According to the graph, PM10 accounted for the majority of AQI readings, indicating that PM10 pollutant concentrations far exceed the healthy level than those of other pollutants making up the unhealthy level for human health. The pollutant SO_2 has the lowest value of them all, the ratio of the percentage of PM10 and SO_2 is 164.35. This PM10 pollutant emission is due to raw coal consumption of household stoves in ger areas.

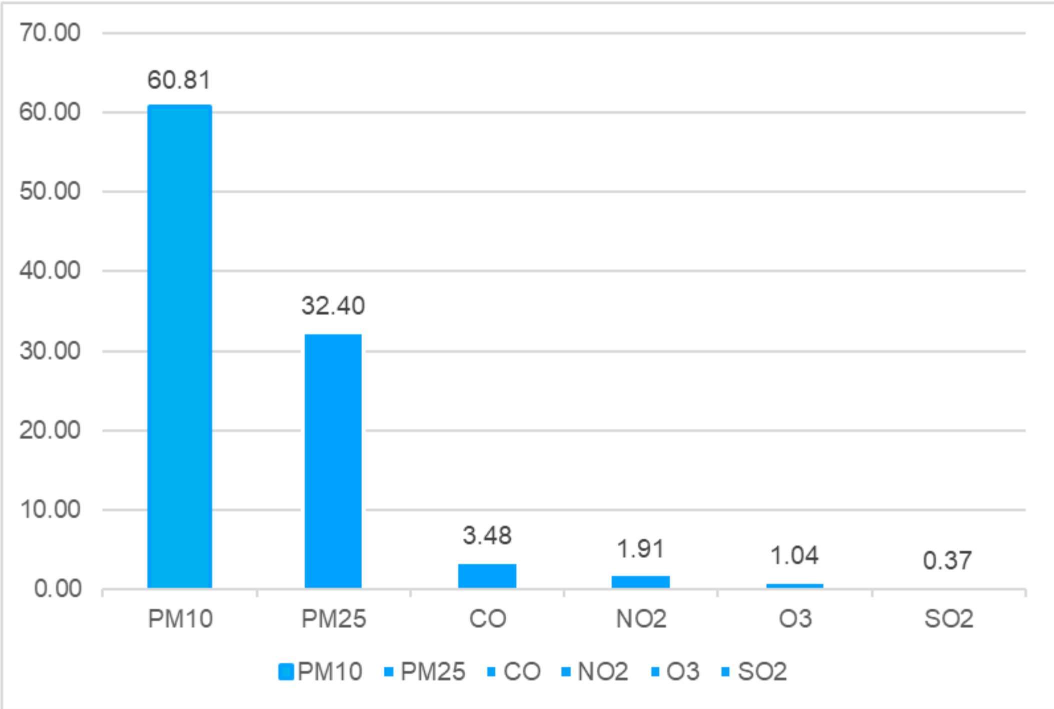


Figure 12. The percentage of pollutants within the overall AQI

Figure 13 shows the variations in AQI by year and hour of the day for 2017-2020. The mean AQI is displayed hourly on the y-axis, monthly on the x-axis, and yearly on the y-axis in this figure. Unlike previous graphs, this graph shows AQI data only from 2017 to 2020 since our assumption excludes data from 2014 to 2017 due to a lack of measurement data. The trends of overall mean AQI values for the study period from 2014 to 2020 are attached in Appendix 2. From this figure, the AQI is bad in the morning and night, but the best during the working hours and from midnight till dawn if we see from hourly graph more detailed. As the PM10 and PM2.5 particles make up the majority in the calculation of AQI, the AQI is unexpectedly poorer and marked in purple (300-400) in the May-June of 2017-2018 (compared to 2019-2020). This is due to spring dust occurrences as well as a shortage of precipitation throughout these months. There are almost no green marked boxes in this graph. But, in the 2020 summer, there are a few days of having good AQI.

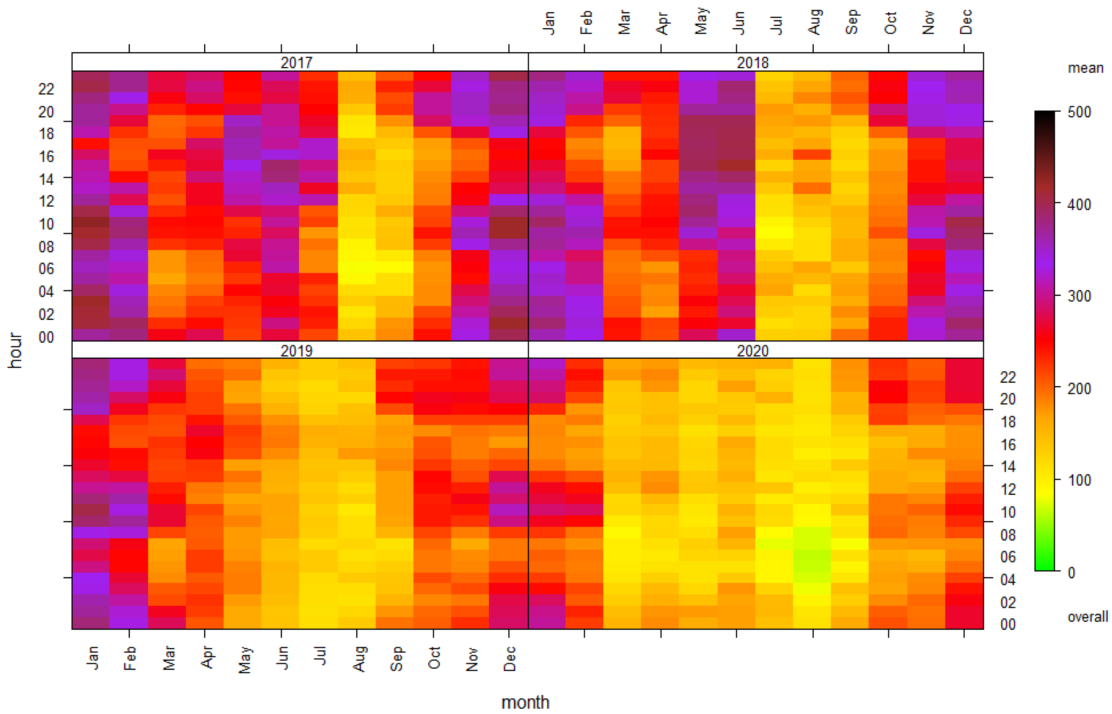
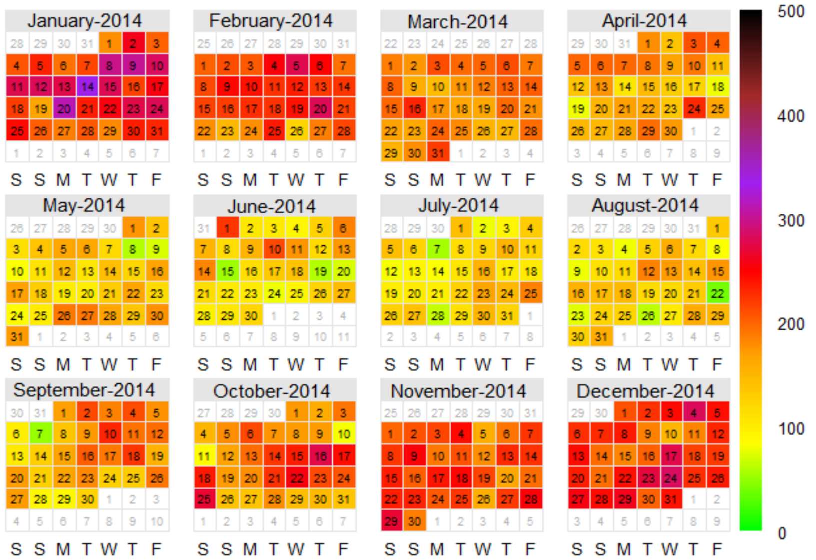
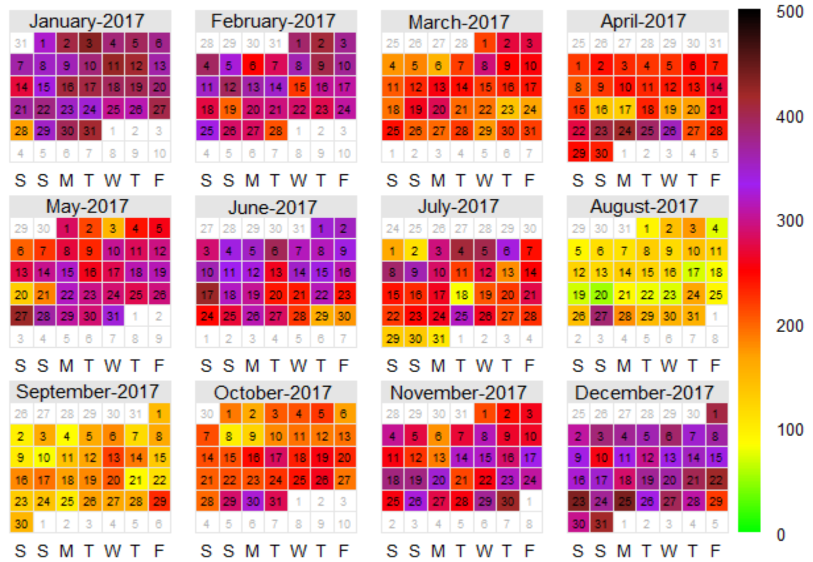


Figure 13. Variations in AQI by year and hour of the day for 2017-2020. (trendLevel)


January-2014
February-2014
March-2014
April-2014
May-2014
June-2014
July-2014
August-2014
September-2014
October-2014
November-2014
December-2014
S S M T W T F
500
400
300
200
100
0


January-2017
February-2017
March-2017
April-2017
May-2017
June-2017
July-2017
August-2017
September-2017
October-2017
November-2017
December-2017
S S M T W T F
500
400
300
200
100
0

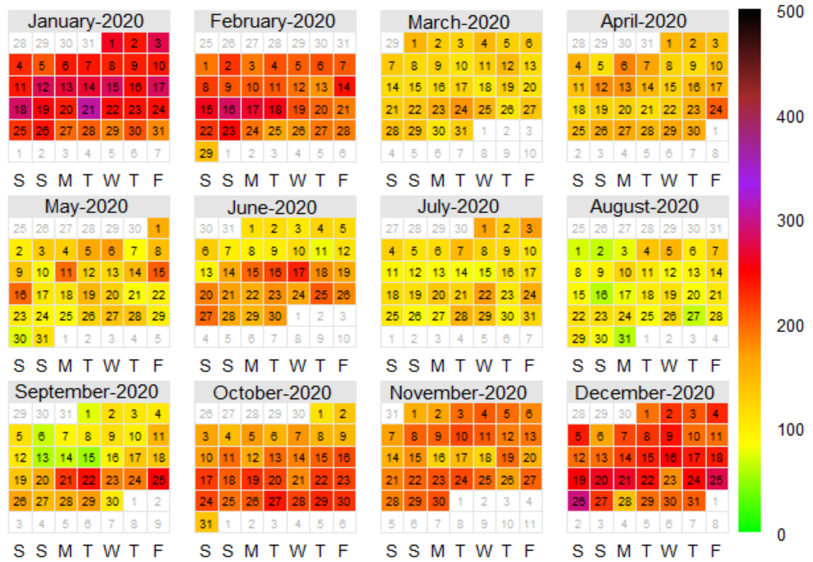

January-2020
February-2020
March-2020
April-2020
May-2020
June-2020
July-2020
August-2020
September-2020
October-2020
November-2020
December-2020
S S M T W T F
500
400
300
200
100
0

Figure 14. Daily mean values of AQI a). of 2014 b). of 2017 c). of 2020.
(calendarPlot)

The daily mean values of overall AQI for 2014, 2017, and 2020 are shown in the calendar chart using a color graduation corresponding levels of AQI categories (0 green to 500 brown) in Figure 14. The daily mean values of overall AQI for 2015,2016,2018 and 2019 are attached in Appendix 3. The AQI values are much higher in 2017 (Figure 14b) and marked in mostly purple compared to the other two charts. The daily AQI values exhibit an increasing trend from 2014 to 2017 and a decreasing trend from 2017 to 2020. In Figure 14c, there are very few higher AQI values marked in purple compared to Figure 14a. According to the Air Quality Assessment and Regulation of Mongolia, the AQI values and purple marks are indicating the classification of the very unhealthy category in 2017. On the other hand, as mentioned before, there is a decreasing trend in AQI values, which indicates better air quality. Especially, in the 2017 to 2020 winter, the AQI values fell from 300-500 to 200-300 drastically. This is also due to the banning of raw coal consumption. From all three charts, the air quality is much better in July and August which indicates the classification of good to moderate air quality.

4.3. The relationship between air quality and weather parameters

Weather conditions have a significant impact on the ambient air quality of a city [10]. Temperature, relative humidity, wind speed, and direction are regarded as key elements because they may impact the dispersion process, removal processes, and particle production in the atmosphere, and so play a considerable role in limiting air pollution concentrations. Meteorological influence has been addressed widely in several studies in Ulaanbaatar (Wang 2017). Table 6 shows the summary statistics of averaged Air Quality Index, wind direction, temperature, and relative humidity yearly from 2014 to 2020. The AQI value is the highest in 2017 and the lowest in 2015, which indicates the air quality was better in 2015 and worst in 2017. The AQI value has increased by 72% from 2015 to 2017, which shows the poorer air quality. However, a clear decrease has been shown from 2017 to 2020. The AQI has decreased by 38% from 2017 to 2020. Relative humidity also decreased by 8.95% from 2017 to 2020. Wind direction has increased by 46 % from 2017 to 2020. From this table, a high negative correlation is clearly shown between the AQI value and wind direction.

Table 6. The AQI and weather parameters' mean values yearly, 2014-2020.

Year	**AQI**	**Wind Direction, degrees**	**Temperature, Celsius**	**Relative Humidity, %**
2014	173.3	159.449	0.910	52.581
2015	149.2	164.909	1.424	51.814
2016	153.7	163.417	0.399	55.744
2017	257.1	88.693	1.336	54.781
2018	249.6	109.940	0.768	55.168
2019	208.8	116.654	1.031	48.267
2020	159.5	164.630	1.873	49.877

Figure 15 illustrates the correlation between the average AQI and average wind direction in degrees yearly from 2014 to 2020. The trendline of this figure shows a high negative correlation between the index and the wind direction. The wind direction is the highest in 2015, but, the AQI value is the lowest in 2015. It indicates that if the wind direction decreases, the air quality will worsen. This negative relationship shows a downward slope of –0.68. This could mean when the wind direction becomes near 90 degrees, the air quality becomes worse. When the wind breezes in horizontal direction, air pollutants in the atmosphere are static.

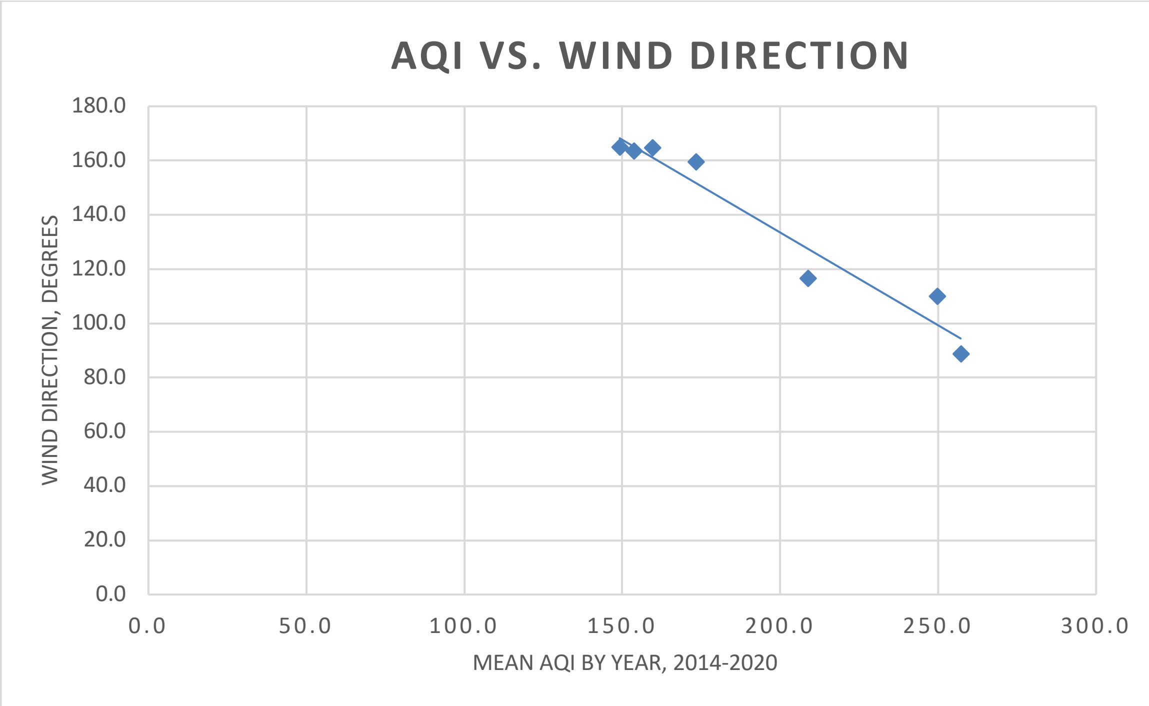


Figure 15. Correlation between the mean AQI and mean Wind direction

Figure 16 depicts the link between mean AQI and mean temperature across the 2014-2020 research period. This graph shows that there is practically no correlation between the AQI and temperature. The slope of this trendline is indeed -0.001. This explains that as the AQI rises, there is practically no trend for the temperature to rise in a particular direction. Due to the fluctuations of the temperature in Mongolia, the correlation between the mean AQI and the mean temperature is not seen in detail. The correlation between the average AQI and the average temperature calculated monthly is illustrated in Figure 16. In this figure, the high negative correlation exhibits clearly. As the temperature fell off, the AQI increases dramatically. This indicates that the temperature fall is strongly related to an increase in the AQI, which means the air quality became worse throughout the cold season in Ulaanbaatar. The slope of this trendline in this figure is -0.116 showing a downward direction, which indicates a high negative correlation.

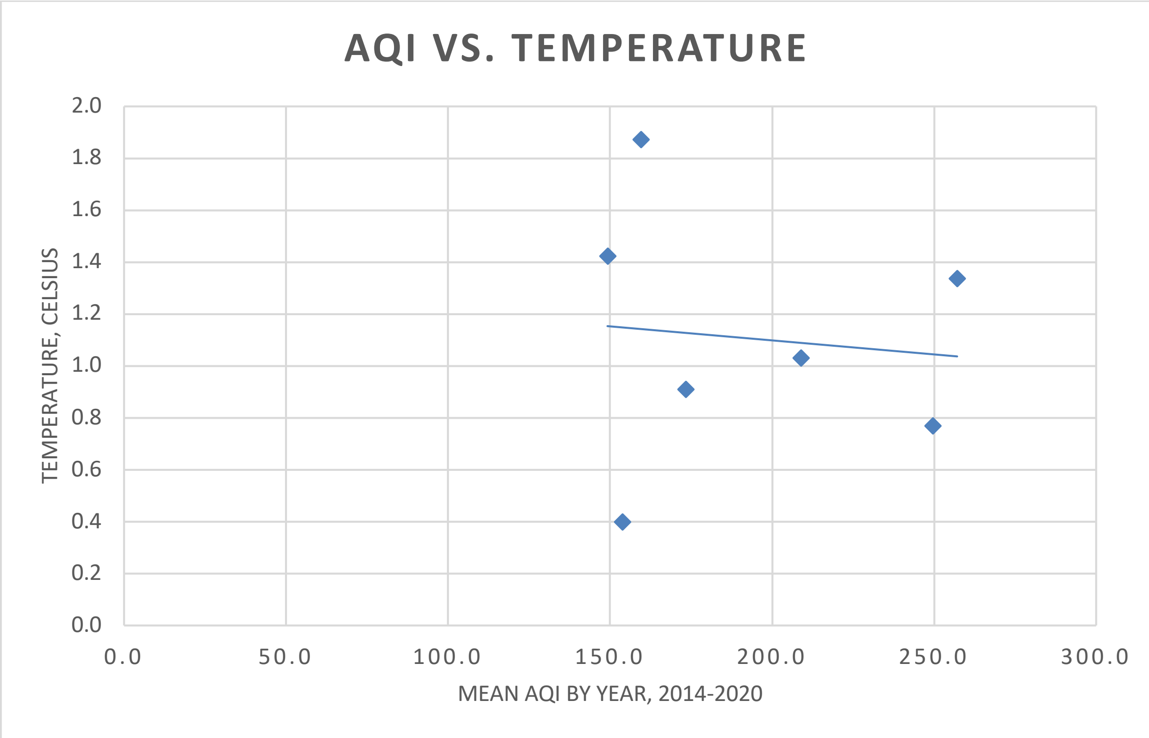


Figure 16. Correlation between the mean AQI and mean temperature.

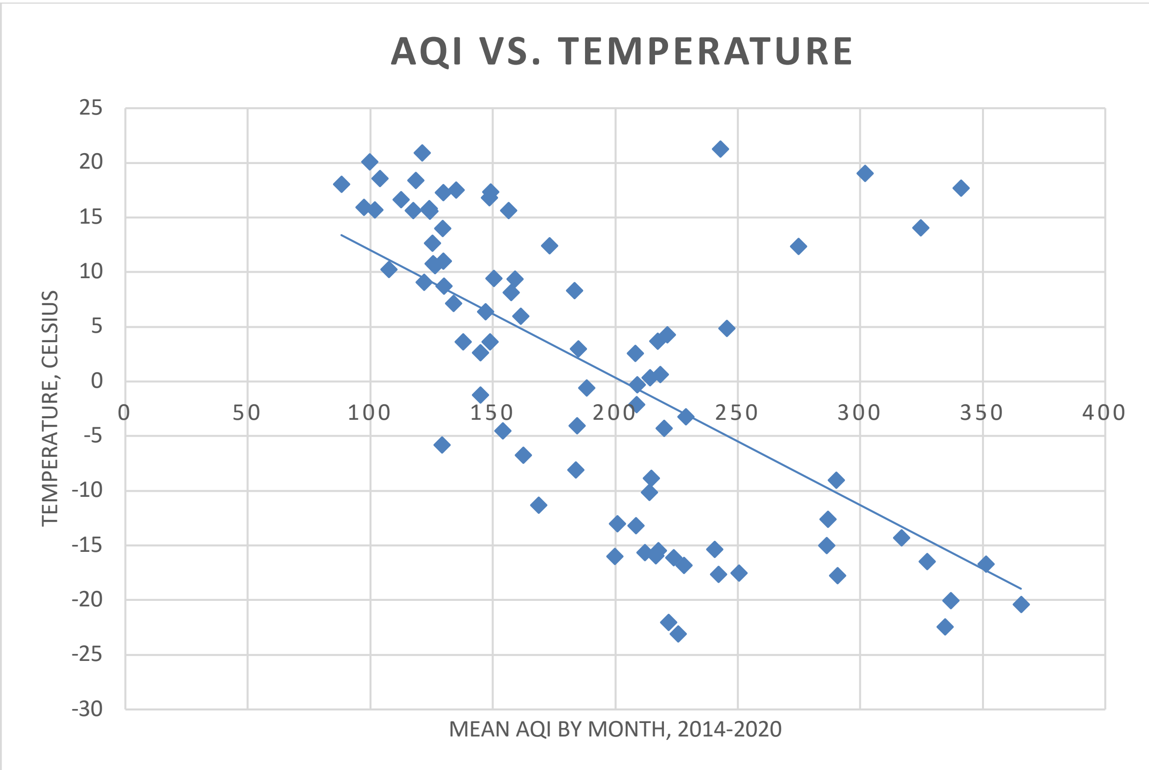


Figure 17. Correlation between the mean AQI and the mean Temperature by month

The correlation between the average Air Quality Index and average relative humidity is shown in Figure 17. There is a moderate positive correlation between these 2 parameters, and the slope of this trendline is 0.02. Because increased humidity in the atmosphere limits the quantity of solar energy reaching the earth's surface, this moderately positive correlation may be attributed to the establishment of an inversion layer.

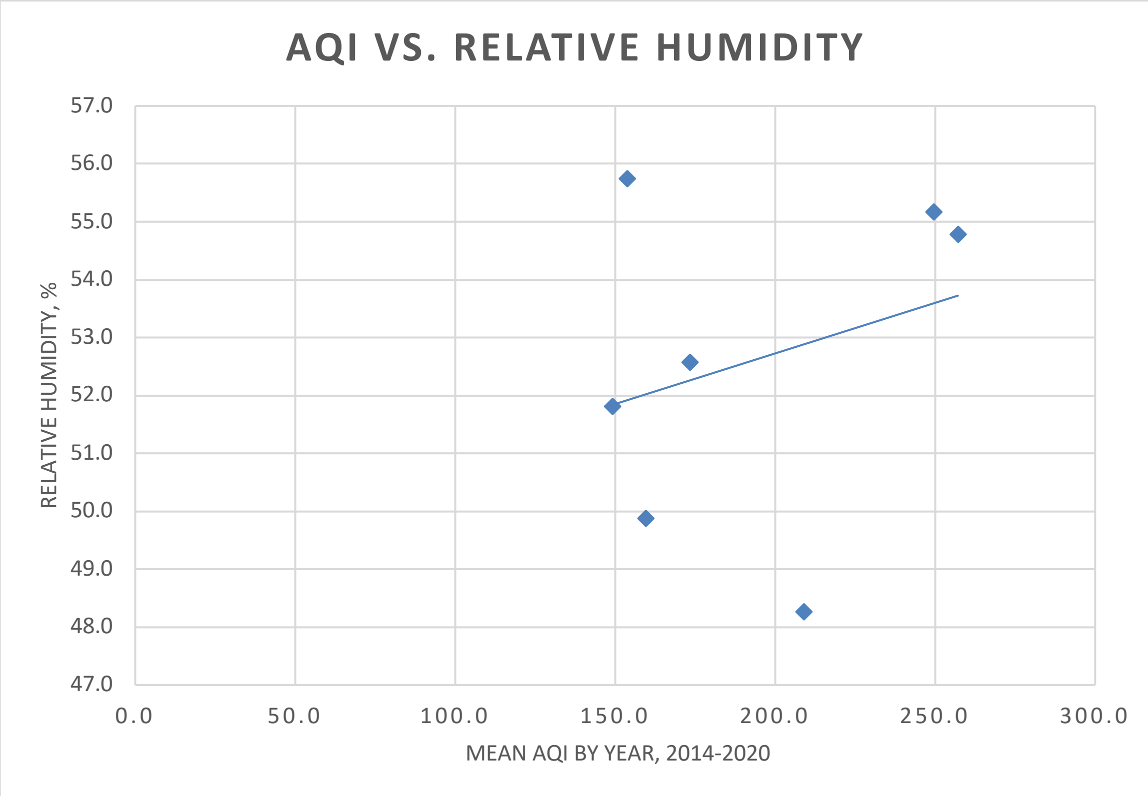


Figure 18. Correlation between the mean AQI and mean Relative Humidity by year

Figure 19 illustrates the trends of daily mean PM10, PM 2.5 pollutants concentration, temperature and relative humidity from 2014 to 2020. These mean values are averaged over the air quality monitoring stations in Ulaanbaatar city. The negative correlation between PM10, PM2.5 pollutants and temperature are clearly shown in this figure. Additionally, there is a clear positive correlation between PM10, PM2.5 pollutants and relative humidity. And PM10 pollutant values are relatively higher than the mean PM2.5 pollutant concentrations during the study period. These correlations show the PM2.5 and PM10 pollutants' concentrations were higher in the winter season due to coal stoves in ger areas and vehicle emissions in Ulaanbaatar city.

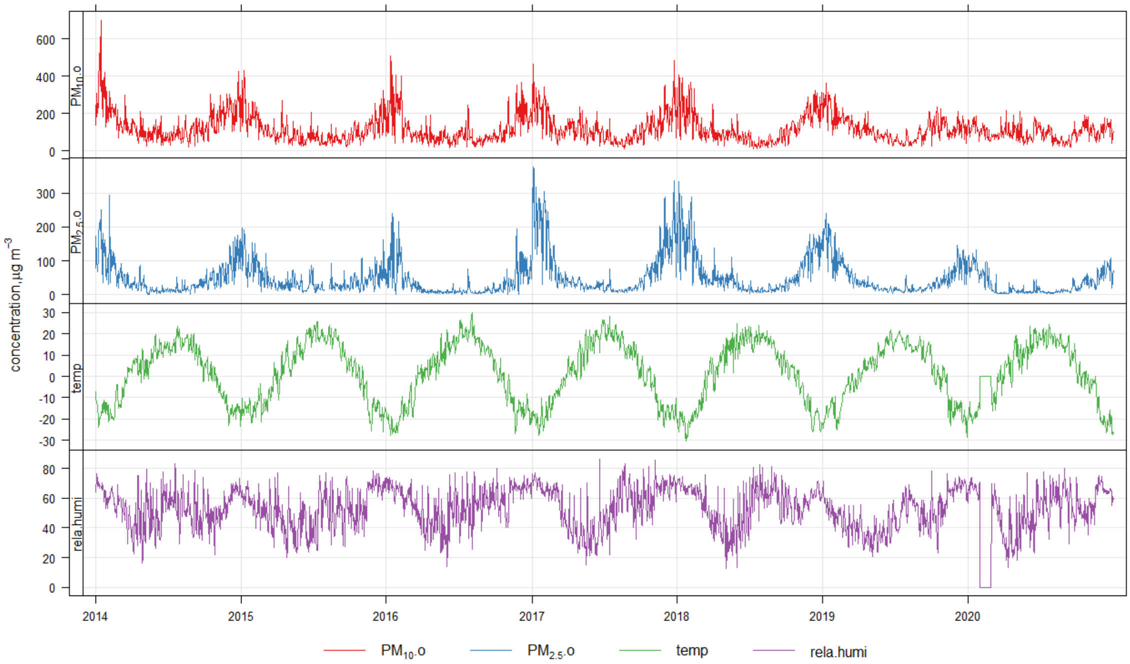


Figure 19. The trends of average PM10, PM2.5, temperature and relative humidity for the study period, 2014 to 2020.

5. Conclusion & Recommendations

According to the research, the air quality in Ulaanbaatar is poor. However, from 2017 to 2020, there is a distinct steady reduction in the concentrations of all contaminants. This drop is attributable to the prohibition on the use of raw coal. The mean concentrations were greater in the winter and lower in the summer. This is because air particle pollutants are emitted mostly by coal combustion in household stoves used for heating, mainly at night, whereas emissions from vehicles and soil dust disturbed by vehicle passage also contribute to diurnal PM emissions. Concentrations were regularly raised at night and throughout working days.

During this investigation, the air quality in the city reduced as the wind direction drops near 90 degrees. This is because the city is surrounded by mountains, which limit both the vertical and horizontal dispersion of air particle pollution. These meteorological and geographical factors contribute to the high concentrations of PM2.5 and PM10, as well as the poor air quality. Temperature decrease also affected poorer air quality.

To conclude, the air quality in Ulaanbaatar city is becoming way better than it was in 2017-2018 and the weather conditions have a strong effect on air quality matter.

Recommendations:

a). In Mongolia, there are no legislative requirements for the allowed amounts of indoor air pollution, which need to be established explicitly. Both outdoor and indoor air pollution create serious health concerns.

b). It is recommended that a study be undertaken on the effects of human activities on pollutant features and behavior, such as traffic-related air pollution. Furthermore, because the surrounding environment of the monitoring sites influences the measurement, more research into the influencing factors on measurement sites is required. As dust storms are a common source of coarse particles throughout the non-heating season in Mongolia, comprehensive research to distinguish between natural and anthropogenic sources of particulate matter should be carried out.

c). The research on air quality modeling methodologies of computational fluid dynamics, urban air pollution, and climate integrated modeling will considerably increase knowledge of air pollution behavior and its environmental consequences, as well as allow for the simulation of future scenarios. Aside from modeling operations, measurements of various parameters in various regions, particularly in clearly contaminated areas, should be expanded and intensified.

6. References

[1] World Data information, Mongolia. 2022; https://www.worlddata.info/asia/mongolia/index.php

[2] The population of Mongolia, Mongolian Statistical Information Center. https://1212.mn/tables.aspx?tbl_id=DT_NSO_0300_004V1&RESIDENT_select_all=0&RESIDENTSingleSelect=_11&SOUM_select_all=0&SOUMSingleSelect=_5&YearY_select_all=0&YearYSingleSelect=_2021&viewtype=table

[3] Ganbat G, Soyol-Erdene TO, Jadamba B. Recent Improvement in Particulate Matter (PM) Pollution in Ulaanbaatar, Mongolia. Aerosol Air Qual. Res. 2020; 20:2280-2288. Available from: https://doi.org/10.4209/aaqr.2020.04.0170

[4] Wang M, Kai K, Sugimoto N, Enkhmaa S. Meteorological factors affecting winter particulate air pollution in Ulaanbaatar from 2008 to 2016. Asian J Atmos. Environ. 2018; 12:244–254. https://doi.org/10.5572/ajae.2018.12.3.244

[5] Allen R.W, Gombojav E, Barkhasragchaa B, Byambaa T, Lkhasuren O, Amram O, Takaro T.K, Janes C.R. An assessment of air pollution and its attributable mortality in Ulaanbaatar, Mongolia. Air Qual. Atmos. 2013; Health 6, 137–150. https://doi.org/10.1007/s11869- 011-0154-3

[6] Yan S, Cao H, Chen Y, et al. Spatial and temporal characteristics of air quality and air pollutants in 2013 in Beijing. 2016;13996–14007. https://doi.org/10.1007/s11356-016-6518-3.

[7] Wang M, Kai K, Jin Y, Sugimoto N, and Dashdondog B. Air particulate pollution in Ulaanbaatar, Mongolia: Variation in atmospheric conditions from autumn to winter. 2017; SOLA, 13, 90−95, doi:10.2151/sola.2017-017.)

[8] Perry K Davy, Gerelmaa Gunchin, Andreas Markwitz, William J. Trompetter, Bernard J. Barry, Dagva Shagjjamba, Sereeter Lodoysamba. Air particulate matter pollution in Ulaanbaatar, Mongolia: determination of composition, source contributions, and source locations, Atmospheric Pollution Research. 2011;126-137, ISSN 1309-1042. https://doi.org/10.5094/APR.2011.017.

[9] Soyol-Erdene T.O, Ganbat G, Baldorj B. Urban Air Quality Studies in Mongolia: Pollution Characteristics and Future Research Needs. Aerosol Air Qual. 2021; Res. 21, 210163. https://doi.org/10.4209/aaqr.210163

[10] Kayes I, Shahriar S.A, Hasan K, Akhter M, Kabir M, Salam M.A. The relationships between meteorological parameters and air pollutants in an urban environment. 2019. DOI: 10.22034/gjesm.2019.03.01

[11] 10 facts about air pollution on World Environment Day. 2019. https://www.weforum.org/agenda/2019/06/10-facts-about-air-pollution-on-world-environment-day

[12] World Air Quality Report. Region & City PM2.5 ranking. 2021. https://www.iqair.com/world-air-quality-report

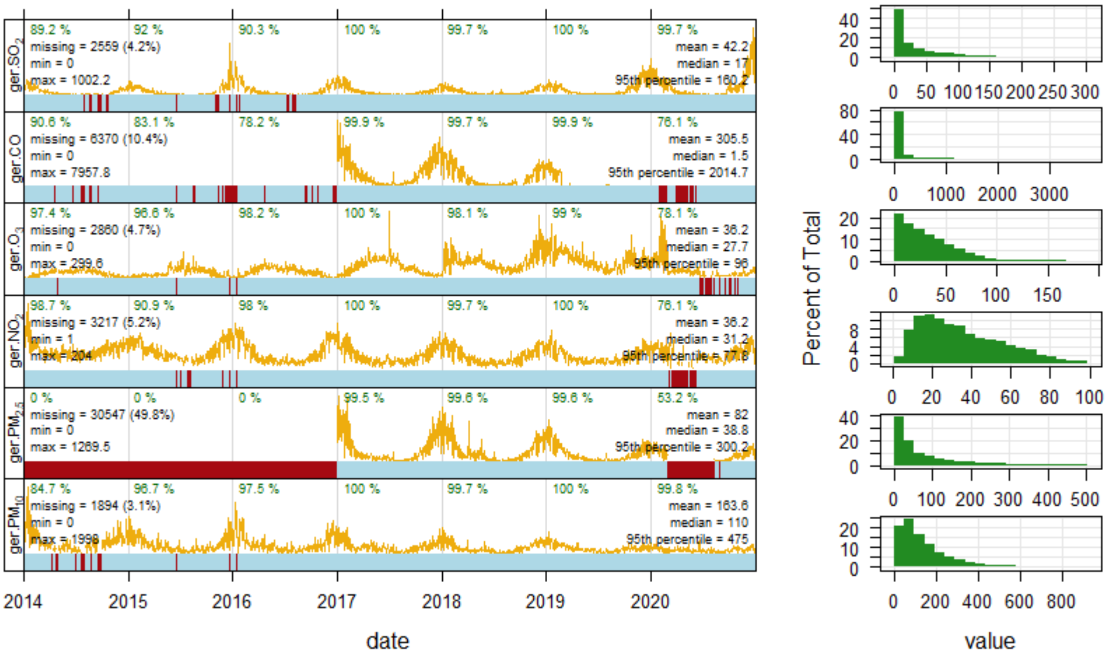
[13] NAAQS table by EPA. 2022. https://www.epa.gov/criteria-air-pollutants/naaqs-table

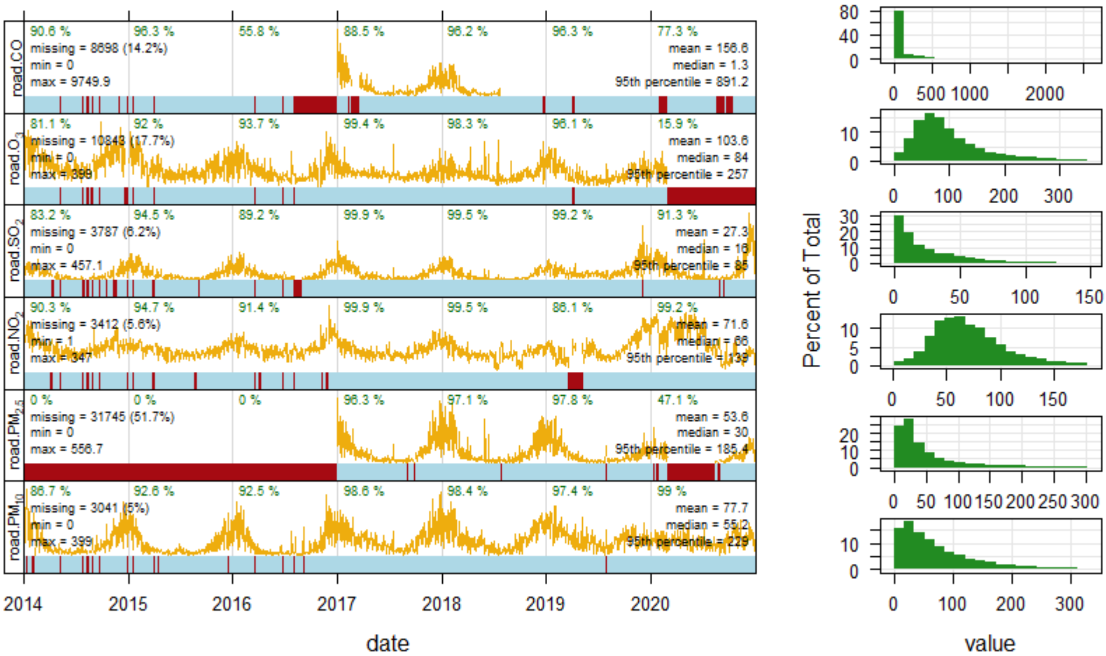
[14] World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide. World Health Organization. 2021; https://apps.who.int/iris/handle/10665/345329. License: CC BY-NC-SA 3.0 IGO

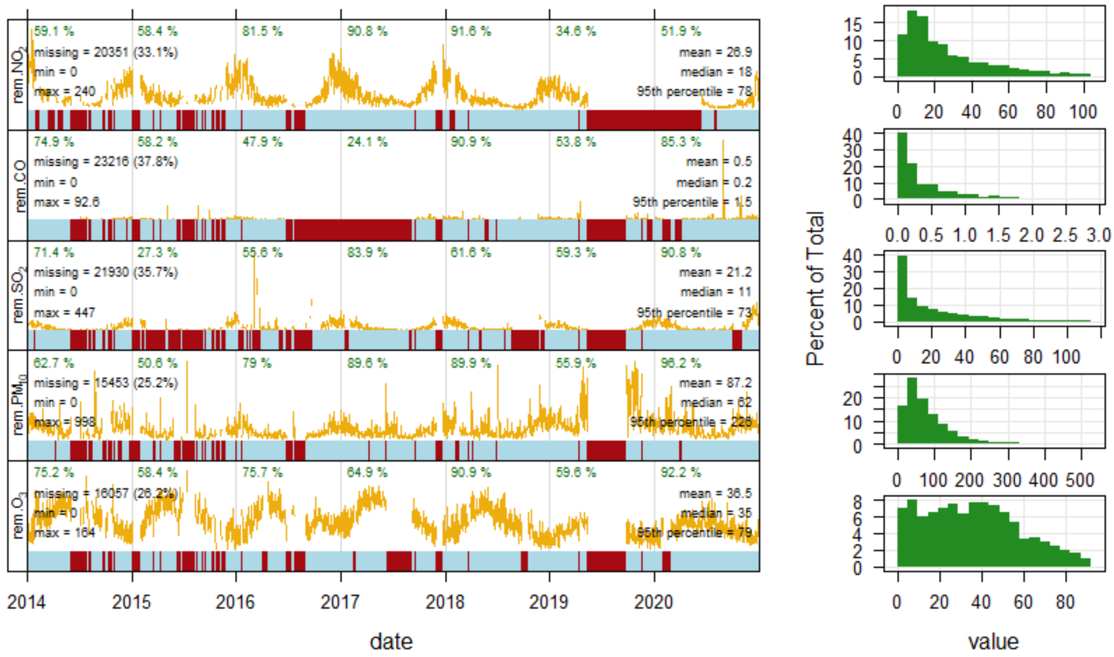
[15] The Mongolian National Standard of Air Quality, General technical requirements. MNS 4585:2016. 2016; https://estandard.gov.mn/standard/reader/3377#2-heibmhmoqmecfajb.jpg

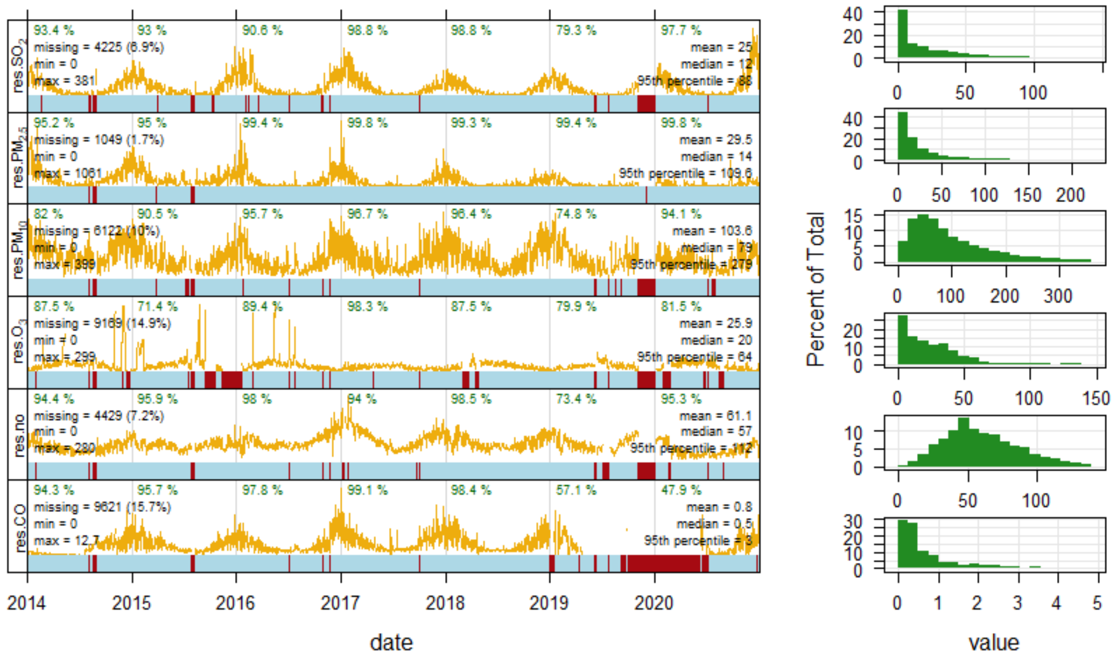
APPENDIX

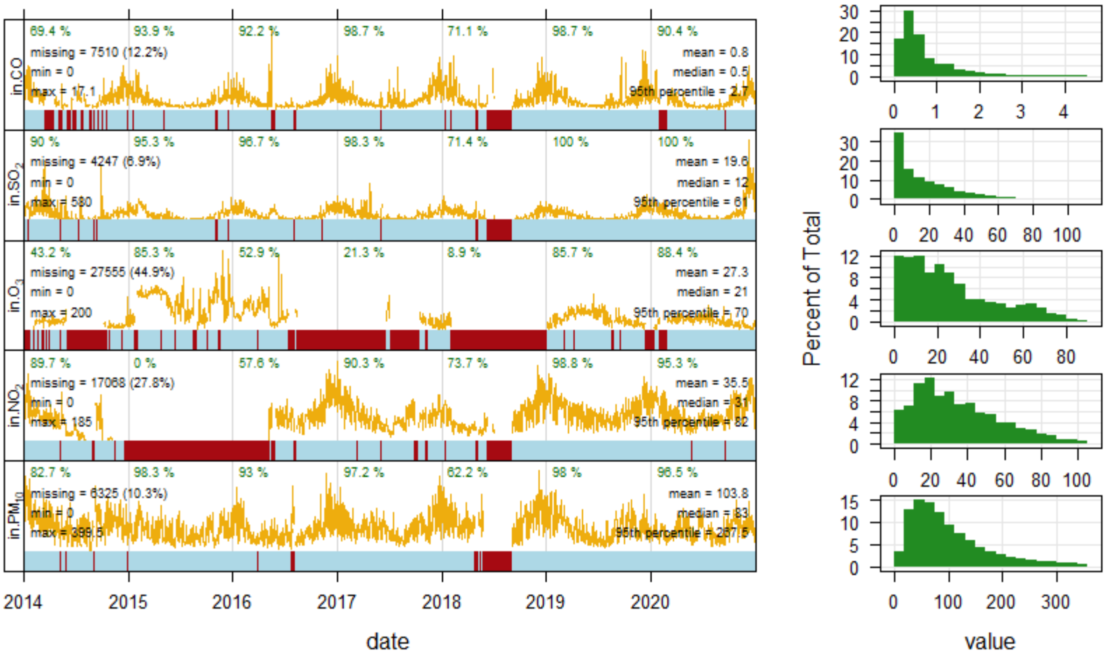
Appendix 1. Trends of air pollutants categorized in areas (ger, industrial, roadside, remote and residential





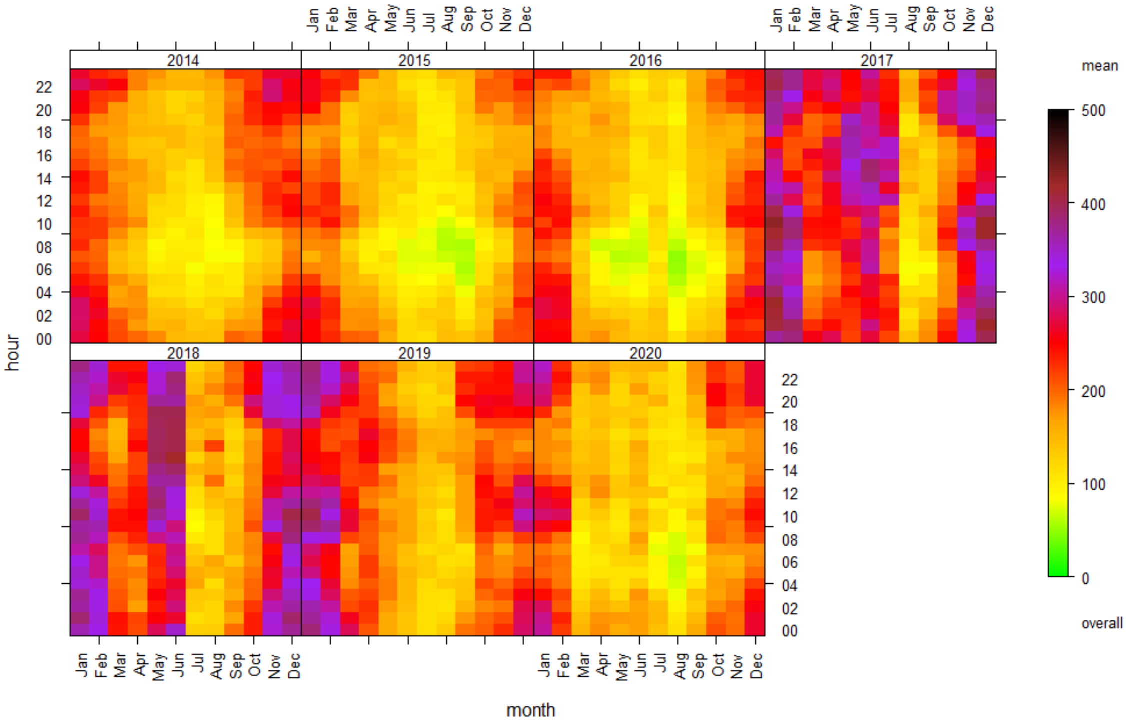

rem.NO2
59.1 % 58.4 % 81.5 % 90.8 % 91.6 % 34.6 % 51.9 %
missing = 20351 (33.1%)
min = 0
max = 240
mean = 26.9
median = 18
95th percentile = 78
rem.CO
74.9 % 58.2 % 47.9 % 24.1 % 90.9 % 53.8 % 85.3 %
missing = 23216 (37.8%)
min = 0
max = 92.6
mean = 0.5
median = 0.2
95th percentile = 1.5
rem.SO2
71.4 % 27.3 % 55.6 % 83.9 % 61.6 % 59.3 % 90.8 %
missing = 21930 (35.7%)
min = 0
max = 447
mean = 21.2
median = 11
95th percentile = 73
rem.PM10
62.7 % 50.6 % 79 % 89.6 % 89.9 % 55.9 % 96.2 %
missing = 15453 (25.2%)
min = 0
max = 998
mean = 87.2
median = 62
95th percentile = 226
rem.O3
75.2 % 58.4 % 75.7 % 64.9 % 90.9 % 59.6 % 92.2 %
missing = 16057 (26.2%)
min = 0
max = 164
mean = 36.5
median = 35
95th percentile = 79
2014 2015 2016 2017 2018 2019 2020
date
Percent of Total
value


res.SO2
93.4 % 93 % 90.6 % 98.8 % 98.8 % 79.3 % 97.7 %
missing = 4225 (6.9%)
min = 0
max = 381
mean = 25
median = 12
95th percentile = 88
res.PM2.5
95.2 % 95 % 99.4 % 99.8 % 99.3 % 99.4 % 99.8 %
missing = 1049 (1.7%)
min = 0
max = 1061
mean = 29.5
median = 14
95th percentile = 109.6
res.PM10
82 % 90.5 % 95.7 % 96.7 % 96.4 % 74.8 % 94.1 %
missing = 6122 (10%)
min = 0
max = 399
mean = 103.6
median = 79
95th percentile = 279
res.O3
87.5 % 71.4 % 89.4 % 98.3 % 87.5 % 79.9 % 81.5 %
missing = 9169 (14.9%)
min = 0
max = 299
mean = 25.9
median = 20
95th percentile = 64
res.no
94.4 % 95.9 % 98 % 94 % 98.5 % 73.4 % 95.3 %
missing = 4429 (7.2%)
min = 0
max = 280
mean = 61.1
median = 57
95th percentile = 112
res.CO
94.3 % 95.7 % 97.8 % 99.1 % 98.4 % 57.1 % 47.9 %
missing = 9621 (15.7%)
min = 0
max = 12.7
mean = 0.8
median = 0.5
95th percentile = 3
2014 2015 2016 2017 2018 2019 2020
date
Percent of Total
value

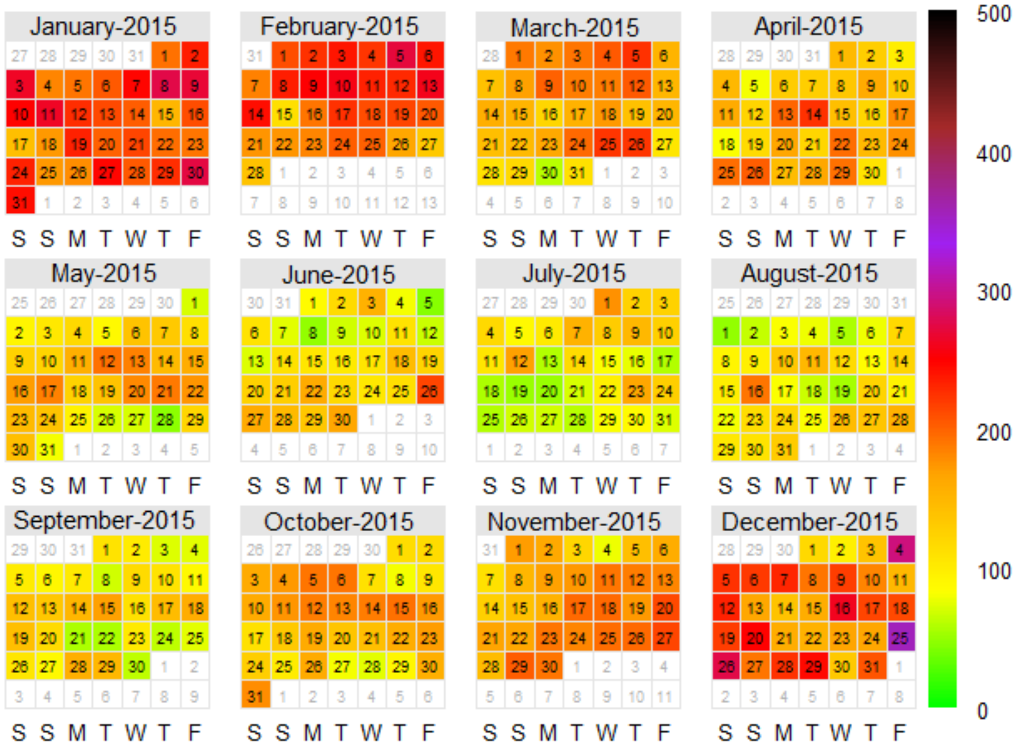


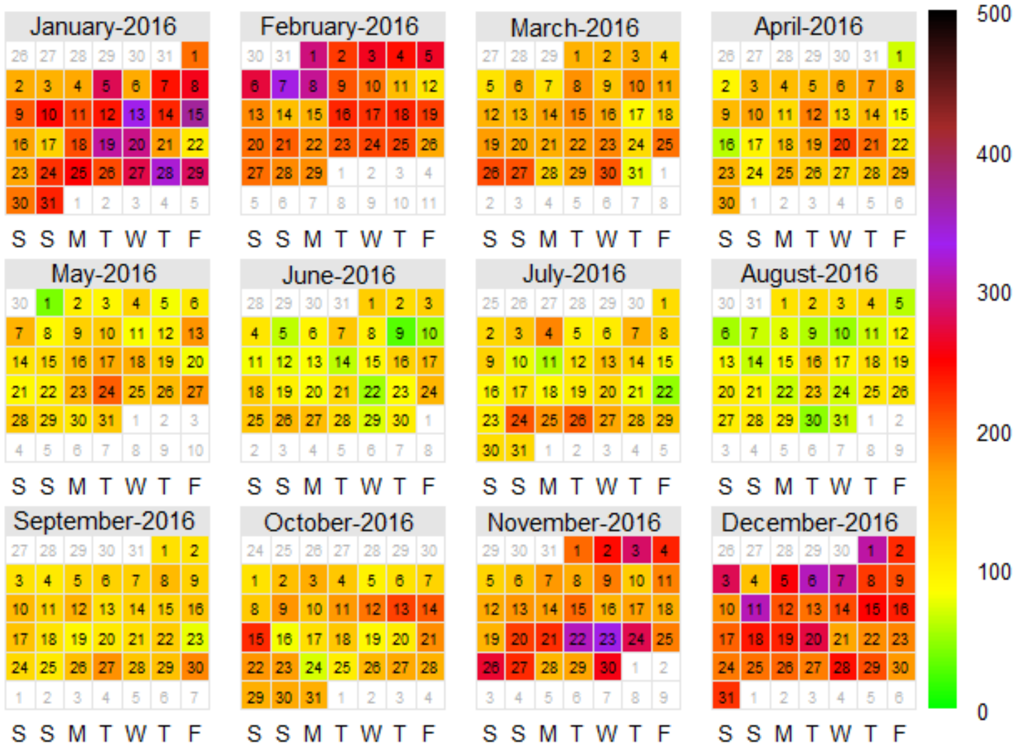
in.CO
69.4 %
93.9 %
92.2 %
98.7 %
71.1 %
98.7 %
90.4 %
missing = 7510 (12.2%)
min = 0
max = 17.1
mean = 0.8
median = 0.5
95th percentile = 2.7
in.SO2
90 %
95.3 %
96.7 %
98.3 %
71.4 %
100 %
100 %
missing = 4247 (6.9%)
min = 0
max = 580
mean = 19.6
median = 12
95th percentile = 61
in.O3
43.2 %
85.3 %
52.9 %
21.3 %
8.9 %
85.7 %
88.4 %
missing = 27555 (44.9%)
min = 0
max = 200
mean = 27.3
median = 21
95th percentile = 70
in.NO2
89.7 %
0 %
57.6 %
90.3 %
73.7 %
98.8 %
95.3 %
missing = 17068 (27.8%)
min = 0
max = 185
mean = 35.5
median = 31
95th percentile = 82
in.PM10
82.7 %
98.3 %
93 %
97.2 %
62.2 %
98 %
96.5 %
missing = 6325 (10.3%)
min = 0
max = 399.5
mean = 103.8
median = 83
95th percentile = 267.5
2014
2015
2016
2017
2018
2019
2020
date
Percent of Total
value

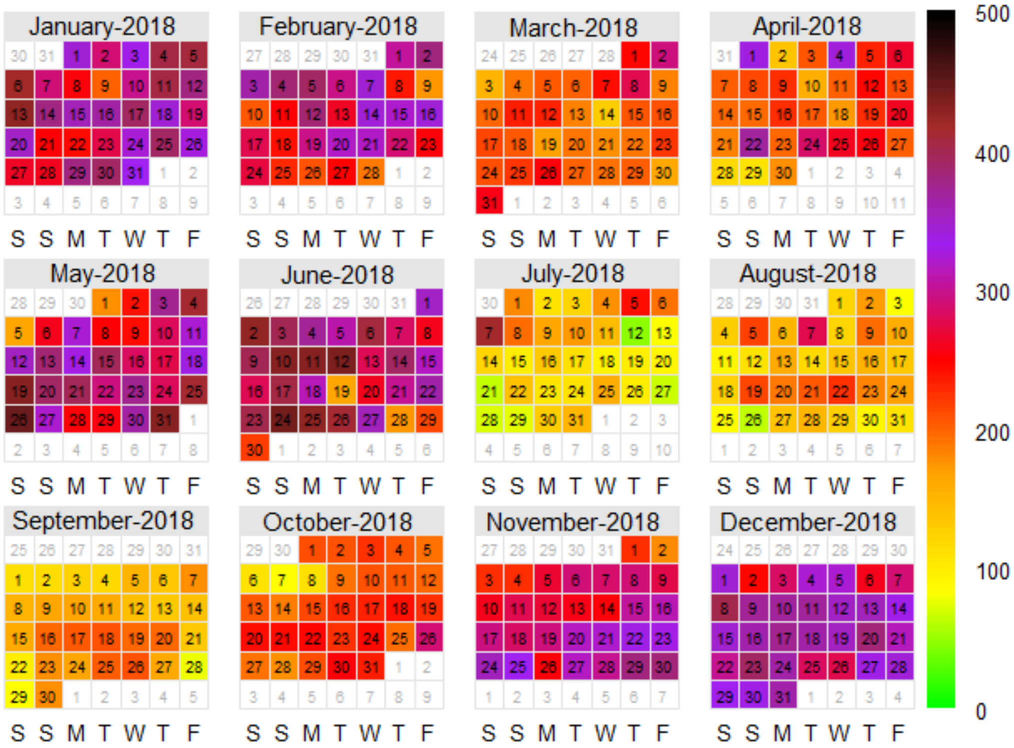
Appendix 2. Variations in AQI by year and hour of the day for 2014-2020

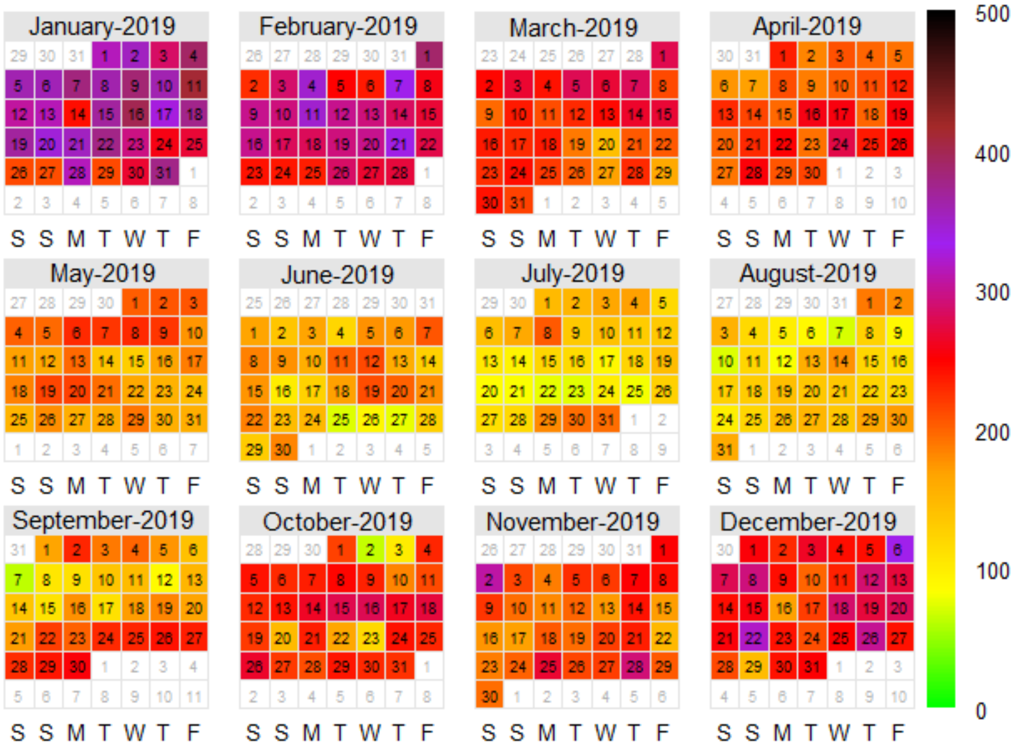


Appendix 3. Daily mean values of overall AQI during 2015-2016 and 2018-2019






January-2018
February-2018
March-2018
April-2018
May-2018
June-2018
July-2018
August-2018
September-2018
October-2018
November-2018
December-2018
S S M T W T F
500
400
300
200
100
0


January-2019
February-2019
March-2019
April-2019
May-2019
June-2019
July-2019
August-2019
September-2019
October-2019
November-2019
December-2019
S S M T W T F
500
400
300
200
100
0

Appendix 4. The Air Quality Assessment and Regulation of Mongolia, Mongolian version

Өмнөх Дараах

МОНГОЛ УЛСЫН СТАНДАРТ

Ангилалтын код 13.040.01

Агаарын чанар. Техникийн ерөнхий шаардлага	**MNS 4585 : 2016**
Air quality. General technical requirements	**MNS 4585 : 2007-ын оронд**

Стандартчиллын үндэсний зөвлөлийн 2016 оны 06 дугаар сарын 23-ний өдрийн 37 дугаар тогтоолоор батлав.

Энэ стандарт нь 2016 оны 07 дугаар сарын 08 –ны өдрөөс эхлэн хүчинтэй.

1. Зорилго

Хүн амын эрүүл, аюулгүй орчинд амьдрах нөхцлийг бүрдүүлэх, экосистемийн тэнцлийг хангах зорилгоор хүрээлэн байгаа агаар болон аливаа орон байрны доторх орчны агаар дахь түгээмэл тархацтай бохирдуулах бодисын хүлцэх хэм хэмжээг тогтооход оршино.

2. Хамрах хүрээ

2.1. Энэхүү стандарт хот, суурин газрын агаарын чанар болон орон байрны доторх орчны агаарын чанарыг хянах, үнэлэхэд хамаарна.

2.2. Энэхүү стандартад зохих журам, аргачлалын дагуу тогтоосон ажлын байрны агаарын чанарын үзүүлэлт хамаарахгүй болно.

3. Норматив эшлэл

Энэ стандартад дараах стандартуудыг эш татсан бөгөөд өөрчлөлт орсон тохиолдолд хамгийн сүүлчийн албан ёсны материалаас эш татаж хэрэглэнэ. Үүнд;

ДЭМБ, 85-хэвлэл, 2006, Агаарын чанарын зөвлөмж;
40 CFR part 50, 2006, *Хүрээлэн байгаа орчны агаарын чанарын стандарт.*
АНУ-ын Байгаль хамгаалах агентлаг, Агаар бохирдуулах бодисийн үзүүлэлт

4. Нэр томьёо, тодорхойлолт

4.1
Агаарын чанар
Агаарын чанарын стандартад нийцэж байгаа эсэхийг илэрхийлэх агаарын физик, хими, биологийн цогц шинж чанар

4.2
Хүрээлэн байгаа агаар
байгаль орчны бүрэлдэхүүн хэсгийн нэг болох хийн мандлын байгалийн төлвөөрөө байгаа хийн хольц

4.3.
Агаарын бохирдол
Хүрээлэн байгаа агаарт шууд хаягдсан, эсхүл физик, химийн урвалын дүнд шинээр үүсч бий болсон бохирдуулах бодисын агууламж нь агаарын чанарын стандартаас хэтрэх

4.4.
Агаар бохирдуулах бодис
Бохирдлын аливаа эх үүсвэр, эсхүл түүнээс хаягдаж хүрээлэн байгаа агаар бохирдуулж байгаа физик, хими, биологийн болон цацраг идэвхит бодис, тэдгээрийн хольц

4.5.
PM10 тоосонцор
Агаар дахь 10 микрометрээс жижиг аэродинамик эквивалент диаметртэй тоосонцор

4.6.
PM2.5 тоосонцор
Агаар дахь 2.5 микрометрээс жижиг аэродинамик эквивалент диаметртэй тоосонцор

4.7.
Агаарын чанарын стандарт
Хүрээлэн байгаа агаар дахь бохирдуулах бодисын хүний эрүүл мэнд, хүрээлэн байгаа орчинд сөрөг нөлөө үзүүлэхгүй байх хүлцэх хэм хэмжээ

4.8.
Орон байрны доторх агаар
Гадна орчноос байгууламж хийцээр тусгаарлагдсан орон байрны доторх агаарын төлөв байдал.

5. Техникийн шаардлага

5.1. Агаар дахь бохирдуулах бодисын хүлцэх агууламж, физик нөлөөллийн зөвшөөрөгдөх дээд хэмжээг 1 дүгээр хүснэгтэд заасны дагуу тогтооно.

5.2. Агаарт байгаа түгээмэл тархацтай бохирдуулах бодисын хүлцэх агууламж болон физикийн сөрөг нөлөөллийн зөвшөөрөгдөх дээд хэмжээнээс хэтэрсэн тохиолдолд бохирдсонд тооцож, агаарын чанарыг сайжруулах арга хэмжээг авч хэрэгжүүлнэ.

5.3 Хүрээлэн байгаа агаарын чанарыг агаарын чанарын индекс (АЧИ)-ээр үнэлж, өдөр тутам олон нийтэд мэдээлнэ.

1-р хүснэгт Агаар дахь түгээмэл тархацтай бохирдуулах бодисын хүлцэх агууламж болон физикийн сөрөг нөлөөллийн зөвшөөрөгдөх дээд хэмжээ

Үзүүлэлтийн нэр	Хэмжилтийн дундаж хугацаа	Хэмжих нэгж	Хүлцэх агууламж
Химийн нөлөөлөл			
Хүхэрлэг хий (SO_2)	20 минутын дундаж 24 цагийн дундаж Жилийн дундаж	мкг/м^3	450 50 20
Нүүрстөрөгчийн дутуу исэл (CO)	20 минутын дундаж 1 цагийн дундаж 8 цагийн дундаж	мкг/м^3	60000 30000 10000
Азотын давхар исэл (NO_2)	20 минутын дундаж 24 цагийн дундаж Жилийн дундаж	мкг/м^3	200 50 40
Озон (O_3)	8 цагийн дундаж	мкг/м^3	100
Нийт тоосонцор	20 минутын дундаж 24 цагийн дундаж Жилийн дундаж	мкг/м^3	500 150 100
PM 10 тоосонцор	24 цагийн дундаж Жилийн дундаж	мкг/м^3	100 50
PM 2.5 тоосонцор	24 цагийн дундаж Жилийн дундаж	мкг/м^3	50 25
Хар тугалга (Pb)	24 цагийн дундаж Жилийн дундаж	мкг/м^3	1 0,25
Бенз-а-пирен ($C_{20}H_{12}$)	24 цагийн дундаж	мкг/м^3	0,001
Физикийн нөлөөлөл			
Үзүүлэлтийн нэр	**Хэмжилтийн дундаж хугацаа**	**Хэмжих нэгж**	**Зөвшөөрөгдөх дээд хэмжээ**
Дуу шуугиан - Өдрийн цаг (07-22 цаг) - Шөнийн цаг (22-07 цаг)	16 цагийн дундаж 8 цагийн дундаж	дБА	60 45

6. Орон байрны доторх агаарын чанарын үзүүлэлт.

6.1. Орон байрны доторх агаар дахь бохирдуулах бодис, физик нөлөөллийн зөвшөөрөгдөх дээд хэмжээ, хязгаарыг 2 дугаар хүснэгтэд заасны дагуу тогтооно.

2-р хүснэгт Орон байрны доторх агаар дахь бохирдуулах бодис, физик нөлөөллийн зөвшөөрөгдөх дээд хэмжээ, хязгаар

Үзүүлэлтийн нэр	Үнэлгээний нөхцөл	Хэмжих нэгж	Зөвшөөрөгдөх дээд хэмжээ, хязгаар
Температур	Дундаж хэмжилтээр	Цельсийн градус	18-22
Агаарын урсгалын хурд	Дундаж хэмжилтээр	м/с	0,2- 0,4
Харьцангуй чийглэг	Дундаж хэмжилтээр	Хувь	30-60
Нүүрсхүчлийн хий (CO_2)	24 цагийн дундаж	мг/м^3	1800
Гэрэлтүүлэг - Хүн байнга суудаг - Хүн байнга суудаггүй	Дундаж хэмжилтээр	Люкс	150-300 50-150

7. Агаарын чанарын шинжилгээ
7.1. Агаарын чанарын үзүүлэлтийг холбогдох норм, дүрэм, стандарт, арга аргачлалын дагуу тодорхойлно.

ТӨГСӨВ.