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ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

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В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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SPATIAL DISTRIBUTION OF PM2.5 AND PM10 POLLUTANTS IN RESIDENTIAL AREA OF PAVLODAR, KAZAKHSTAN

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Annotation. This study aimed to analyze the spatial and temporal distribution of PM2.5 and PM10 pollutants in Pavlodar City, Kazakhstan, and identify the trends in their distribution. Data from seven monitoring stations were analyzed for the period 2022–2023, and the Air Quality Index (AQI) was utilized as the main indicator to assess pollution levels. The study found that the level of air pollution in Pavlodar City's residential area is elevated, with the annual average concentration of PM2.5 exceeding the World Health Organization's (WHO) recommended limit of 10 μg m^{-3} in six out of seven monitoring stations in 2023. Additionally, the standard for PM10 (20 μg m^{-3}) was exceeded at two locations. The analysis of the AQI demonstrated that PM2.5 is the predominant pollutant affecting air quality in the city, with only one location recording an AQI level corresponding to "good" in 2023. The results of the correlation analysis showed a linear relationship between pollution levels and distance from industrial areas, with the most environmentally friendly areas of the city located in the southwestern part of the city, near the Irtysh riverbank. The distance from both the northern and eastern industrial zones was found to be the most reliable predictor of air pollution trends within the city. Statistical correlation analysis revealed a strong positive correlation between PM2.5 and PM10 concentrations, suggesting a common source of origin and similar distribution trends. The study highlights the need to address air quality issues in Pavlodar City to safeguard public health and the environment in the region.

Keywords: Air Quality Index; PM2.5 and PM10 pollutants; Pavlodar city; spatial distribution; air pollution

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Conflict of interest: *The authors declare no conflict of interest.*

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ҚАЗАҚСТАН, ПАВЛОДАР ҚАЛАСЫНЫҢ СЕЛИТЕБТІК АУМАҒЫНДА РМ2.5 ЖӘНЕ РМ10 ЛАСТАҒЫШТАРЫНЫҢ КЕҢІСТІКТЕ ТАРАЛУЫ

Аннотация. Осы зерттеудің мақсаты Павлодар қаласында (Қазақстан) РМ2.5 және РМ10 ластағыш заттарының кеңістіктік-уақытша таралуын талдау және олардың бөліну үрдісін анықтау болып табылады. Зерттеу барысында 2022–2023 жж. кезеңі үшін мониторингілеудің жеті станциясының деректері талданды, ластану деңгейін бағалау үшін негізгі көрсеткіш ретінде ауа сапасының индексі (AQI) пайдаланылды. Зерттеу Павлодар қаласының селитебтік аумағында ауаның ластану деңгейі жоғары болып табылатындығын көрсетті: 2023 жылы мониторинглеудің жеті станциясының алтауының дерегі бойынша РМ2.5-тің жылдық орташа шоғырлануы Дүниежүзілік денсаулық сақтау ұйымымен (ДДСҰ) ұсынылған 10 мкг $м^{-3}$ шегінен асады. Бұдан бөлек, екі локацияда РМ10 (20 мкг $м^{-3}$) үшін норматив асып кеткен. AQI индексінің талдауы қаладағы ауаның сапасына әсер ететін басым ластағыш РМ2.5 болып табылатындығын көрсетті, 2023 жылы тек бір локацияда AQI-дің «жақсы» деңгейі тіркелді. Корреляциялық талдау нәтижесі өнеркәсіп аймақтарынан алшақтығы мен ластану деңгейі арасындағы сызықты тәуелділікті және де барынша экологиялық таза аумақ Ертіс өзенінің жағалауына таяу қаланың оңтүстік-батыс бөлігінде орналасқанын көрсетті. Солтүстік және шығыс өнеркәсіптік аймақтарынан жалпылама алшақтық қаладағы ауа ластану серпінінің барынша сенімді предикторы болып табылды. Статистикалық корреляциялық талдау PM2.5 және PM10 қойырлығы арасында мықты жағымды өзара байланысты анықтады, бұл шығу тегінің жалпы көзі мен таралудың ұқсас үрдістері туралы дәлелдейді. Жүргізілген зерттеу тұрғындардың денсаулығы мен өңірдегі қоршаған ортаны сақтау үшін Павлодар қаласында ауа сапасының мәселелерін шешу қажеттілігін айқындайды.

Түйін сөздер: ауа сапасының индексі (AQI); PM2.5 және PM10 ластағыш заттары; Павлодар қаласы; кеңістікте таралу; ауаның ластануы

Қаржыландыру: *Бұл зерттеу ИРН AP19677560 «Машиналық оқыту әдістерін қолдана отырып, Павлодар қаласының ауа ортасының экологиялық жай-күйін мониторингілеу және картаға түсіру» нысаналы қаржыландыру бағдарламасы аясында Қазақстан Республикасы Ғылым және жоғары білім министрлігінің Ғылыми зерттеу комитетімен қаржылық қолдау көрсетуімен жүргізілді.*

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ПРОСТРАНСТВЕННОЕ РАСПРЕДЕЛЕНИЕ ЗАГРЯЗНИТЕЛЕЙ PM2.5 И PM10 В СЕЛИТЕБНОЙ ЗОНЕ Г. ПАВЛОДАР, КАЗАХСТАН

Аннотация. Целью данного исследования является анализ пространственно-временного распределения загрязняющих веществ PM2.5 и PM10 в г. Павлодар (Казахстан) и выявление тенденций в их распределении. В ходе исследования были проанализированы данные семи станций мониторинга за период 2022–2023 гг., в качестве основного показателя для оценки уровня загрязнения использовался индекс качества воздуха (AQI). Исследование показало, что уровень загрязнения воздуха в селитебной зоне г. Павлодар является повышенным: среднегодовая концентрация PM2.5 превышает рекомендуемый Всемирной организацией здравоохранения (ВОЗ) предел в 10 мкг $м^{-3}$ по данным шести из семи станций мониторинга в 2023 году. Кроме того, в двух локациях был превышен норматив для PM10 (20 мкг $м^{-3}$). Анализ индекса AQI показал, что преобладающим загрязнителем, влияющим на качество воздуха в городе, является PM2.5, только в одной локации в 2023 году был зафиксирован «хороший» уровень

AQI. Результаты корреляционного анализа показали линейную зависимость между уровнем загрязнения и удаленностью от промышленных зон, причем наиболее экологически чистый участок расположен в юго-западной части города, вблизи берега реки Иртыш. Обобщенная удаленность от северной и восточной промышленных зон оказалась наиболее надежным предиктором динамики загрязнения воздуха в городе. Статистический корреляционный анализ выявил сильную положительную корреляцию между концентрациями PM2.5 и PM10, что свидетельствует об общем источнике происхождения и сходных тенденциях распространения. Проведенное исследование подчеркивает необходимость решения проблем качества воздуха в городе Павлодар для сохранения здоровья населения и окружающей среды в регионе.

Ключевые слова: Индекс качества воздуха (AQI); загрязняющие вещества PM2.5 и PM10; город Павлодар; пространственное распределение; загрязнение воздуха

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Конфликт интересов: *авторы заявляют об отсутствии конфликта интересов.*

Introduction

Air pollution is a global public health challenge, affecting urban areas across the world. It is a leading environmental risk factor, contributing to a wide range of health problems, including respiratory diseases (such as asthma and chronic obstructive pulmonary disease) (Tatayeva & Burumbayeva, 2014; Wang et al., 2021; Yan et al., 2022), cardiovascular diseases (including heart attacks and strokes) (Chen et al., 2023; Gale et al., 2020; Huang & Chen, 2021; Ren et al., 2021), lung cancer (Oh et al., 2023; Zhang et al., 2023; Zhou, 2021), and a variety of other adverse health outcomes. Poor air quality is responsible for millions of premature deaths each year worldwide (Goodwin, 2023; Roy, 2018; Van Der Wall, 2015).

Beyond its effects on human health, air pollution has significant environmental consequences. It can harm ecosystems, damage vegetation, and contribute to soil and water pollution (Vallero, 2014). Particulate matter and other pollutants released into the atmosphere can have a negative impact on biodiversity and ecosystems (Sharma et al., 2013).

The economic costs associated with air pollution are substantial on a global scale. These costs include healthcare expenses for treating pollution-related illnesses, lost labor productivity due to health impacts, and damage to infrastructure and crops. Addressing air pollution is not only a public health imperative but also an economic one (Hidalgo & Sanz Bedate, 2022).

As countries strive for economic growth and development, urbanization and industrialization play pivotal roles in shaping their trajectories. Rapid urbanization and industrialization in many parts of the world have led to increased emissions of air pollutants. This growth, while promising economic opportunities, also brings significant challenges related to air quality. As cities grow and industrial activities expand, the concentration of pollutants in the air can rise, posing a direct threat to urban populations (Ma et al., 2017).

The expansion of industrial activities is a major source of air pollutants, including particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds. Factories, power plants, manufacturing units, and other industrial facilities release these pollutants into the atmosphere as byproducts of production processes (Kaur & Jhamaria, 2021). In many cases, the push for increased production and economic gains has, at times, taken precedence over environmental concerns, contributing to elevated pollution levels.

Countries and regions worldwide are implementing a range of technological and policy solutions to combat air pollution, including transitioning to cleaner energy sources, promoting public transportation, regulating industrial emissions, and adopting stricter vehicle emission standards (Amann et al., 2020). Many of these efforts also intersect with initiatives aimed at reducing greenhouse gas emissions (GHGs), highlighting the interconnected nature of these environmental challenges. While the challenge of urban air pollution is complex and pressing, it is far from insurmountable. Cities and nations around the globe are increasingly recognizing the importance of sustainable urban planning, cleaner industrial processes, and the widespread adoption of renewable energy sources. Critical steps toward achieving cleaner urban air include the enforcement of stringent emission regulations, the expansion of public transportation networks, and the encouragement of electric vehicle usage, all of which contribute to improved air quality and the well-being of urban populations (Jonidi Jafari et al., 2021).

Increasing awareness of the health and environmental impacts of air pollution and advocating for clean air is essential. Public awareness, grassroots movements, and global advocacy efforts contribute to pressure on governments and industries to take action to reduce pollution levels.

Thus, the issue of air pollution is a global concern with profound effects on public health, the environment, the economy, and climate change. Addressing air pollution is a multifaceted challenge that requires coordinated efforts at the local, national, and international levels, emphasizing the need for cleaner technologies, sustainable urban planning, and policies that prioritize air quality and human well-being.

The Republic of Kazakhstan has undergone significant industrialization, leading to pressing environmental issues that urgently require resolution. Pavlodar region stands as one of the country's most industrially advanced areas, featuring a multi-sectoral industrial complex that specializes in electrical energy production, alumina, oil refining, mechanical engineering, food industry, and construction materials. Currently, there exist over 200 registered enterprises (Azhayev et al., 2020) in the city of Pavlodar that cumulatively produce approximately 180,000 tons of pollutant emissions (MEGNRRK, 2021). Notable large-scale industrial enterprises include Pavlodar Petrochemical Plant, JSC "Kaustik" (former Pavlodar Chemical Plant), Pavlodar Aluminum Plant, Electrolysis Plant, and businesses involved in the creation of metal structures and electrical installation products. Furthermore, the city encompasses three combined heat and power plants, over 20 boiler houses, and approximately 5,000 households that collectively consume more than 3.5 million tons of coal annually.

Atmospheric air quality in the Pavlodar region undergoes monitoring by The Republican State Enterprise "Kazgidromet" branch with the utilization of 11 fixed observation stations for air pollution. These posts are situated in the cities of Pavlodar (7 posts), Ekibastuz (3 posts), and Aksu (1 post). The pollutants that have been analyzed comprise of suspended particles PM-2.5 and PM-10, sulfur dioxide, carbon monoxide, nitrogen oxide, nitrogen dioxide, ozone, hydrogen sulfide, a sum of hydrocarbons, ammonia, methane, phenol, chlorine, hydrogen chloride, and sulfates (MEGNRRK, 2021). Nevertheless, there is no public information available on these pollutants, along with their spatial dispersion within the city limits. The primary contributors to atmospheric pollution in the Pavlodar region are classified as I category environmental hazards (1 and 2 classes of sanitary hazards), which include thermal power plants that use high-ash coal. These plants are responsible for 85-86% of the emissions in the area. The remaining enterprises in the other categories of environmental hazard contribute approximately 10 % of total emissions. Meanwhile, 4 % of emissions stem from enterprises in categories II, III, and IV of environmental hazard (Nossenko et al., 2018).

The issue of monitoring of air quality in industrial cities of Kazakhstan has not been widely revealed in publications. There were few scientific studies on this issue, particularly several articles were devoted to considering the situation in Pavlodar. Thus, Tatayeva et al. (Tatayeva & Burumbayeva, 2014) analyzes air pollution in Pavlodar and other cities in Kazakhstan, highlighting the impact of pollutants on lung cancer incidence. Kakabayev et al. (Kakabayev et al., 2023) discusses the consequences of industrial development in Pavlodar, including high emissions of pollutants into the atmosphere and the need to improve the environmental situation. Mardenov et al. (Mardenov et al., 2014) focuses on the atmospheric air condition in Ekibastuz, a city in Pavlodar region, emphasizing the negative influence of power engineering and metallurgic industry on air quality. Azhayev et al. (Azhayev et al., 2020) evaluates the geoecological environmental situation in Pavlodar region, emphasizing the concentration of air pollutants in industrial centers and the potential negative impact on tourism.

These papers collectively suggest that air quality in Pavlodar, Kazakhstan is affected by industrial activities and pollutants, which may have implications for public health and the environment. However, all of these publications didn’t consider spatial and temporal distribution of air quality index (AQI) based on the U.S. Environmental Protection Agency's (EPA) National Ambient Air Quality Standards (NAAQS), which allows conducting comparative studies with other territories considered in different scientific works (Li et al., 2017). As well in this article current data on air pollutants’ distribution for the period 2022-2023 is presented based on the information from the independent source waqi.info (AQICN, 2020). Thus, the study aims to fill gap in the knowledge about evaluation and detection patterns in the distribution of PM2.5, PM10 pollutants, and AQI within the residential area of Pavlodar city, a major center of industry in the Republic of Kazakhstan.

Methods and materials

Study Area. Pavlodar City is located in Pavlodarskaya Oblast in the northern part of Republic of Kazakhstan. It is a multifaceted industrial center covering an area of 326,882 hectares (0.3 thousand square kilometers), with a population exceeding 300,000 people. The climate in Pavlodar City is severely continental, with moderate levels of humidity. It is characterized by harsh winters, with an average temperature of -16.7 in January, strong winds, and snowstorms. Spring is marked by cold returns, and late spring and early autumn are accompanied by frosts. Despite an abundance of sunlight, summers are hot; however, they are relatively short with an average temperature of +21.2 in July according to 2023 data (pogodaiklimat.ru, n.d.).

More than 90 industrial enterprises are registered within the city limits. These include aluminum, machine-building, cardboard-rubberoid, chemical, petrochemical, shipbuilding and ship-repair, instrumental, tractor, rubber-technical plants, metal construction, and electrical wiring plants, among others. The largest of these businesses are situated within the city. In addition, Pavlodar has three thermal power plants, over twenty boiler houses, and 5000 private homes that collectively burn more than 3.5 million tons of coal annually. Moreover, there are more than 60,000 garden plots within city limits, as well as countless vegetable gardens maintained by private households, where the cultivation of vegetables, potatoes, fruits, and berries is concentrated.

In 2021, the stationary sources in Pavlodar region released 736.1 thousand tons of pollutants into the atmosphere, according to the Bureau of National Statistics of RK. The majority of industrial enterprises are concentrated in three cities, resulting in the main volume of pollutant emissions into the atmospheric air of Pavlodar region. Ekibastuz accounts for 45.9 %, followed by Aksu with 27.7 %, and Pavlodar with 24.4 %. Other districts within the oblast contribute only 2 % of emissions. The fuel and energy sector emits the largest volumes of pollutants, accounting for 65.4 % of total emissions, followed by metallurgy at 26 %, petrochemicals at 3.2 %, mining at 1.2 %, and other industries at 4.2 %. The primary atmospheric pollutants are sulfur dioxide, nitrogen oxides, solid substances, and carbon monoxide (MEGNRRK, 2021).

Mobile sources, specifically motor vehicles, significantly contribute to air pollution. In 2021, the Bureau of National Statistics of the Republic of Kazakhstan reported that there were 145.2 thousand passenger cars and 22.8 thousand trucks in the Pavlodar region. Emissions from mobile sources totaled 32.8 thousand tons in 2021 (MEGNRRK, 2021).

According to the Information Bulletin on the state of the environment of the Republic of Kazakhstan for September 2023, provided by the national hydrometeorological service of the Republic of Kazakhstan (Republican State Enterprise "Kazhydromet" of the Ministry of ecology and natural resources of the Republic of Kazakhstan) Pavlodar belongs to the cities with an increased level of atmospheric air pollution (Kazhydromet, 2023).

The city's territory is nominally divided into four zones: northern (industrial), eastern (industrial), central (residential), and northern suburbs (Pavlodarskoye village, Zangar village). This study focuses on air quality in the residential area of Pavlodar and covers an area of 84.37 km^2. The research area is presented in Figure 1.

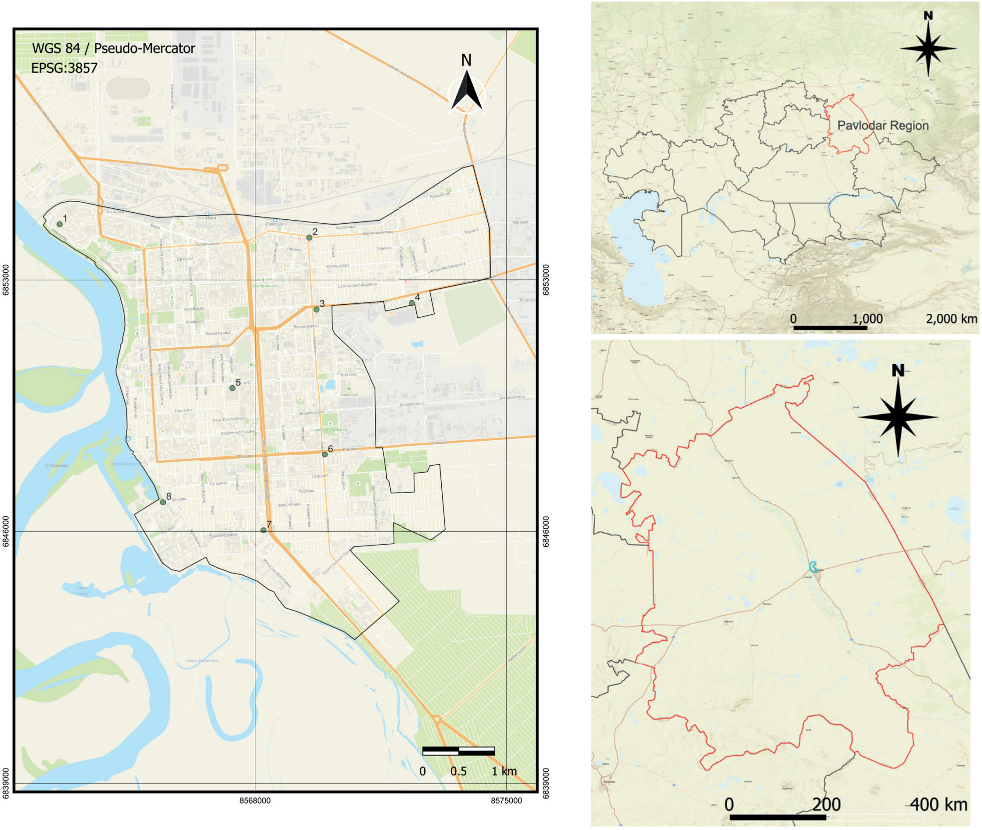

Figure 1. Research area with sampling map.

Sampling and analysis methods

PM2.5 and PM10 concentrations were measured using Plantower PMS5003 dust sensors (China). The PMS5003 is a digital and versatile sensor capable of measuring suspended particles in the air, or particle concentration, and transmitting output data through a digital interface. The laser scattering principle is utilized in the sensor, wherein a laser is used to create scattering of the suspended particles in the air. The scattered light is then collected to obtain the curve of change in scattering light with time. Eventually, a microprocessor-based on MIE theory is used to calculate the equivalent particle diameter and the number of particles with different diameters per unit volume.

The measurements were obtained from the open source portal waqi.info (waqi.info, n.d.), which translates data from 7 stations located in various parts of Pavlodar city's residential area. Although the stations did not function synchronously, the most data was available for the years 2022 and 2023, so these years were used for analysis. The sampling map is displayed in Figure 1, while Tables 1 and 2 present the descriptive statistics for the daily average PM2.5 and PM10 concentrations. N represents the number of measurements taken each day.

Table 1 – Descriptive statistics for average daily PM2.5 levels (μg m^{-3}) recorded in 2023.

Location	N	mean	median	std	min	max
L1	215	67	15	19	5	130
L2	289	46	22	15	11	81
L3	264	38	16	13	5	72
L4	281	62	29	21	13	110
L5	247	17	12	5	7	28
L6	93	10	7	3	4	15
L7	213	38	16	14	4	72

Table 2 – Descriptive statistics for average daily PM10 levels (μg m^{-3}) recorded in 2023

Location	N	mean	median	std	min	max
L1	215	86	18	24	6	166
L2	290	52	25	17	13	91
L3	0	-	-	-	-	-
L4	282	81	39	28	17	144
L5	247	21	14	6	7	34
L6	93	12	8	3	5	19
L7	213	48	20	17	6	90

AQI

The AQI (air quality index) was used as the main indicator in the study to assess pollution levels. The United States Environmental Protection Agency (USEPA) introduced the Air Quality Index (AQI) 45 years ago to provide the public with crucial data on air pollution (Manjeet et al., 2023). Previously, only select urban areas published information on air quality, and measurements varied among different locations. The implementation of a standardized AQI for assessing air quality across the country has set an important benchmark for similar governmental and regulatory organizations worldwide in the future (Al Rabadi et al., 2023; Horn & Dasgupta, 2024).

AQI was calculated based on tables of correspondence with PM2.5 and PM10 pollutants in accordance with (AirNow.Gov, n.d.; Sarmadi et al., 2021). The convenient levels of AQI are presented in Table 3.

Table 3 – Air Quality Index (AQI) Categories for PM2.5 and PM10 pollutants (AirNow.Gov, n.d.)

AQI Category	AQI Value	PM2.5 (μg m^{-3})	PM10 (μg m^{-3})
Good	0-50	0-12	0-54
Moderate	51 -100	12.1-35.4	55 -154
Unhealthy for Sensitive Groups	101 -150	35.5-55.4	155 - 254
Unhealthy	151 - 200	55.5 -150.4	255-354
Very Unhealthy	201 - 300	150.5 - 250.4	355 - 424
Hazardous	301 - 500	250.5 - 500.4	425 - 604
Beyond Index	>500	> 500.4	>604

Statistical analysis and visualization

The correlation analysis was performed with a Python script using the "corr()" function from the Pandas library. This function calculates pairwise correlation of columns, excluding null or missing values. By default, the function calculates the Pearson correlation coefficient between columns and returns a DataFrame containing the column correlation matrix. Each element of the correlation matrix represents the correlation between two columns and has a square matrix structure. The results of the statistical analysis of the data, graphs and heat maps, were visualized using Seaborn and Matplotlib libraries.

The spatial data analysis for each pollutant utilized a GIS software to map the air pollution variances across the study area. The multilevel b-spline function of the SAGA module was employed to investigate the air quality's spatial distribution characteristics. The generated raster grids were then used to create isoline polygons utilizing the "Contour Lines from Raster" feature in the SAGA module. The geographic information was analyzed and mapped using QGIS 3.28.6 software, which is an official product of the Open Source Geospatial Foundation (OSGeo) and licensed under the GNU General Public License.

Results

Spatio-temporal analysis of air quality. The air quality monitoring outcomes for Pavlodar city, which comprise data regarding the concentrations of the PM2.5 and PM10 pollutants, are displayed in Table 4. Please note that PM10 content measurements were not taken at L3 site, and the L6 station was non-operational in 2022. Only 22 daily mean pollutant values were gathered from L1 station in 2022. The inconsistency in collecting data from monitoring stations is related to technical problems of uninterrupted power supply and Internet access.

Table 4 – Air quality parameters measured in the study territory in 2022-2023 years

Year	Location	N[1] (PM2.5)	PM2.5[2], μg m^{-3}	N (PM10)	PM10[3], μg m^{-3}	AQI (concerning pollutant)	PM2.5 exceeding[4], %	PM10 exceeding[5], %	AQI exceeding[6]
2023	L1	215	14.96	215	18.24	57 (PM2.5)	19.53	6.05	46.98
	L2	289	22.16	290	25.32	72 (PM2.5)	31.49	13.45	43.6
	L3	264	16.29	0	-	60 (PM2.5)	22.73	-	49.24
	L4	281	29.44	282	39.48	87 (PM2.5)	38.08	20.57	85.77
	L5	247	12.09	247	14.34	51 (PM2.5)	11.34	4.05	30.77
	L6	93	7.33	93	8.28	31 (PM2.5)	0	0	13.98
	L7	213	15.66	213	19.57	58 (PM2.5)	23	12.21	41.78
2022	L1	28	17.09	28	21.87	61 (PM2.5)	17.86	3.57	64.29
	L2	321	32.63	321	37.57	94 (PM2.5)	51.71	22.74	85.05
	L3	302	15.69	0	-	59 (PM2.5)	19.87	-	54.97
	L4	286	23	286	29.58	74 (PM2.5)	34.62	15.73	63.29
	L5	260	20.29	260	24.56	68 (PM2.5)	27.69	9.23	63.46
	L6	0	-	0	-	-	-	-	-
	L7	257	21.37	257	25.97	70 (PM2.5)	37.74	10.51	64.98

[1] Number of daily measurements

[2] Average daily concentration of PM2.5

[3] Average daily concentration of PM10

[4] Share of days with PM2.5 exceeded WHO daily limit value (25 μg m^{-3}), % (WHO, 2006)

[5] Share of days with PM10 exceeded WHO daily limit value (50 μg m^{-3}), % (WHO, 2006)

[6] Share of days with AQI exceeded “Good” air pollution level (>50)

In 2023, the average annual level of PM2.5 exceeds the WHO standard (10 μg m^{-3}) in six out of seven locations, as per the findings (WHO, 2006). The only location that does not exceed the average annual WHO standard is L6, located farthest from the industrial zones near the Irtysh River to the southwest of the city center. In 2023, the standard for the PM10 pollutant (20 μg m^{-3}) (WHO, 2006) is only exceeded at two sites - L2 and L4, with levels of 25.32 and 39.48 μg m^{-3}, respectively. The lowest amounts of pollution are observed at location L6, as well as L5, which is situated at the center of the study area.

In 2022, all monitoring locations surpassed the WHO annual average standard for PM2.5. However, it is important to note that the monitoring station at location L6 was not operational during that year. The highest recorded PM2.5 level, reaching thrice the threshold standard, was observed at location L2. This location is situated in close proximity to both the northern and eastern industrial areas. In contrast, a more unfavorable situation was observed for the pollutant PM10 compared to 2023. Thus, all monitoring stations exceed the threshold level recommended by the WHO. The station at location L2, in particular, recorded an almost double exceedance of the standard - 37.57 μg m^{-3}.

Annual average AQI calculations by location indicate that PM2.5 has the most significant impact on air quality. In 2023, only one location out of seven (14%) recorded an AQI level that corresponds to a "good" level and did not exceed a threshold value of 50. The remaining locations (86 %) had an AQI level below 100, indicating a "medium" level of air pollution. The maximum AQI level of 87 was recorded at location L4, which is directly adjacent to the eastern industrial zone of Pavlodar city. A large number of small production sites and warehouses are situated in this area. The overall AQI distribution remains the same in 2022, but pollution levels have slightly increased. The maximum AQI value in 2022 is 94 and was registered at location L2.

Based on the gathered data, we analyzed the percentage of days in the observed period when the average daily concentration of pollutants exceeded the average daily limit values according to the WHO recommendations. Our findings reveal that L6 had the most favorable air quality. As a matter of fact, no PM2.5 and PM10 threshold concentrations exceeded the recommended levels in this location in 2023. In locations L2 and L4, the percentage of days where the daily average concentration of PM2.5 exceeded the threshold level was 38.08 % and 31.49 %, respectively. The proportion of days where PM10 exceeded the daily mean threshold value was considerably lower. Therefore, the highest proportion of days with threshold value exceedances occurred at location L4 and reached 20.57 %. These indicators showed improvement in air quality in 2023 compared to 2022 when the values were higher. In 2022, the areas with the highest PM2.5 levels exceeding the daily average threshold were observed at locations L2, L7, and L4, respectively reaching 51.71%, 37.74%, and 34.62 %. Meanwhile, for PM10, the situation was more positive in 2022 as well as in 2023 compared to PM2.5, with all locations experiencing exceedances of recommended levels but a lower level of exceedance for PM10 than PM2.5.

The annual average AQI was exceeded for all sites in both 2023 and 2022. A higher overall percentage of days exceeding the AQI 50 threshold was observed in 2022 compared to 2023. For instance, at location L2 in 2022, AQI values above 50 were recorded on 85.05% of monitored days, indicating "moderate" to "unhealthy" ambient air quality. The percentage of days with recorded exceedance of the AQI 50 threshold is more than 60% for L1, L4, L5, L7.

Figure 2 illustrates the yearly distribution diagrams of average monthly concentrations of PM2.5 and PM10 pollutants, monthly average AQI values, and monthly average wind speed dynamics. The average pollutant concentrations displayed a distinct seasonal pattern. The highest values of pollutant concentrations were observed in the winter months and late fall, while the lowest values of concentrations, as well as AQI values, were observed in the summer months.

The annual distribution of monthly averages is comparable across all monitoring locations. Peak values are generally seen during winter in December and February, which also correspond to annual minimums of mean monthly wind speed. Pollutant concentrations tend to decrease in January. Winter peaks may significantly increase the occurrence and dispersion of particulate matter during the colder months due to fuel combustion activities (such as CHP, residential heating with coal stoves, and more intensive combustion of motor fuels for prolonged motor vehicle warming). Additionally, lower wind speeds in the same period can further exacerbate the levels of fine particulate matter present in the atmosphere. It is important to note that wind speed reduction in September does not result in a similar effect, which could be attributed to the fact that the period is still warm enough, and the sources of PM2.5 and PM10 pollutants discussed earlier are not active.

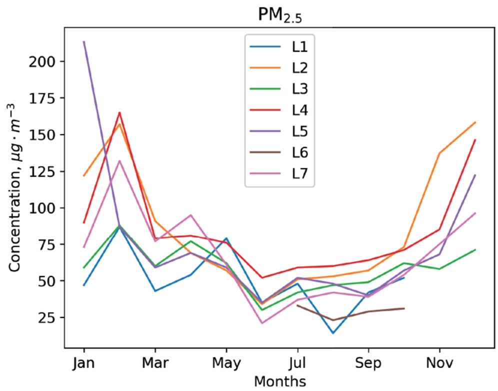

Figure 2.1

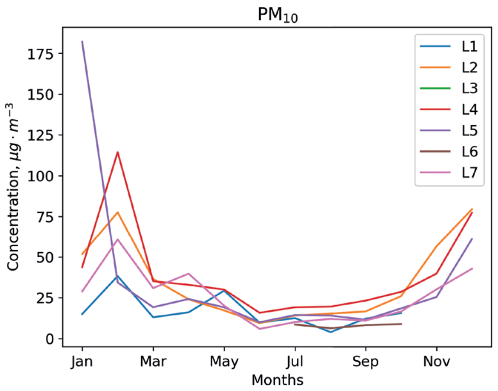

Figure 2.2

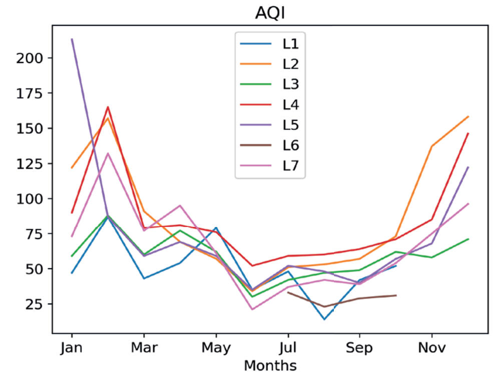

Figure 2.3

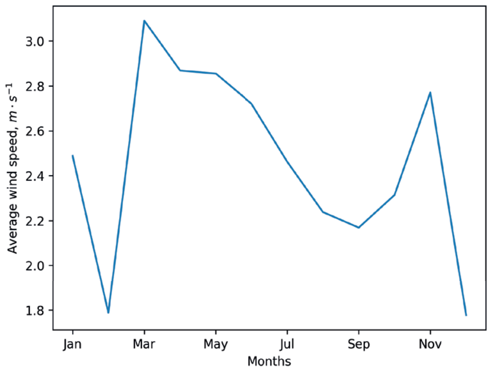

Figure 2.4

Figure 2. Annual distribution of monthly average concentrations of PM2.5 (2.1), PM10 (2.2), AQI (2.3), and wind speed (2.4).

Figure 3 illustrates the spatial distribution of air quality index (AQI) values and locations exceeding AQI 50. The greatest AQI values correspond to locations L4 and L2, which are geographically close to the northern and eastern industrial sectors. It is worth noting that there is a reduction in the adverse environmental impact of industrial facilities on the residential area of the city towards the Irtysh River. The distribution of pollutants indicates a linear relationship between pollution levels and distance from industrial areas. The most environmentally friendly areas of the city are located in the southwestern part of the city, near the Irtysh river bank. However, as we move to the southeast, pollution levels increase, potentially due to the influence of the industrial enterprises operating in the eastern industrial zone. Statistical correlation analysis of the presented visualized data was used to analyze the trends of air pollution distribution.

Statistical correlation analysis. We utilized a correlation matrix with Pearson correlation coefficients to evaluate the connections among diverse components in the study region. The Pearson correlation coefficient indicates the degree of linear association between two variables on a spectrum ranging from -1 to 1. A -1 value indicates a fully inverse linear correlation, 0 indicates no linear association, and 1 demonstrates a positive linear correlation.

The correlation analysis is predicated on the following hypotheses:

1) the concentration of pollutants is contingent upon the location of the area under examination. The coverage area of the study is determined by the minimum bounding rectangle of the study region. The coverage area of the study is determined by the minimum bounding rectangle of the study region.

2) The concentration of pollutants decreases as distance increases from the northern boundary of the study area, as the northern industrial zone of Pavlodar is located on that side of the residential area.

3) As the eastern industrial zone of Pavlodar is situated on the other side of the residential area, pollutants decrease in concentration when moving away from the eastern boundary of the study area.

4) Both the northern and eastern industrial zones impact the distribution of particulate matter in the air. Thus, their influence jointly affects the pollution level. This may result in a correlation between pollution and the hypotenuse of a right triangle, where the catheti represent the distances from the studied location to the northern and eastern coverage boundaries.

Figure 4 displays the correlation matrix computed from the given dataset, which includes the north distance (distance from this location to the northern limit of study area coverage), east distance (distance to the eastern limit of coverage), hypotenuse at north and east distances, as well as PM2.5 and PM10 concentrations at this location.

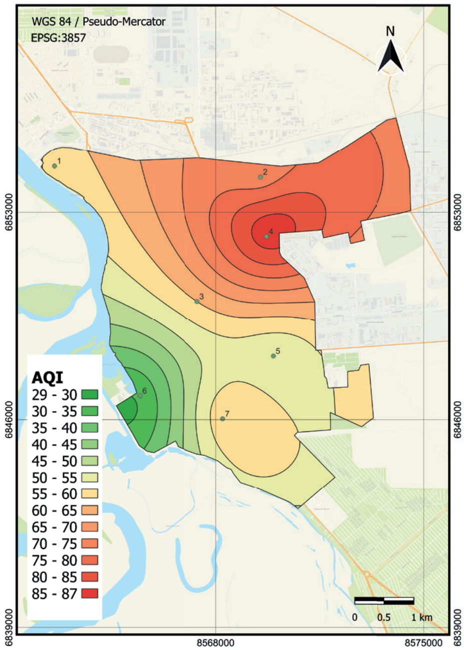

Figure 3.1

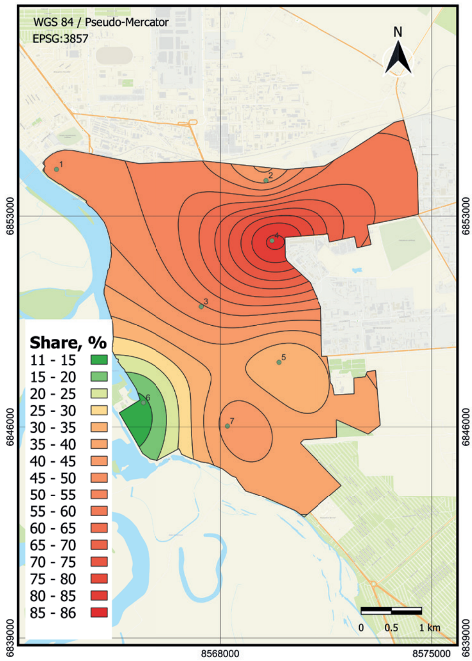

Figure 3.2

Figure 3. Spatial distribution of AQI (3.1) and percentage of days with recorded AQI higher than 50 (3.2).

The correlation matrix indicates patterns and trends within the data. The Pearson's coefficient (r) reflects a strong positive correlation (0.98) between PM2.5 and PM10 concentrations, which suggests the pollutants share a common source of origin and have a similar distribution trend over the territory. Additionally, there is a moderately negative correlation (-0.57) between PM2.5 concentration and the distance to the northern boundary of the coverage area. The weakly negative correlation (-0.47) between PM2.5 parameters and distance to the east suggests that the northern industrial zone has a slightly greater influence on the ecological conditions within the residential area of Pavlodar city.

A strong negative correlation exists between the hypotenuse and the PM2.5 and PM10 parameters at -0.81 and -0.74, respectively. These findings suggest a mutual impact of the two industrial zones on the city's territory. Additionally, the data implies a trend of decreasing air pollution levels towards the southwest, in agreement with the spatial distribution maps for AQI.

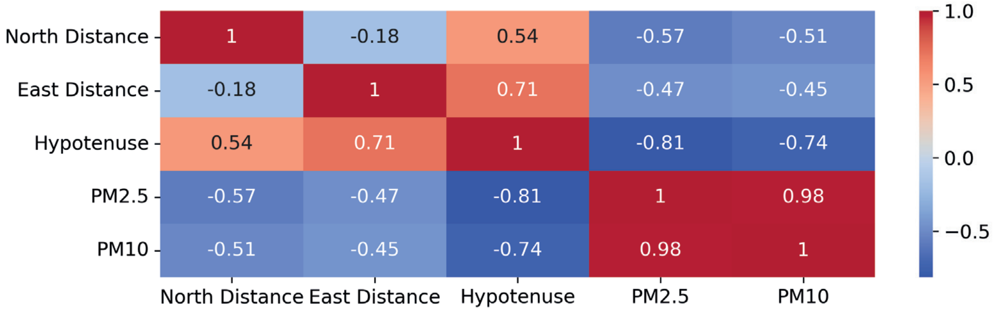

Figure 4. Correlation matrix with Pearson's coefficients

To visualize the Pearson coefficients, scatter plots were constructed. The slope angle and direction of a straight trend line, which minimizes the distance between points and the line itself, can then be determined. This line directly correlates with the Pearson coefficient for the two variables analyzed. Figure 5 presents the scatter plots for the analyzed pairs of values. The presented plots indicate a moderate negative trend with significantly scattered relationship points in plots 5.1 and 5.2. Thus, a linear relationship between air pollution levels and distance from solely one industrial zone (north or east) cannot be definitively established. Graph 5.3 illustrates a stronger correlation between PM2.5 concentration and the hypotenuse, which represents the equidistance from two industrial zones. This correlation is evident not only in terms of the Pearson's coefficient value but also visually. Therefore, this parameter is a more reliable reflection of the trend in the distribution of pollutants in the air of Pavlodar city's residential zone. Furthermore, it confirms the hypothesis of a mutual influence of both industrial zones on the city's atmosphere.

Discussion

The research presented in this article was aimed at analyzing the level of air pollution in the residential area of Pavlodar city, as well as identifying trends in the spatial distribution of PM2.5 and PM10 pollutants. For this purpose, data from 7 monitoring stations were analyzed for the period 2022-2023. The methodology of the study correlates with previous studies conducted in Almaty (Kazakhstan) (Kerimray et al., 2020), Astana (Kazakhstan) (Kerimray et al., 2018), Yanbu (Saudi Arabia) (Al Rabadi et al., 2023), Shenzhen (China) (Liu et al., 2023).

The results of the analysis of the air quality correlate with the conclusions published in the Information bulletin on the state of the environment of the Republic of Kazakhstan for September 2023 (Kazhydromet, 2003) that the level of air pollution in Pavlodar is increased. The results of the study are also consistent with previously published works

(Kakabayev et al., 2023; Lukyanets et al., 2023). For example, the annual average level of PM2.5 exceeds the WHO recommended limit (10 μg m^{-3}, (WHO, 2006)) in six out of seven monitoring stations. The standard for PM10 (20 μg m^{-3}, (WHO, 2006)) is exceeded at only two sites in 2023. However, the WHO annual average standard for PM10 was exceeded at all monitoring stations in 2022. The AQI calculation showed that PM2.5 is the main influencing component in all cases. The annual average AQI values in 86% of the locations show a "moderate" level of pollution.

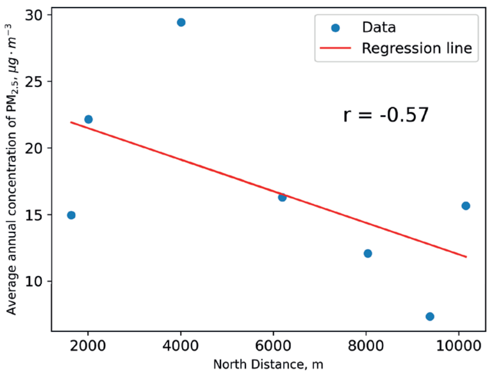

Figure 5.1

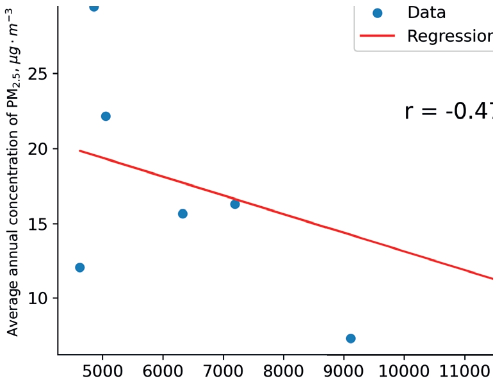

Figure 5.2

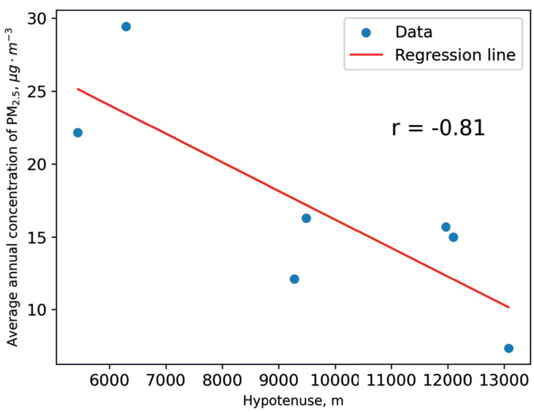

Figure 5.3

Figure 5. Scatter plots of parameter pairs with lines of best fit and Pearson's coefficients

The highest levels of PM2.5 and PM10 are observed in locations adjacent to the northern and eastern industrial zones of the city. This is probably due to the presence of a large number of small industrial and economic facilities in these areas, as well as in these zones are located large enterprises, such as Pavlodar Petrochemical Plant, three thermal power plants, Pavlodar Aluminum Plant and others. A significant contribution to air pollution in the city of Pavlodar is made by mobile sources, in particular motor vehicles. Thus, according to official sources, emissions from mobile sources in 2021 amounted to 32.8 thousand tons (MEGNRRK, 2021). The most environmentally friendly areas of the city are located in the south-west, away from industrial zones. There is a certain correlation between the decrease in wind speed and the increase in the concentration of air pollutants, especially in winter. In general, the AQI level peaks in the winter months.

Based on the results of the statistical analysis, it can be concluded that among the proposed methods for modeling the dispersion of air pollution, the most adequate correlation is observed between the concentration of pollution and the hypotenuse expressing the distance from both the northern and eastern industrial zones. The concentrations of PM2.5 and PM10 show a strong positive correlation with a Pearson coefficient of 0.98, indicating with high probability the same sources of origin and distribution trends of both pollutants. Due to the high degree of correlation, it is sufficient to follow the trends of one pollutant for prediction. Since PM2.5 has the strongest negative influence and is also the most influential pollutant in the AQI calculation, it is recommended to use this pollutant for the prediction of particulate matter dispersion.

Poor air quality in the city of Pavlodar has a negative impact on public health. Exposure to PM2.5 and PM10 can cause various health problems, including respiratory diseases (Tatayeva & Burumbayeva, 2014; Wang et al., 2021; Yan et al., 2022), cardiovascular diseases (Huang & Chen, 2021; Ren et al., 2021), stroke (Chen et al., 2023; Gale et al., 2020), and cancer (Oh et al., 2023; Zhang et al., 2023; Zhou, 2021).

According to WHO recommendations, not only particulate matter, but also sulfur dioxide, nitrogen dioxide, carbon monoxide and ground-level ozone have a significant impact on human health (WHO, 2006). Therefore, in order to continue this scientific research, we plan to study the distribution of the above-mentioned pollutants in the city of Pavlodar. Also, in the future it is necessary to carry out a more complete correlation analysis of pollutant concentrations with meteorological data such as humidity, wind speed and direction, temperature, pressure.

Conclusion

In this study, we conducted an extensive analysis of air quality in the residential area of Pavlodar City, Kazakhstan. Our research aimed to investigate the spatial distribution and temporal trends of PM2.5 and PM10 pollutants and their impact on air quality. We analyzed data collected from seven monitoring stations over the years 2022 and 2023, and our findings revealed several critical insights.

First, the results indicate that the level of air pollution in Pavlodar City's residential area is elevated. In 2023, the annual average concentration of PM2.5 exceeded the WHO recommended limit of 10 $\mu g\ m^{-3}$ in six out of seven monitoring stations. Additionally, the standard for PM10 (20 $\mu g\ m^{-3}$) was exceeded at two locations. Comparatively, in 2022, all monitoring stations exceeded the WHO annual average standard for PM2.5, highlighting the persistence of air quality issues.

The analysis of the Air Quality Index (AQI) demonstrated that PM2.5 is the predominant pollutant affecting air quality in the city. In 2023, only one location recorded an AQI level corresponding to "Good", while the remaining locations exhibited a "Medium" level of air pollution. The maximum AQI level was observed near the eastern industrial zone of Pavlodar City. A similar pattern was observed in 2022, but with slightly higher pollution levels.

Our study also identified geographical correlations between industrial zones and pollution levels. Locations near the northern and eastern industrial areas of the city experienced higher concentrations of PM2.5 and PM10. This is attributed to the presence of numerous industrial facilities in these regions, including major enterprises such as Pavlodar Petrochemical Plant, thermal power plants, and aluminum production facilities.

We further observed that the wind speed has a significant influence on pollutant concentrations, particularly in the winter months. Pollution levels tended to peak during the colder seasons, attributed to increased fuel combustion activities for heating and reduced wind speeds that limit dispersion.

Statistical correlation analysis revealed a strong positive correlation between PM2.5 and PM10 concentrations, suggesting a common source of origin and similar distribution trends. Furthermore, we established that the distance from both the northern and eastern industrial zones (represented as the hypotenuse in a right triangle) is the most reliable predictor of air pollution trends within the city amongst suggested.

The implications of poor air quality are concerning, as exposure to PM2.5 and PM10 pollutants can lead to various health problems, including respiratory and cardiovascular diseases, stroke, and cancer. Additionally, other pollutants like sulfur dioxide, nitrogen dioxide, carbon monoxide, and ground-level ozone, as recommended by the WHO, can also have detrimental effects on human health.

In future research, we plan to expand our investigation to other air pollutants and consider meteorological data such as humidity, wind speed and direction, temperature, and pressure. This comprehensive approach will provide a more complete understanding of the factors contributing to air pollution in Pavlodar City. Ultimately, our findings underscore the urgency of addressing air quality issues to safeguard public health and the environment in the region.

REFERENCES

Al Rabadi S.J., Al-Zboon K., Alrawashdeh K.A. & AL-Samrraie L. (2023). Assessment of ambient air quality in heavy industrial localities: A case study of Yanbu industrial city. Environmental Monitoring and Assessment, — 195(6). — https://doi.org/10.1007/s10661-023-11267-w

Amann M., Kiesewetter G., Schöpp W., Klimont Z., Winiwarter W., Cofala J., Rafaj P., Höglund-Isaksson L., Gomez-Sabriana A., Heyes C., Purohit P., Borken-Kleefeld J., Wagner F., Sander R., Fagerli H., Nyiri A., Cozzi L., & Pavarini C. (2020). Reducing global air pollution: The scope for further policy interventions. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, — 378(2183), — 20190331. — https://doi.org/10.1098/rsta.2019.0331

AQICN. (2020). A Beginner's Guide to Air Quality Instant-Cast and Now-Cast. Aqicn.Org. — Retrieved October 22, — 2023, — https://aqicn.org/faq/2015-03-15/air-quality-nowcast-a-beginners-guide/

AQI Calculator. AirNow.gov, U.S. EPA. — Retrieved October 22, — 2023, — https://www.airnow.gov/aqi/aqi-calculator

Azhayev G., Esimova D., Sonko S.M., Safarov R.Z., Shomanova Zh.K. & Sambou A. (2020). Geoecological environmental evaluation of Pavlodar region of the republic of Kazakhstan as a factor of perspectives for touristic activity. GeoJournal of Tourism and Geosites, — 28(1), — 104–113. — https://doi.org/10.30892/gtg.28108-455

Chen W., Luo Y., Quan J., Zhou, J., Yi B. & Huang Z. (2023). PM2.5 induces renal tubular injury by activating NLRP3-mediated pyroptosis. Ecotoxicology and Environmental Safety, — 265. — https://doi.org/10.1016/j.ecoenv.2023.115490

Gale S.D., Erickson L.D., Anderson J.E., Brown B.L. & Hedges D.W. (2020). Association between exposure to air pollution and prefrontal cortical volume in adults: A cross-sectional study from the UK biobank. Environmental Research, — 185. — https://doi.org/10.1016/j.envres.2020.109365

Goodwin J. (2023). Guest Editorial: Emissions Standards Delivering Cleaner Air on the Road to Net Zero. Johnson Matthey Technology Review, — 67(2), — 128–129. — https://doi.org/10.1595/205651323X16790500384938

Hidalgo D. & Sanz Bedate S. (2022). Economic Valuation and Cost of Air Pollution: In A. Rafay (Ed.), Advances in Finance, Accounting, and Economics. — Pp. 278–300. IGI Global. — https://doi.org/10.4018/978-1-7998-8210-7.ch011

Horn S.A. & Dasgupta P.K. (2024). The Air Quality Index (AQI) in historical and analytical perspective a tutorial review. Talanta, — 267. https://doi.org/10.1016/j.talanta.2023.125260

Huang Q. & Chen Q. (2021). The Effects of PM2.5 on chronic cardio-cerebrovascular diseases and respiratory diseases in different groups. — 1774(1). — https://doi.org/10.1088/1742-6596/1774/1/012016

Jonidi Jafari A., Charkhloo E. & Pasalari H. (2021). Urban air pollution control policies and strategies: A systematic review. Journal of Environmental Health Science and Engineering, — 19(2), — 1911–1940. — https://doi.org/10.1007/s40201-021-00744-4

Kakabayev A., Yermekova A., Baikenova G., Abdurahmanov I. & Baituk G. (2023). Technogenic impact assessment on the environment of Pavlodar region using GIS technologies. — 386. — https://doi.org/10.1051/e3sconf/202338606001

Kaur J. & Jhamaria C. (2021). Urban Air Pollution and Human Health: A Review. Current World Environment, — 16(2), — 362–377. — https://doi.org/10.12944/CWE.16.Special-Issue1.01

Kazhydromet. (2023). Monthly newsletter on the state of the environment—Kazhydromet [Ezhemesyachnyy informacionnyy byulleten o sostoyanii okruzhayuschey sredy]. — Retrieved October 22, — 2023, — https://www.kazhydromet.kz/en/ecology/ezhemesyachnyy-informacionnyy-byulleten-o-sostoyanii-okruzhayuschey-sredy (in Russ.).

Kerimray A., Azbanbayev E., Kenessov B., Plotitsyn P., Alimbayeva D. & Karaca F. (2020). Spatiotemporal Variations and Contributing Factors of Air Pollutants in Almaty, Kazakhstan. Aerosol and Air Quality Research, — 20(6), — 1340–1352. — https://doi.org/10.4209/aaqr.2019.09.0464

Kerimray A., Bakdolotov A., Sarbassov Y., Inglezakis V. & Poulopoulos S. (2018). Air pollution in Astana: Analysis of recent trends and air quality monitoring system. Materials Today: Proceedings, — 5(11), — 22749–22758. — https://doi.org/10.1016/j.matpr.2018.07.086

Li Y., Tang Y., Fan Z., Zhou H. & Yang Z. (2017). Assessment and comparison of three different air quality indices in China. Environmental Engineering Research, — 23(1), — 21–27. — https://doi.org/10.4491/eer.2017.006

Liu C., Wu C., Kang X., Zhang H., Fang Q., Su Y., Li Z., Ye Y., Chang M. & Guo J. (2023). Evaluation of the prediction performance of air quality numerical forecast models in Shenzhen. Atmospheric Environment, — 314. — https://doi.org/10.1016/j.atmosenv.2023.120058

Lukyanets A., Gura D., Savinova O., Kondratenko L. & Lushkov R. (2023). Industrial emissions effect into atmospheric air quality: Mathematical modeling. Reviews on Environmental Health, — 38(2), — 385–393. — https://doi.org/10.1515/reveh-2022-0005

Ma J., Simonich S., & Tao S. (2017). New Discoveries to Old Problems: A Virtual Issue on Air Pollution in Rapidly Industrializing Countries. Environmental Science & Technology, — 51(20), — 11497–11501. — https://doi.org/10.1021/acs.est.7b04885

Manjeet Anurag, Niwas R., Kumar A., Khichar M.L., Shekhar C. & Kumar N. (2023). Spatial and temporal variation in the seasonal air quality index of Haryana, India. Mausam, — 74(3), — 787–794. — https://doi.org/10.54302/mausam.v74i3.1486

Mardenov M.P., Shaimardenov B.M. & Sivaraksha D.M. (2014). The Condition of the Atmospheric Air in Ekibastuz City. In C. Drebenstedt & R. Singhal (Eds.), Mine Planning and Equipment Selection. — Pp. 737–738. — https://doi.org/10.1007/978-3-319-02678-7-71

MEGNRRK. (2021). National Report on the State of the Environment and the Use of Natural Resources of the Republic of Kazakhstan for 2021 [Natsionalnyi doklad o sostoianii okruzhaiushchei sredy i ob ispolzovanii prirodnykh resursov Respubliki Kazakhstan za 2021 god]. Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan. — Retrieved October 22, — 2023, — https://www.gov.kz/memleket/entities/ecogeo/documents/details/383692?lang=ru (in Russ.).

Nossenko Yu.G., Safarov R.Z., Mukanova R.Zh., Zhunusova K.Z., Bajmurat M. & Zhanibekova A.T. (2018). Environmental problems of Pavlodar region [Ekologicheskie problemy Pavlodarskoi oblasti]. Materials of the International Scientific Conference "Global Science and Innovations 2018", Eger, Hungary, — 217–223. — Retrieved October 22, — 2023, — https://ecir.kz/assets/docs/Proceedings_GSI2018.pdf (in Russ.).

Oh I.-J., Park C.-K., Min K.-B., Min J.-Y., Chung C., Yoon S.-H., Kim C. & Yang S.-H. (2023). Healthcare utilization of lung cancer patients associated with exposure to fine particulate matter: A Korean cohort study. Thoracic Cancer, — 14(27), — 2777–2784. — https://doi.org/10.1111/1759-7714.15070

Ren Z., Liu X., Liu T., Chen D., Jiao K., Wang X., Suo J., Yang H., Liao J. & Ma L. (2021). Effect of ambient fine particulates (PM2.5) on hospital admissions for respiratory and cardiovascular diseases in Wuhan, China. Respiratory Research, — 22(1). — https://doi.org/10.1186/s12931-021-01731-x

Roy R. (2018). A race against the clock. Our Planet, —2017. — (4), — 38–39. — https://doi.org/10.18356/a388b131-en

Sarmadi M., Rahimi S., Rezaei M., Sanaei D. & Dianatinasab M. (2021). Air quality index variation before and after the onset of COVID-19 pandemic: A comprehensive study on 87 capital, industrial and polluted cities of the world. Environmental Sciences Europe, — 33(1). — https://doi.org/10.1186/s12302-021-00575-y

Sharma S., Jain S., Khirwadkar P. & Kulkarni S. (2013). The effects of air pollution on the environment and human health. — https://www.semanticscholar.org/paper/THE-EFFECTS-OF-AIR-POLLUTION-ON-THE-ENVIRONMENT-AND-Sharma-Jain/a2ab90fda60b29ef2478dc3b6633c06ae79fb3d2

Tatayeva R. & Burumbayeva M.B. (2014). Air pollution as a factor of lung cancer in Kazakhstan. Ecology & Safety, — 8, 533–539. — https://api.semanticscholar.org/CorpusID:126606614

Vallero D. (2014). Air Pollution's Impact on Ecosystems. In Fundamentals of Air Pollution. — Pp. 341–368. — https://doi.org/10.1016/B978-0-12-401733-7.00014-1

Van Der Wall E.E. (2015). Air pollution: 6.6 million premature deaths in 2050! Netherlands Heart Journal, — 23(12), — 557–558. — https://doi.org/10.1007/s12471-015-0763-9

Wang F., Chen T., Chang Q., Kao Y.-W., Li J., Chen M., Li Y. & Shia B.-C. (2021). Respiratory diseases are positively associated with PM2.5 concentrations in different areas of Taiwan. PLoS ONE, — 16(4 April). — https://doi.org/10.1371/journal.pone.0249694

Weather in Pavlodar-Climate Monitor for July — 2023 [Pogoda v Pavlodare—Klimaticheskii monitor za iyul 2023 goda]. Retrieved October 22, — 2023, — from http://pogodaiklimat.ru/monitor.php?id=36003&month=7&year=2023 (in Russ.).

Weather in Pavlodar-Climate Monitor for January — 2023 [Pogoda v Pavlodare—Klimaticheskii monitor za yanvar 2023 goda]. — Retrieved October 22, — 2023, — http://pogodaiklimat.ru/monitor.php?id=36003&month=1&year=2023 (in Russ.).

World Health Organization. (2006). Air Quality Guidelines: Global Update 2005: Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide. World Health Organization. — https://books.google.kz/books?id=7VbxUdlJE8wC

World's Air Pollution: Real-time Air Quality Index. Waqi. Info. — Retrieved October 22, — 2023, — https://waqi.info/

Yan M., Ge H., Zhang L., Chen X., Yang X., Liu F., Shan A., Liang F., Li X., Ma Z., Dong G., Liu Y., Chen J., Wang T., Zhao B., Zeng Q., Lu X., Liu Y. & Tang N.-J. (2022). Long-term PM2.5 exposure in association with chronic respiratory diseases morbidity: A cohort study in Northern China. Ecotoxicology and Environmental Safety, — 244. — https://doi.org/10.1016/j.ecoenv.2022.114025

Zhang P., Zhou C., Zhao K., Liu C., Liu C., He F., Peng W., Jia X. & Mi J. (2023). Associations of air pollution and greenness with global burden of breast cancer: An ecological study. Environmental Science and Pollution Research, — 30(47), — 103921–103931. — https://doi.org/10.1007/s11356-023-29579-2

Zhou B. (2021). The epidemiological trends in the burden of lung cancer attributable to PM2.5 exposure in China. — https://doi.org/10.6084/m9.figshare.c.5391184.v1

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