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IDAUP XXXVI Cycle

Air Pollution Cavity Area. The effect of Urban Form on Air Pollution
Dispersal. *Case Study, Tirana, January to March 2023*

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Università
degli Studi
di Ferrara

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Air Pollution Cavity Area.

The Effect of Urban Form on Air
Pollution Dispersal.

Case study, Tirana, January to March 2023

Candidate: Rodion GJOKA
POLIS Supervisor: Dr. Rudina TOTO
DA Supervisor: Prof. Dr. Romeo Farinella

Cycle XXXVI

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INTERNATIONAL DOCTORATE IN ARCHITECTURE AND URBAN PLANNING

Cycle XXXVI

IDAUP Coordinator Prof. Roberto DI GIULIO

Thesis Title

**Air Pollution Cavity Areas, the effect of Urban Form on air pollution dispersal.
*Case study, Tirana from January to March 2023***

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THESIS TITLE:

Air Pollution Cavity Areas, the effect of Urban Form on air pollution dispersal.
Case study, Tirana – January – March 2023

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Acknowledgements:

The inception of my academic endeavour dates back to the midpoint of 2019, when I was distinguished with the highest score among the chosen candidates for the 36th cycle of the joint international Doctoral program between Polis University and the University of Ferrara. This marked the commencement of a profound journey that had been conceptualized even prior to this accolade, stemming from a deep-seated resolve to delve into a research domain that, while challenging, piqued my intellectual curiosity. The focal point of my investigation—air pollution, noise pollution, and ecosystem services within urban environments—has been a subject of considerable discourse among the public since the early 1990s and has garnered attention from the scientific community dating back to the onset of the Industrial Revolution. My ambition was to bridge the disciplinary divide, bringing urban and territorial considerations into closer dialogue with environmental research and the professional community dedicated to these concerns.

The interconnection between urban morphology and the natural dispersion of pollutants emitted in urban contexts emerges as a critical, yet underexplored, facet of environmental and urban planning. Despite the extensive analysis of vortex phenomena for aerodynamic purposes within the automotive industry, applying these insights to urban planning and densification strategies presents a novel challenge. The endeavour to recognize and integrate these phenomena into the urban fabric aims to enhance our understanding and approach to mitigating pollution in densely populated areas. This thesis represents not merely an academic exercise, but a concerted effort to contribute to a body of knowledge that bridges theoretical insights with practical applications in urban and environmental planning. Now, that this journey is being concluded, while new and more intriguing horizons have been opened to me along the way, I extend my deepest gratitude to all those who have supported me on this challenging and rewarding journey towards completing my doctoral thesis." Special thanks to my thesis supervisor and advisor, Dr. Rudina Toto, for her unwavering guidance, patience, and expertise. Dr. Toto insights and encouragement have been invaluable to my research and personal growth both at a professional and academic level. I am also grateful to my co-supervisor from Ferrara University, Prof. Ass. Romeo Farinella for his constructive feedback and support.

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Note: By the end of this journey, together with my family we moved from Tirana to Bonn in Germany. Among various reasons, one was indeed the daily exposure towards air pollution, noise and lack of public recreational areas for my kids in Tirana. Herby this research goes beyond academic purposes and it represent a heartfelt cause to me since we did not manage to inherit to the new generation that minimal quality of life and social interactions we used to obtain from our city just one generation ago.

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1. Abstract

This research reflects upon the promotion of a sustainable solutions for the next generation of urban planning systems addressing the decreasing ecosystem services in urban areas vis a vis the natural dispersal of air pollution and further depollute the cities as one of the main objective of 2050 Green Ageda (European Commision, 2020).

Currently, 73% of Europe's population live in cities and this is projected to increase up to 82% by 2050, resulting in over 36 million new urban citizens. **Cities are a dynamic and diverse habitat**, not only for people, but also for plants, animals and various natural cycles that interlink by offering a fertile and in the same time fragile nexus. With the ever-expanding urban area, there are **less suitable conditions for nature fulfilling its cycles and providing services** that could ease climate related events. Crafting a resilient future for urban areas that should be able in the same time to host and nurture qualitative and healthy life, **nature should be included in the design of new developments and regenerative programs** (United Nations, 2017).

This research is occurring with regard to Western Balkans climatic region as well as its urban characteristics. Last decade environment related occurrences in Western Balkans have undoubtedly proved that the Intergovernmental Panel on Climate Change predictions on the escalation of extreme climate events shall affect our societies and economies. The extent is such that today's required actions/measurers will soon turn into imposed norms. When adding the effects of the COVID-19 global pandemic and the recent energy crisis to this already complex algorithm of the climate emergency, it becomes evident that what is missing is resilience with regard to environment and climate change. Third National communication of Albania indicates that recent climate change scenarios predict a rise in mean temperature and change in precipitation patterns leading in seasonal increasing temperatures and decrease of precipitation.

In addition to climate change, the **urban environment quality represents one of the main concerns globally with regard to the public health status**. There is a scientific consensus that the warming of the climate system is unequivocal while the situation is aggravated by human activities, such as continued pollution in urban areas, poorly managed urbanization or careless land use, all these contributing in environment degradation and biodiversity loss.

Migration in main urban areas affected land use, accommodating needs for residential, commercial and infrastructure developments decreased permeability and overall urban green areas, thus impacting the resilience towards climate change effects and quality of life.

The highest concentration and consequently the largest health impacts are observed in central and eastern European countries, more specifically Balkan peninsula (EEA, 2021).

Despite the growing knowledge on air pollution, with recent technological and practical monitoring systems being implemented from ground level to satellites, numerous studies and research linking air pollution with urban health, other gaps appear to require further research: 1) ways in which urban form can influence a range of outcomes, including air pollution, public health, and social equity. 2) how designing in line with nature ecosystem services, in this case harvesting the power of wind to naturally disperse air pollution from urban areas. 3) can we actually enable such services to be naturally harvested by communities for their well-being.

This research is developed around the central question if urban form (at a rather small scale / neighbourhood level) can affect the natural dispersion of air pollutants and even create areas where pollution is captured creating thus unintended hot-spot. Taking into consideration that odd phenomena during monitoring at ground level indicate that certain areas within the cities appear to have higher concentration of air pollution even though they appear far from emitting sources or even protected from them.

Methodologically, the geographical area of this research is the capital city of Albania, Tirana. Whereas the exact locations, selected through a scrupulous approach based into their urban form, proximity with emission sources, orientation and morphology. These 4 areas are the following: KIKA complex, MAGENT complex, Delijorgji complex (all constructed between 2010-2020) and prefabricated complex behind "Ish-Ekspozita" (constructed during the 70s).

Besides developing a critical and discussion on Urban Air Pollution and its linkage with Urban Form, the research includes field works through: daily monitoring the concentration (*in ppm and $\mu\text{g}/\text{m}^3$*) of the gaseous Nitrogen Dioxide (NO_2), Particular Matters $\text{PM}_{2.5}$ and PM_{10} , daily monitoring of wind direction and speed, humidity, meteorological conditions. Monitoring conducted from 1st January to 31st March 2023. Daily site monitoring sheets were filled and digitalized into excel database and further in GIS, whereas mapping of pollution dispersal and the effect of meteorological conditions indicated and visualized the temporal effect that urban form had on the phenomena of "Air Pollution Cavity Areas". The existences of such phenomena is reflected in the results of these daily monitoring of 9 monitoring points per each of the study areas.

The utilization of the Statistical Correlation Coefficient, denoted as "r", is pivotal in quantitatively assessing the magnitude and orientation of a linear correlation between observed variables, such

as pollutant concentration levels and wind velocity. This metric, a seminal contribution by Karl Pearson—a distinguished British mathematician and biometrician—during the transition from the 19th to the 20th century, serves as a foundational statistical tool in elucidating the dynamics between environmental variables. Pearson's introduction of correlation factor, facilitates a nuanced understanding of the interdependencies within environmental systems, particularly in the context of urban air quality management.

This study leverages the Correlation Coefficient as a cornerstone in constructing a sophisticated analytical framework aimed at an in-depth investigation of urban air pollution dynamics and their natural dispersion mechanisms in relation to urban form. Further the logical framework of this research could be expanded and include Computational Fluid Dynamics (CFD), fostering to simulate and analyse the intricate flow patterns of air pollutants within urban environments, offering insights into the mechanisms driving their dispersion. The integration of micro-climate observations furthers the comprehension of localized atmospheric conditions, could lead future researchers to enriching the analysis of pollutant dispersal phenomena.

Finally, the incorporation of sustainable urban planning practices within this analytical framework underscores a proactive approach to mitigating the adverse spatial and temporal impacts of Air Pollution Cavity Areas on public health. By synthesizing years of site-monitoring and detailed literature, combined with empirical climatic data and forward-thinking urban design principles, the research candidate delineates a path towards reducing the environmental and health ramifications of urban air pollution. Through such a multidisciplinary methodology, the study not only contributes to the academic discourse on environmental science and urban planning but also proposes actionable strategies to enhance urban air quality and, by extension, public health outcomes.

Abstract:

Questa ricerca riflette sulla promozione di soluzioni sostenibili per la prossima generazione di sistemi di pianificazione urbana affrontando la diminuzione dei servizi ecosistemici nelle aree urbane vis-a-vis la dispersione naturale dell'inquinamento atmosferico e ulteriormente decontaminare le città come uno degli obiettivi principali dell'Agenda Verde 2050 (Commissione Europea, 2020).

Attualmente, il 73% della popolazione europea vive nelle città e si prevede che questo aumenterà fino all'82% entro il 2050, risultando in oltre 36 milioni di nuovi cittadini urbani. Le città sono un habitat dinamico e diversificato, non solo per le persone, ma anche per piante, animali e vari cicli naturali che si interconnettono offrendo un nexus al tempo stesso fertile e fragile. Con l'espansione urbana sempre crescente, ci sono meno condizioni adatte affinché la natura compia i suoi cicli e fornisca servizi che potrebbero alleviare gli eventi climatici correlati. Creare un futuro resiliente per le aree urbane che dovrebbe essere in grado allo stesso tempo di ospitare e nutrire una vita qualitativa e sana, la natura dovrebbe essere inclusa nella progettazione di nuovi sviluppi e programmi rigenerativi (Nazioni Unite, 2017).

Questa ricerca si svolge in relazione alla regione climatica dei Balcani Occidentali così come alle sue caratteristiche urbane. Gli avvenimenti ambientali dell'ultimo decennio nei Balcani Occidentali hanno indubbiamente dimostrato che le previsioni del Gruppo Intergovernativo sui Cambiamenti Climatici sull'escalation di eventi climatici estremi influenzeranno le nostre società e economie. L'entità è tale che le azioni/misure richieste oggi diventeranno presto norme imposte. Quando si aggiungono gli effetti della pandemia globale di COVID-19 e la recente crisi energetica a questo già complesso algoritmo dell'emergenza climatica, diventa evidente che ciò che manca è la resilienza rispetto all'ambiente e ai cambiamenti climatici. La Terza Comunicazione Nazionale dell'Albania indica che gli attuali scenari di cambiamento climatico prevedono un aumento della temperatura media e un cambiamento nei modelli di precipitazione che portano a un aumento delle temperature stagionali e una diminuzione delle precipitazioni.

Oltre al cambiamento climatico, la qualità dell'ambiente urbano rappresenta una delle principali preoccupazioni a livello globale per quanto riguarda lo stato di salute pubblica. Esiste un consenso scientifico sul fatto che il riscaldamento del sistema climatico è inequivocabile mentre la situazione è aggravata dalle attività umane, come l'inquinamento continuo nelle aree urbane, l'urbanizzazione mal gestita o l'uso negligente del suolo, contribuendo tutti alla degradazione ambientale e alla

perdita di biodiversità. La migrazione nelle principali aree urbane ha influenzato l'uso del suolo, soddisfacendo le esigenze residenziali, commerciali e di sviluppo infrastrutturale diminuendo la permeabilità e le aree verdi urbane complessive, incidendo così sulla resilienza agli effetti del cambiamento climatico e sulla qualità della vita. La più alta concentrazione e conseguentemente i maggiori impatti sulla salute sono osservati nei paesi dell'Europa centrale e orientale, più specificamente nella penisola balcanica (AEA, 2021).

Nonostante la crescente conoscenza sull'inquinamento atmosferico, con recenti sistemi di monitoraggio tecnologici e pratici implementati dal livello del suolo ai satelliti, numerosi studi e ricerche che collegano l'inquinamento atmosferico alla salute urbana, emergono altre lacune che richiedono ulteriori ricerche: 1) modi in cui la forma urbana può influenzare una gamma di risultati, inclusi l'inquinamento atmosferico, la salute pubblica e l'equità sociale. 2) come progettare in linea con i servizi ecosistemici della natura, in questo caso sfruttando il potere del vento per disperdere naturalmente l'inquinamento atmosferico dalle aree urbane. 3) possiamo effettivamente consentire a tali servizi di essere naturalmente raccolti dalle comunità per il loro benessere.

Questa ricerca si sviluppa attorno alla domanda centrale se la forma urbana (a una scala piuttosto piccola / livello di quartiere) può influenzare la dispersione naturale degli inquinanti atmosferici e persino creare aree dove l'inquinamento viene catturato creando così punti caldi non intenzionali. Prendendo in considerazione che fenomeni strani durante il monitoraggio a livello del suolo indicano che alcune aree all'interno delle città sembrano avere una maggiore concentrazione di inquinamento atmosferico anche se sembrano lontane dalle fonti di emissione o addirittura protette da esse.

Metodologicamente, l'area geografica di questa ricerca è la città capitale dell'Albania, Tirana. Mentre le esatte località, selezionate attraverso un approccio scrupoloso basato sulla loro forma urbana, prossimità con fonti di emissione, orientamento e morfologia. Queste 4 aree sono le seguenti: complesso KIKA, complesso MAGENT, complesso Delijorgji (tutti costruiti tra il 2010-2020) e complesso prefabbricato dietro "Ish-Ekspozita" (costruito negli anni '70).

Oltre a sviluppare una critica e discussione sull'Inquinamento Atmosferico Urbano e il suo collegamento con la Forma Urbana, la ricerca include lavori sul campo attraverso: monitoraggio giornaliero della concentrazione (in ppm e $\mu\text{g}/\text{m}^3$) del biossido di azoto gassoso (NO_2), Particelle Particolari $\text{PM}_{2.5}$ e PM_{10} , monitoraggio quotidiano della direzione e velocità del vento, umidità, condizioni meteorologiche. Il monitoraggio è stato condotto dal 1° gennaio al 31 marzo 2023. I fogli

di monitoraggio giornalieri sono stati compilati e digitalizzati in un database Excel e ulteriormente in GIS, mentre la mappatura della dispersione dell'inquinamento e l'effetto delle condizioni meteorologiche hanno indicato e visualizzato l'effetto temporale che la forma urbana aveva sul fenomeno delle "Aree Cavità di Inquinamento Atmosferico". L'esistenza di tale fenomeno si riflette nei risultati di questi monitoraggi giornalieri di 9 punti di monitoraggio per ciascuna delle aree di studio. L'utilizzo del Coefficiente di Correlazione Statistica, denotato come " r ", è fondamentale per valutare quantitativamente la grandezza e l'orientamento di una correlazione lineare tra variabili osservate, come i livelli di concentrazione degli inquinanti e la velocità del vento. Questa metrica, un contributo fondamentale di Karl Pearson, un eminente matematico e biometrico britannico, durante il passaggio dal 19° al 20° secolo, serve come strumento statistico fondamentale per chiarire la dinamica tra variabili ambientali. L'introduzione di Pearson del fattore di correlazione facilita una comprensione sfumata delle interdipendenze all'interno dei sistemi ambientali, in particolare nel contesto della gestione della qualità dell'aria urbana.

Questo studio sfrutta il Coefficiente di Correlazione come pietra angolare nella costruzione di un quadro analitico sofisticato mirato a un'indagine approfondita delle dinamiche dell'inquinamento atmosferico urbano e dei loro meccanismi di dispersione naturale in relazione alla forma urbana. Inoltre, il quadro logico di questa ricerca potrebbe essere ampliato e includere la Dinamica dei Fluidi Computazionale (CFD), promuovendo la simulazione e l'analisi dei complessi modelli di flusso degli inquinanti atmosferici negli ambienti urbani, offrendo intuizioni sui meccanismi che guidano la loro dispersione. L'integrazione di osservazioni microclimatiche approfondisce la comprensione delle condizioni atmosferiche localizzate, potrebbe portare i futuri ricercatori ad arricchire l'analisi dei fenomeni di dispersione degli inquinanti.

Infine, l'incorporazione di pratiche di pianificazione urbana sostenibile all'interno di questo quadro analitico sottolinea un approccio proattivo alla mitigazione degli impatti spaziali e temporali delle Aree Cavità di Inquinamento Atmosferico sulla salute pubblica. Sintetizzando anni di monitoraggio in loco e letteratura dettagliata, combinati con dati climatici empirici e principi di design urbano all'avanguardia, il candidato alla ricerca delinea un percorso verso la riduzione delle ramificazioni ambientali e sanitarie dell'inquinamento atmosferico urbano. Attraverso una metodologia multidisciplinare, lo studio non solo contribuisce al discorso accademico su scienza ambientale e pianificazione urbana, ma propone anche strategie azionabili per migliorare la qualità dell'aria urbana e, di conseguenza, i risultati della salute pubblica.

2. CHAPTER I: THESIS INTRODUCTION AND ITS SCOPE

2.1. Background and context

Numerous scientific articles highlight the direct correlation between human exposure to PM and NO₂ particles and their detrimental impact on human health. Furthermore, it is alarming to note that micro-plastics have already infiltrated the food chain, posing additional risks. Also, the negative effects of noise pollution on the socio- psychological well-being of citizens should not be overlooked. It is important to recognize that all these consequences incur costs both on the health and financial fronts for individuals. Moreover, it is important to reiterate that pollution is a global challenge. In recognition of this, the UN Resolution 76/300, recently adopted by (United Nations, 2022), incorporates the provision of a healthy and sustainable environment into the framework of basic human rights. This resolution underscores the significance of ensuring a stable and healthy environment for all individuals.

The candidate delves into the intricate relationship between urban form, its architecture, and the natural dispersion of air and pollutants due to climatic conditions. During the candidate work on air pollution monitoring, since mid. 2017, it occurred through spontaneous monitoring practices that certain locations had higher pollution concentration even-though there were no sources of emission at the same location. The candidate hypothesis was that urban form was affecting natural ventilation and often causing vortexes that captured pollution for longer periods compared to nearby (but better ventilated locations) thus causing pollution cavity areas (PCA).

This research was conducted within the build urban environment, taking into consideration Tirana's different micro-climatic conditions. Employing a combined and multi-criteria methodology, the study integrates various analytical tools and techniques, including comparative and correlative analysis, heat-map and dispersal calculations, meteorological and climate observations, and assessments of ecosystem services. Through this investigation, the candidate aims to elucidate how urban design and architectural features impact the unfettered movement of air pollutants in an urban setting. By applying detailed monitoring register and heat-maps, the researcher seeks to visualize and quantify the patterns of air dispersion and pollution concentration caused by urban form. It also considers the role of climatic architecture in influencing these patterns, as well as its potential to facilitate natural air exchange and minimize pollutant build-ups phenomena.

Through argumentative debates and critical analysis, the research aims to establish a comprehensive understanding of how urban design decisions can affect the dispersal of air

pollutants, impacting both environmental quality and public health. Ultimately, this research contributes to the discourse on the importance of urban planning and architecture in dense cities. The candidate, by shedding light on the intricate interplay between urban form, architectural choices and climatic conditions, resulting into the creation of PCA Pollution Cavity Areas.

Moreover, to a local level, the concept of urban pollution in Albania is clearly linked to the discharge of harmful substances which, both naturally and unnaturally, enter and persist in cities and urban areas. Emissions related to human activities such as construction, transportation, housing, industry, etc., are identified as the major pollutants in these urban zones; this is due to the high concentration of people and activities in urban centres. The impact that these types of pollutants have necessitates that preventive or mitigative measures be implemented at local levels. Local and national reports have been absent in Albania for more than 4 years. The National Environmental Agency and the Public Health Institute are responsible for informing the public about air quality and noise levels, whilst this legal requirement has not been met since 2016 therefore there is an considerable ambiguity when addressing the matter of air pollution and public health in Albania.

On the other hand, international reports rank Albania as significantly affected by continuous and pervasive urban pollution, in contrast to the seasonal pollution observed in other countries in the region. In Albanian cities, the concentration of pollutants remains constant throughout the year. Moreover, the (EEA, 2023) recently cited that the impacts on public health related to air pollution led to a reduction of life expectancy about 184 days and more than 3400 premature deaths of those exposed to the pollutants.

Specifically, in our country, pollution is entirely manageable and, regrettably, entirely avoidable, as long as there remains a lack of enforcement and inspection of legal obligations to prevent emissions into the air. This situation is exacerbated by inadequate green spaces, excessive construction, poor-quality fuels, and primarily by the non-implementation and inspection of legal obligations to prevent air discharges.

2.2. Scope and Problem Statement

Urbanization presents both challenges and opportunities for sustainable development. As cities grow, they face increasing pressure on infrastructure, resources, and the environment. One of the most pressing challenges is air pollution, exacerbated by the density of human activities and reliance

on fossil fuels. Concurrently, climate change introduces additional stressors on urban systems, necessitating resilient planning and design strategies that can adapt to changing conditions and mitigate adverse impacts. Sustainable development bears a vast number of definitions, sometimes contradicting one the other but there is an overall agreement that sustainable development is a norm that promotes equity and justice within and among generations from a social, economic and environmental point of view (Derisser, 2009)

In particular air pollution, as a significant environmental and public health issue has evolved over centuries, with early observations dating back to the Middle Ages. However, the systematic scientific study and formal academic definition of air pollution as a problem can be traced back to the late 19th and early 20th centuries.

One of the earliest instances where air pollution was studied and documented in a scientific context occurred during the Industrial Revolution. This period, starting from the late 18th century and continuing through the 19th century, saw a significant increase in the burning of coal for industrial processes and domestic heating. This led to visibly polluted skies, particularly in urban and industrial areas like London and other major cities in the United Kingdom and the United States. The infamous London Fog, a combination of smoke and fog, became a symbol of industrial air pollution.

The term "smog" (a portmanteau of smoke and fog) itself was first coined in the early 20th century to describe the peculiar mixture of fog and smoke that plagued London. Dr. Henry Antoine Des Voeux is credited with popularizing the term after presenting a paper titled "Fog and Smoke" at a meeting of the Public Health Congress in 1905, where he discussed the adverse effects of air pollution on public health. This can be considered one of the early academic efforts to define and address the problem of air pollution.

The first significant legislative response to air pollution was the United Kingdom's Public Health Act of 1875, aimed to reduce the pollution caused by coal smoke. However, it was the Great Smog of London in 1952, a severe air pollution event that resulted in thousands of deaths and illnesses, that truly catalysed modern understanding and regulation of air pollution. The disaster led to the Clean Air Act of 1956 in the UK, one of the first laws aimed at controlling air pollution. (UK Public Health, 1956)

In the United States, academic and governmental recognition of air pollution as a significant problem also gained momentum in the early 20th century, with further acceleration in the 1950s and 1960s due to episodes like the 1948 Donora smog in Pennsylvania. The establishment of the

U.S. Environmental Protection Agency (EPA) in 1970 and the enactment of the (US Clean Air Act, 1970) marked significant milestones in addressing air pollution through legislation based on scientific research.

Thus, while concerns about air pollution have been noted for centuries, it was not until the 20th century that the problem was defined academically in the context of public health and environmental science, leading to the development of policies and regulations aimed at mitigating air pollution.

Key facts on Air pollution from World Health Organization, Dec.2022

- *Air pollution is one of the greatest environmental risk to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.*
- *In 2019, 99% of the world's population was living in places where the WHO air quality guidelines levels were not met.*
- *The combined effects of ambient air pollution and household air pollution are associated with 6.7 million premature deaths annually.*
- *Ambient (outdoor) air pollution is estimated to have caused 4.2 million premature deaths worldwide in 2019.*
- *Some 89% of those premature deaths occurred in low- and middle-income countries, and the greatest number in the WHO South-East Asia and Western Pacific Regions.*
- *Policies and investments supporting cleaner transport, energy efficient homes, power generation, industry and better municipal waste management would reduce key sources of outdoor air pollution. Access to clean household energy would also greatly reduce ambient air pollution in some regions.*

For a comprehensive and widely accepted definition of air pollution, including its sources and impacts, academically we can refer to publications and reports from leading health and environmental organizations. One of the most authoritative sources for information on air pollution and its health effects is the World Health Organization (WHO).

Air pollution is defined academically as the **presence of substances in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials.**

There are many types of air pollutants, including gases such as carbon monoxide (CO), sulphur dioxide (SO₂), nitrogen oxides (NO_x), and volatile organic compounds (VOCs), as well as particulate matter (PM), which can be fine particles like PM_{2.5} (particles with a diameter of 2.5 micrometre or smaller) or coarse particles like PM₁₀ (particles with a diameter of 10 micrometre or smaller).

These pollutants can originate from various sources, including industrial processes, vehicle emissions, agricultural activities, natural sources (such as wildfires and volcanic eruptions), and household combustion of fuels. The specific composition of air pollution can vary greatly depending on the geographic area, the local sources of pollution, and meteorological conditions.

Academically, air pollution is studied within the fields of environmental science, public health, and engineering, among others. Researchers investigate the sources and dispersion of pollutants, their physical and chemical transformations in the atmosphere, their impacts on health and the environment, and strategies for their reduction and control. The study of air pollution encompasses both outdoor air pollution (ambient air pollution) and indoor air pollution, which can arise from sources within buildings or structures, such as tobacco smoke, cooking, and heating appliances. The World Health Organization (WHO) and other international bodies provide guidelines for air quality, specifying limits for the concentration of key pollutants in the atmosphere that are considered safe for human health. These guidelines and standards are based on extensive scientific research that examines the relationships between exposure to various pollutants and health outcomes.

Figure 1. Air pollution in Tirana, Albania on 8th August 2023.



Source: Author

Urban air pollution remains one of the most critical environmental and public health challenges of our time. Despite efforts to mitigate its impacts, several persistent problem statements and arguments highlight the ongoing struggle against air pollution in urban areas. Some of the most enduring issues could be considered:

- Health Impacts of Particulate Matter and Noxious Gases:

Exposure to particulate matter (PM_{2.5} and PM₁₀) and noxious gases (such as NO_x, SO₂, and O₃) remains a significant public health concern. These pollutants are linked to a wide range of health issues, including respiratory and cardiovascular diseases, cancer, and premature death. The health impacts of air pollution necessitate urgent action to reduce emissions from key sources such as transportation, industry, and domestic heating.

- Impact on Vulnerable Populations:

Vulnerable populations, including children, the elderly, and those with pre-existing health conditions, are disproportionately affected by urban air pollution. Low-income communities often face higher exposure levels due to their proximity to pollution sources and lack of access to clean environments. Addressing environmental justice and equity is crucial in the fight against urban air pollution. Policies must prioritize the protection of vulnerable populations through targeted interventions and by addressing the socio-economic determinants of health.

- Traffic-Related Air Pollution:

Vehicular emissions are a major contributor to urban air pollution, with road traffic being a significant source of particulate matter, nitrogen oxides, and other pollutants. Sustainable urban transportation solutions are essential to reduce traffic-related air pollution. This includes promoting public transit, cycling, walking, and the adoption of electric vehicles, alongside urban planning strategies that reduce the need for car travel.

- Urban Planning and Development:

Rapid urbanization and inadequate urban planning contribute to the exacerbation of air pollution problems. High population densities, inefficient transportation systems, and lack of green spaces can lead to higher pollution levels and reduced air quality. Integrating air quality considerations into urban planning and development processes is critical. This involves creating compact, mixed-use developments that encourage active transportation, preserving and expanding urban green spaces, and ensuring that industrial activities are suitably located away from residential areas.

- Climate Change and Air Pollution Interactions:

Climate change and air pollution are intrinsically linked, with shared sources and mutually reinforcing impacts. For example, rising temperatures can increase the formation of ground-level ozone, while certain air pollutants contribute to climate change.

Tackling air pollution and climate change requires integrated approaches that address shared sources of greenhouse gases and air pollutants. Efforts to reduce carbon emissions can have co-benefits for air quality, underscoring the need for policies that address both challenges simultaneously.

Douglas Dockery and C. Arden Pope III found a strong association between air pollution, specifically particulate matter, and increased mortality rates. It highlighted the significant public health impact of air pollution and contributed to stricter air quality regulations. (Dockery, 1993) Further numerous actors ranging from central authorities to leading research organizations have decoupled the impact of prolonged exposure to certain pollutants in human health. Regardless of their conclusions, principal values that do safeguard public health have been neglected by the utilitarian approach vis a vis the economic development. Moral values, ethical values, culture, ideologies and other social values are considered subjective and hard to account for with the unavoidable cost and impact of decision-making practices that have ensured development of the cities to the status they bear today. Anyone daring to introduce nonetheless enforce novel principles into urban planning, policy making on spatial development was considered of being ahead of time. For example, Ildefons Cerdà was a Spanish urban planner and civil engineer renowned for his comprehensive study and planning of the extension of Barcelona, known as the "*Eixample*" plan, in the mid-19th century. His work is considered pioneering in the field of urban planning and the study of urban form and morphology. Cerdà introduced innovative concepts and methodologies, focusing on the integration of social, health, and mobility aspects into urban design. He was one of the first to use the term "urbanization" and sought to apply scientific principles to the planning of urban areas. His work was deeply influenced by the industrial revolution and the rapid urbanization it caused, leading to overcrowded and unsanitary living conditions in cities. "Urbanization is not merely a matter of engineering, but much more complex art that involves profound studies of social sciences" (Cerdà, 1867). Cerdà highlighted in his "General Theory of Urbanization" that Industrial Revolution and rapid urbanization was leading to unsanitary cities. He was the first indicating that urban morphology was leading deprivation of its inhabitants from social, health and economical perspectives. He noted that urban

planning should have an integrated approach when addressing the following:

- **Importance of Urban Grid Layout:** a grid layout was essential for efficient urban development. He argued that such a layout facilitated movement, enhanced connectivity, and ensured equitable access to sunlight and ventilation for all residents. This was a departure from the chaotic and unplanned structures of medieval cities.
- **Integration of Social Equity:** A central theme in Cerdà's theory was the integration of social equity into urban planning. He believed that urban development should benefit all residents, regardless of their socio-economic status. His designs included wide streets, public squares, and parks that were accessible to everyone, aiming to promote social interaction and cohesion.
- **Expansion of Public Services:** Cerdà emphasized the need for comprehensive public services and infrastructure, including sewage systems, clean water supply, and transportation networks. He saw these services as fundamental to improving public health and the overall quality of urban life.
- **Economic Efficiency and Urban Functionality:** He argued that urbanization should be planned in a way that supports economic efficiency and functionality. This included the optimization of land use and the promotion of economic activities that could sustain urban growth and development.
- **Incorporation of Green Spaces:** Unlike many urban planners of his time, Cerdà recognized the importance of integrating green spaces into urban environments. He concluded that parks and open spaces were crucial for public health, serving as "lungs" for the city to improve air quality and provide residents with spaces for recreation and relaxation.
- **Adaptability and Flexibility:** Cerdà's theory acknowledged the dynamic nature of urban development and the need for urban plans to be adaptable and flexible. He understood that cities would continue to grow and change over time and that planning should accommodate future developments and technological advancements.
- **Scientific Approach to Urban Planning:** Cerdà advocated for a scientific approach to urban planning, relying on data and empirical evidence to guide design and policy decisions. His work included detailed statistical analyses of population density, land use, and traffic patterns, which were innovative for his time.

Cerda's approach had a profound impact on urban planning principles, yet urban form remained a very argumentative subject. Later in 1925 another leading architect and urban planner, Le Corbusier stated "A house is a machine for living" scaling down the concept of a complex city into the dimensions of one house. This quote encapsulates Le Corbusier's approach to architecture and urban design as functional and efficient, much like a machine. He believed that buildings and, by extension, cities should be designed to meet the needs of their inhabitants with precision, efficiency, and simplicity. This perspective influenced his ideas on urban form, where he envisioned cities that were organized, spacious, and integrated with nature to provide a healthy and productive environment for their residents. This quote underscores his belief in the importance of functionalism in architecture, where form follows function, and every element of design serves a purpose in contributing to the overall efficiency and liveability of the urban environment. Herby provoking debate and in the same time inspiration for criticism when compared with Cerda's perspective.

Le Corbusier was critical of the chaotic and unplanned nature of traditional cities, which he believed were inefficient, unhealthy, and aesthetically displeasing. He argued that the design of cities had failed to keep pace with the changes brought about by the industrial revolution, resulting in congested, polluted, and disorderly urban environments. (Corbusier, 1929)

He proposed a radical redesign of urban spaces, envisioning the "Contemporary City" for three million inhabitants and the "Radiant City" (Ville Radieuse) as models that emphasized open space, green areas, and sunlight. These concepts were characterized by large-scale, high-density residential towers set within extensive park-like settings, aiming to combine the benefits of urban life with access to nature.

One of Le Corbusier's key principles was the separation of urban functions into distinct zones for living, working, recreation, and transportation. He believed that such zoning would promote efficiency and improve the quality of life for city dwellers by reducing congestion and creating more organized and functional urban spaces. Le Corbusier placed a strong emphasis on the role of transportation in urban planning. He advocated for the integration of highways and road networks within the city to facilitate smooth traffic flow, alongside the provision of large open spaces for pedestrians. His designs included the use of elevated highways and the segregation of pedestrian paths from vehicular roads. He was a proponent of using modern construction techniques and materials, such as steel and reinforced concrete, to create buildings and urban forms that were not

only functional but also expressive of the modern era. This approach allowed for the creation of large open spaces, flexible floor plans, and innovative architectural forms. Le Corbusier's vision for urban form included the extensive use of skyscrapers and high-rise buildings as a means to increase density while simultaneously freeing up ground space for public use. He saw verticality as a solution to the problem of urban sprawl and a way to accommodate growing urban populations without sacrificing open space.

Despite his focus on grand urban schemes and modernist aesthetics, Le Corbusier also emphasized the importance of designing urban environments that catered to the needs and well-being of their inhabitants. His concept of the "*Modular*" was a system of proportions based on human measurements intended to bring a human scale to architecture and urban design. While other authors such as William H. Whyte, Aldo Rossi, Lewis Mumford, Camillo Sitte, Kevin Lynch and Christopher Alexander have expanded the perception of urban morphology and its interaction with cities functionality, cities perception by its inhabitants, history of urban planning, technical organization and design of the cities. Jane Jacobs and Jan Gehl are notably orienting planning visions towards the concept Cities of People. Outlining principles of a human-centred environment, thus pointing out that for a city to become vibrant and for an urban space to support evolution it must provide to its inhabitants an abundance and as close to their natural state, the core elements of life: Air, Water, Fire (energy) Soil.

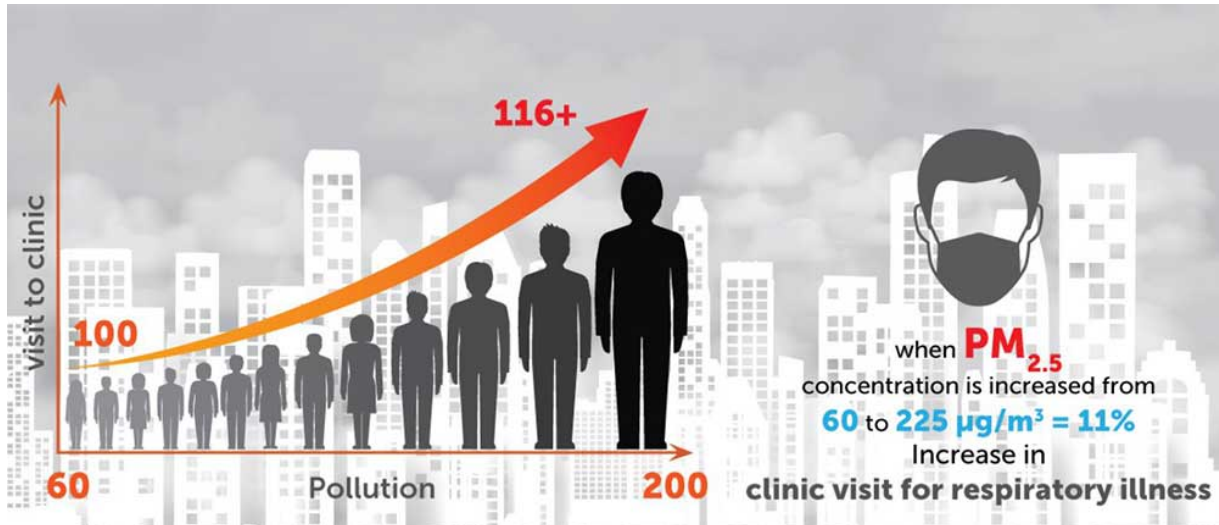
These theoretical discussions highlight a crucial fact: Urban Ecosystem aside of being crucial to its inhabitants contribute above all to the very essence of development. Nature has offered to humans the resources required for its evolution and development from know-how to the very elements used in all processes. Herby it should be considered both a moral and ethical discussion that in urban planning the degree of usage of these elements and the concept of placing them into a spatial e temporal perspective should be based on the very knowledge we have upon these elements and their interaction with the surrounding environment. We are in a moment in history whereas the type of rights we have upon the environment exceed our knowledge limitation upon specific phenomena and natural principles. Abusing with the system that we have created to assig these rights while neglecting crucial findings from several studied phenomena, we have created again a chaotic planning practice whereas novel concepts and sustainable practices are being used just as means of propaganda to cover the easiest way to meet daily demands of growing cities by ensuring maximal economic profit. Nowadays, even cities governed by Green Political Parties across European Union.

Back to the cause of urban Air pollution, Majid Ezzati work has focused on the global health impacts of environmental risks, including air pollution. This publication concluded that air pollution is a major global risk factor for disease, underscoring the need for international cooperation in tackling air pollution. (Ezzati, 2022) His publication concluded that air pollution is a major global risk factor for disease, underscoring the need for international cooperation in tackling air pollution. Julian D. Marshall research on the intersection of urban form and air pollution emphasizes the role of energy-efficient urban planning in reducing air pollution and improving public health outcomes indicated that there is room for improvement even within the existing realm nonetheless such improvement does not indicate the mitigation of the pollution just by energy – efficiency measures. (Marshall, 2008) Mark Z. Jacobson work addresses the complex interactions between climate change and air pollution. He concludes that reducing fossil fuel combustion can simultaneously address climate change and reduce air pollution-related mortality. (Jacobson, 2008)

Supporting the argument that exposure to urban air pollution leads to decrease of human health quality, numerous authors have provided evidence-based data from their research background and locations. For instance, Kan's research in Shanghai provides evidence that both fine and coarse particulate matter significantly affect daily mortality rates, with nuanced differences in their health impacts, underscoring the importance of targeting all forms of particulate pollution in air quality management. (Kan, 2012). Furthermore, Francesca Dominici work has been pivotal in demonstrating the acute health effects of fine particulate air pollution, including increased hospital admissions for cardiovascular and respiratory diseases, highlighting the urgent need for air quality improvements to protect public health (Dominici, 2006). Whereas segregation of the air pollution impact into the overall public health began to draw interest since not only the category of the elders and those chronically ill indicated health related problems when pollution exceeded allowed standards but also the juvenile and neonate category was indicating an increase in several health issues.

McConnell's studies focus on the impact of traffic-related air pollution on children's health, concluding that exposure to such pollution is significantly associated with the development of asthma in childhood, pointing to the need for strategies to reduce children's exposure to harmful pollutants. (McConnell, 2010)

Figure 2. New-Delhi Increase in clinic visit for respiratory illness due to increase of PM_{2.5} concentration in urban air.



Source: The Energy and Resource Institute

Annette Peters research indicates that short-term exposure to traffic, a major source of air pollution, significantly increases the risk of myocardial infarction (heart attacks), underscoring the cardiovascular risks of air pollution. (Peters, 2004). Zev Ross conducted a comprehensive review and meta-analysis that confirmed long-term exposure to nitrogen dioxide, a common urban air pollutant, is associated with increased mortality risk, highlighting NO₂ as a significant public health concern. (Ross, 2016) These authors and their publications offer a broad perspective on the complex issue of urban air pollution, its sources, its impacts on health, and the importance of integrating air quality considerations into urban planning and public policy. Their collective work underlines the urgency of addressing air pollution to protect public health and ensure sustainable urban development

Particulate matter, especially PM_{2.5}, is of particular concern due to its ability to penetrate deep into the respiratory tract. The European Environment Agency reports that in 2019, PM_{2.5} was responsible for about 417,000 premature deaths across 41 European countries (European Environment Agency, 2021). Cities like Sofia, Bucharest, and Belgrade frequently appear on lists of Europe's most polluted capitals, with PM levels significantly above the WHO's recommended limits. For instance, Sofia has experienced PM_{2.5} levels more than twice the WHO guideline, contributing to Bulgaria having one of the highest rates of air pollution-related deaths in the EU (AirVisual, 2020).

Nitrogen dioxide, largely emitted from road traffic, is another potent urban air pollutant. Prolonged exposure to NO₂ is associated with increased risks of respiratory diseases, including asthma and bronchitis. A study encompassing several European cities found that long-term exposure to NO₂ is linked to an increased rate of mortality, highlighting the need for effective traffic management and

emission reduction strategies (Faustini, 2014) The situation is similarly dire in the Balkans, where outdated industrial practices and heavy reliance on coal and wood for heating exacerbate urban air pollution. Sarajevo, for example, faces severe air quality issues during winter months, with PM10 levels often reaching five times the WHO's safe limit. The health implications are profound, with increased hospital admissions for cardiovascular and respiratory conditions. Children and the elderly are particularly vulnerable to the health effects of air pollution. Research indicates that children exposed to high levels of air pollution are more likely to suffer from asthma, reduced lung function, and respiratory infections (Landrigan, 2016). Furthermore, the European Heart Journal published a study estimating that air pollution causes 8.8 million extra deaths globally per year, with cardiovascular diseases as the leading cause (Lelieveld, 2019). This statistic is alarming and underscores the urgent need for concerted action to improve air quality in urban environments.

The economic cost of air pollution in terms of healthcare expenses and lost productivity is staggering. The European Public Health Alliance (EPHA) reports that air pollution costs European countries hundreds of billions of euros annually, making it not only a health crisis but also a significant economic burden. In response to these challenges, cities across Europe and the Balkans are implementing measures to reduce air pollution and mitigate its health impacts. These include promoting public transportation, transitioning to cleaner energy sources, and enhancing green urban spaces. However, progress is uneven, and many urban areas continue to struggle with high pollution levels.

In conclusion, the evidence is clear as well as the statement of the problem: air pollution in urban areas presents a significant threat to public health, contributing to the premature death of hundreds of thousands of individuals in Europe and the Balkans each year. Addressing this issue requires a comprehensive approach that combines policy intervention, urban studies, technological innovation, and behavioural change. It is imperative that governments, communities, and individuals work together to reduce emissions and exposure to harmful pollutants, safeguarding the health and well-being of current and future generations.

2.3. Research Objectives and Limitations

Humans benefit from ecosystem services to satisfy their daily direct or non-direct needs, most often these services are considered granted to them and hereby no specific attention to control or manage them is channelled to research nor to practical interventions. Alterations into land cover or even

urban patterns seem to have a direct consequence to humans. Such alterations cause loss of ecosystem services, loss of sun exposure, alternation and modification of wind patterns and speed, changes that latter affect the microclimate of the area and further decrease those ecosystems services perceived earlier as a granted right.

Air pollution refers to the presence of harmful substances, such as particulate matter, nitrogen oxides, sulphur dioxide, ozone, and carbon monoxide, in the air we breathe. These substances can have a range of negative impacts on human health, as well as on the environment.

Sources of air pollution include transportation (cars, trucks, and airplanes), industrial activities (factories and power plants), agriculture (livestock and fertilizer use), and natural phenomena (dust and wildfires). In urban areas, traffic congestion and the burning of fossil fuels for heating and electricity generation are major contributors to air pollution.

Exposure to air pollution can cause a range of health problems, including respiratory and cardiovascular diseases, as well as cancer. Children, the elderly, and people with pre-existing health conditions are particularly vulnerable to the effects of air pollution. Air pollution also has environmental impacts, such as contributing to climate change, acid rain, and the degradation of ecosystems. To address air pollution, governments and communities have implemented a range of strategies, including regulations on emissions from industry and transportation, investment in public transportation and cycling infrastructure, and public education campaigns to promote awareness of the health impacts of air pollution.

Advances in technology, such as electric vehicles and renewable energy sources, also offer promise for reducing the sources of air pollution in the future. Among all the above-mentioned facts, the least addressed factor is urban form. This research can prove that urban form can have a significant impact on air pollution levels in cities. The layout of a city, the density and height of buildings, the transportation infrastructure, and the location of industrial and commercial activities can all affect air quality.

One of the key factors affecting air pollution in cities consist on its reliance on burning fossil fuels for transportation. Cities that are designed around automobile use, with wide roads and sprawling suburbs, tend to have higher levels of air pollution than cities with compact, walkable urban cores and efficient alternatives for public transportation systems. In car-oriented cities, the high volume of traffic, particularly during rush hour, can lead to significant increase on emissions of pollutants such as nitrogen oxides and particulate matter. On the other hand, the density and height of

buildings can also affect the dispersal and natural wash-out air pollutants. Tall buildings can create "urban canyons" that trap air pollutants, leading to higher concentrations in certain areas. Buildings can also affect wind patterns and air circulation, which can impact the dispersion of pollutants.

The location of industrial and commercial activities can also contribute to air pollution in urban areas. Industrial facilities and construction/infrastructure activities that emit pollutants such as sulphur dioxide, nitrogen oxides, and particulate matter can have a significant impact on air quality, particularly in low-income neighbourhoods and marginalized communities that are often located near these facilities.

To address air pollution in urban areas, planners and policymakers can implement a range of strategies, including promoting sustainable transportation options, incentivizing green buildings and green infrastructure, and regulating emissions from industrial facilities. Additionally, increasing public awareness of the health impacts of air pollution can help to build support for these strategies and create a sense of urgency around the need to improve air quality in cities.

Contributing to the evolving discussion and planning theory through evidence-based research with regard to urban form being affected by climate patterns, air pollution and finally impacting urban health. By characterizing Urban Pollution Cavity Areas, understanding its cause and influencing factors, the candidate is further developing predictive assumptions for the study aiming to provide actionable insights for mitigating PCA and improving air quality, thereby contributing to the creation of healthier and more environmentally sustainable cities.

Bridging the gap between architecture, urban planning and environment /climate could lead to healthier and more sustainable urban design practices in the future or even mitigate the PCA phenomena from dense inhabited areas. A number of studies have examined the ways in which urban form has influenced air pollution levels in Beijing. For example, one study published in the *Journal of Cleaner Production* found that urban sprawl, as measured by the city's urban expansion rate, was positively correlated with air pollution levels. The study found that more compact, walkable neighbourhoods with good access to public transit tended to have lower levels of air pollution than more sprawling neighbourhoods. Overall, the case of Beijing illustrates the importance of considering the relationship between urban form and air pollution in rapidly growing cities. As urban areas around the world continue to expand, it will be increasingly important to design and plan cities in ways that prioritize public health and environmental sustainability.

The impact of the research lays on exploring and addressing the hypothesis and uncertainty upon how can nowadays cities can transit towards an air pollution-free future through practical urban adjustments or designs that preserve existing cultural / historical layers but do avoid PCA phenomena as well as ease natural ventilation of the city rather than block it.

The candidate provides an attempt to scientifically determine the role of existing urban forms, correlating with micro-climate factors and further causing a temporal effect on the air pollutants concentration in certain location within different urban forms. Such approach is expected to grasp and contribute on existing theoretical discussion on how can nowadays cities can transit towards mitigating air pollution and decrease health implications deriving from exposure. Last but not least, the limitations that such research intends to address relies on the uncertainty how an urban/build ecosystem can be re-conceptualized through urban design concepts and practices that contribute to human health. Addressing one of the main barriers consist on measuring or predicting the effect of Pollution Cavity Areas caused by disruption of air dispersal and vortex during the wind washout of cities. Restrictions of this research are connected to its research location, herby on the physical layout of the highly dense urbanized areas and climatic pattern. Hypothetically results would be efficient for Western Balkans and Mediterranean Basin cities.

2.4. Proposed Methodology

Numerous studies on Air Pollution have focused on a specific industrial installation or city level, but air pollution is influenced by complex interactions and dynamics that occur at various spatial scales. Understanding this interaction with larger urban and regional air quality patterns, as well as how they relate to global atmospheric processes, is a challenge that requires integrated modelling and data analysis across multiple scales. The interactions between local factors (such as urban morphology, traffic patterns, and building materials) and larger-scale meteorological conditions need to be better understood to provide a comprehensive picture of pollution natural or induced dispersion. Herby this research methodology focuses on grasping to further address such theoretical and practical gap. As the issue of air pollution dispersal at ground level requires collaborative efforts among atmospheric scientists, urban planners, and environmental researchers to develop comprehensive models and tools that can capture the intricate interactions and feedback loops between different scales of air pollution dynamics. This research can provide a more holistic understanding of certain phenomena's occurring within the broader context of urban areas

composed by two different morphologies. Candidates intend to initially understand how natural dispersal is occurring and what are the differences between linear but **parallel high dwellings** placed in line with the wind patterns of the study areas, providing corridors for natural ventilation vis a vi the **closed blocks** that do actually interfere with natural ventilation.

In total 4 study locations were selected. Two linear and two closed blocks but with different distance to emitting sources. Further on it will analyse, explain and develop contextualized tools and solution scenarios that will address depollution for a healthy city. Also, some aspects of the research will be exploratory since there is not much historical literature approaching air pollution and climate related planning for WB region, Mediterranean Basin and in particular for Albania. On the other hand, it will have a technical approach as the research foresees specific site monitoring, inspections, auditing and empirical calculation for a qualitative approach in order to achieve the highest purpose of determining contextualized tools that are elaborated based on evidence and certified data.

Detailed research methodology is comprising:

- Research areas selection methodology / analysis based on specific criteria;
- Air pollutants selection criteria;
- Climate / Meteorological pattern selection criteria;
- Monitoring procedure, frequency, duration, protocol and data elaboration technics;
- Equipment's certifications (sensor accreditation);
- Heat-maps;
- Factsheets, digitalization and data register;
- Graphics and Correlation factors.

The candidate, implemented the monitoring methodology on the selected locations from January 1st 2023 until 31 March 2023 conducting a total of 3240 monitoring practices within these areas.

This research methodology is broadly based on a combined theoretical and technical approach of research. It is theoretical because it seeks to address the unknown effectiveness that Urban Form could have on a spatial and temporal level for urbanized areas and their community's exposure to air pollution. Initially by identifying if such assumed phenomena (PCA) is real and further pointing vulnerable inhabitants being exposed to increased pollutants just by living, working or having leisure time in these exact locations.

Finally, the theoretical and practical findings will be synchronized into a reliable product/finding on how Air Pollution Cavity Areas could be applied in the local and national planning practices as well as put in use for the very purpose of shifting from urban densification toward a Climate Resilient and Healthy Cities.

2.5. Theoretical Gaps

Through this research the author attempts on addressing to some extend the following gaps:

First gap, rather theoretical, expected to be tackled as a result of this research relates to the fact that there is an emerging need for a more nuanced understanding of the complex interactions between physical, social, and cultural factors that shape the built environment. While many studies have identified the ways in which urban form can influence a range of outcomes, including air pollution, public health, and social equity, these studies often rely on simplified models that do not fully capture the complexities of urban design decisions impacting involuntary the wellbeing and health of its inhabitants.

Second gap relates to the practical factors influencing the shape of urban form. Urban planning and design are often influenced by a range of actors, including developers, politicians, community groups, and other stakeholders, each with their own interests and priorities. These power dynamics can shape the outcomes of planning and design processes, and can lead to outcomes that reinforce existing inequalities and power structures. Herby a crucial input is missing, that of designing in line with nature ecosystem services, allowing or enabling such services to be naturally harvested by communities for their well-being.

The third gap, both practical and theoretical consistent on assessing the temporal dimension of urban form. Urban systems are constantly evolving, and the outcomes of planning and design decisions may not be fully realized for many years. This means that it is often difficult to assess the long-term impacts of urban form decisions. To nurture this argument, for that informed decisions are taking into account the likely outcomes of different planning and design scenarios over time, outcomes of this research might be useful at a temporal dimension too.

Finally, given the need for more research on the potential unintended consequences of urban form interventions, the main outcome of this research shall shed light to an argument and phenomena easily perceived by many but not addressed be the few capable of understanding and quantifying

it. While sustainable urban design and planning interventions may have positive impacts on a range of outcomes, such as reducing air pollution, they may also have unintended consequences that are not fully understood. For example, interventions that prioritize bike lanes and pedestrian walkways may have the unintended consequence of displacing low-income residents or exacerbating existing transportation inequalities.

To address these gaps the candidate has chosen to implement an interdisciplinary approach that draw on a range of theoretical frameworks and methodological approaches, and that prioritize a holistic understanding of urban systems and the complex factors that shape them.

2.6. Expected Results / Outcomes of the research

- a. **Identification of Pollution Cavity Areas (PCA):** The research aims to pinpoint specific locations within urban environments where urban form and architectural features contribute to the formation of pollution cavity areas. By utilizing various analytical tools and techniques, the study intends to provide a comprehensive map of these areas, highlighting hotspots where pollutant concentrations are significantly higher due to localized atmospheric conditions.
- b. **Quantification of Air Pollutant Dispersion Patterns:** Through detailed monitoring registers and heat-map analyses, the research seeks to quantify the patterns of air dispersion and pollution concentration caused by urban form. By elucidating the factors contributing to pollutant accumulation and dispersion, the study will provide valuable insights into the dynamics of air pollution in urban settings.
- c. **Evaluation of Urban Design and Architectural Impact:** The research aims to establish a comprehensive understanding of how urban design decisions and architectural features influence the movement of air pollutants within cities. By examining the role of climatic architecture in facilitating natural air exchange and minimizing pollutant build-ups, the study will provide actionable recommendations for urban planners and architects to mitigate air pollution.
- d. **Assessment of Environmental Quality and Public Health Implications:** By correlating air pollutant dispersion patterns with environmental quality indicators and public health data, the research will shed light on the impact of urban form on public health outcomes.

This assessment will highlight the potential health risks associated with pollution cavity areas and provide evidence-based recommendations for improving environmental quality and public health in urban environments.

- e. **Contribution to Urban Planning and Policy Development:** The research findings will contribute to the discourse on the importance of incorporating air quality considerations into urban planning and policy development processes. By demonstrating the link between urban form, architectural choices, and air pollutant dispersion, the study will provide valuable insights for policymakers seeking to promote sustainable urban development and mitigate the adverse effects of air pollution.
- f. **Enhancement of Climate Resilience in Urban Areas:** Through argumentative debates and critical analysis, the research will advocate for the integration of climate resilience principles into urban planning and design practices. By emphasizing the importance of considering climatic conditions and natural ventilation in urban development, the study will contribute to the creation of more resilient and sustainable cities capable of adapting to the challenges of climate change.

2.7. Stakeholders

i. **Government Agencies and Urban Planning Departments:** Government agencies responsible for urban planning and environmental regulation will be key stakeholders in this research. Engaging with these stakeholders will ensure that the research findings are incorporated into urban planning policies and regulations aimed at improving air quality and public health in urban areas.

ii. **Architectural and Urban Design Firms:** Architectural and urban design firms play a crucial role in shaping the built environment. By collaborating with these stakeholders, the research can influence architectural practices and design decisions to prioritize air quality and environmental sustainability in urban development projects.

iii. **Environmental NGOs and Advocacy Groups:** Environmental NGOs and advocacy groups are important stakeholders in raising awareness about air pollution and advocating for policy changes to address environmental challenges. Engaging with these stakeholders will help amplify the research findings and support efforts to promote sustainable urban development practices.

iv. **Community Organizations and Resident Associations:** Local communities and resident associations are directly impacted by air pollution and urban development decisions. Engaging with these stakeholders will provide valuable insights into community perspectives and concerns, ensuring that the research addresses the needs and priorities of affected communities.

v. **Academic and Research Institutions:** Collaboration with academic and research institutions will facilitate knowledge exchange and peer review of the research findings. Engaging with these stakeholders will help validate the research methodology and ensure that the findings contribute to the broader academic discourse on urban planning and environmental sustainability.

2.8. Theory of Change and International Interest

The main mission and message that this proposal will elaborate is that the current climate emergency and that the urban environmental issues affecting the public health on daily basis are addressed by initially understanding the effectiveness of nature-based approach and later including ecosystem services and nature-based solutions within the planning and decision-making practices.

Since the end of 2016 (referring here to the Paris Agreement) and further on 2019 whereas the European committed to the ne Green Agenda for 2050 a major transition, comparable to industrial revolution is actually happening. Making a substantial shift on how we perceive, treat and co-habitats with our surrounding environment and resources. The vast implications such transition might pose to our society, economy and future have already influenced the research agenda in Albania, Western Balkans and EU. Herby this research is considered as a milestone with regard to:

1. Academic Interest:

- **Advancing Knowledge in Urban Planning and Environmental Science:** The research on the urban form's effect on pollution cavity areas fills a critical gap in the academic literature by providing a comprehensive understanding of the complex interplay between urban design, architectural choices, and air pollutant dispersion. By employing a multi-criteria methodology and integrating various analytical tools and techniques, the study contributes to advancing knowledge in the fields of urban planning and environmental science.
- **Addressing Contemporary Environmental Challenges:** The research addresses contemporary environmental challenges, such as air pollution and climate change, which have significant implications for public health, environmental sustainability, and urban development. By examining the impact of urban form on air pollutant

dispersion patterns, the study provides valuable insights for researchers seeking to develop innovative solutions for creating climate-neutral and decarbonized cities.

- **Promoting Interdisciplinary Collaboration:** The interdisciplinary nature of the research, which integrates insights from urban planning, architecture, environmental science, and public health, fosters collaboration across academic disciplines. By engaging scholars from diverse fields, the study promotes interdisciplinary dialogue and collaboration, leading to holistic approaches to addressing complex urban challenges.

2. Political Interest:

- **Informing Urban Planning Policies and Regulations:** The research findings have significant implications for urban planning policies and regulations aimed at improving air quality and public health in urban areas. By demonstrating the link between urban form, architectural choices, and air pollutant dispersion, the study provides evidence-based recommendations for policymakers seeking to promote sustainable urban development practices. These recommendations can inform the development of regulations related to land use, building design, and transportation planning to mitigate the adverse effects of air pollution.
- **Supporting Climate Resilience Initiatives:** In light of increasing concerns about climate change and extreme weather events, there is growing political interest in promoting climate resilience initiatives in urban areas. The research contributes to these initiatives by highlighting the importance of considering climatic conditions and natural ventilation in urban development projects. By advocating for the integration of climate resilience principles into urban planning and design practices, the study supports policymakers in enhancing the resilience of cities to the impacts of climate change.
- **Addressing Public Health Concerns:** Air pollution is a major public health concern, with significant implications for population health and well-being. Political interest in addressing public health concerns related to air pollution is driving initiatives to improve air quality in urban areas. The research provides valuable insights into the factors contributing to air pollutant dispersion and the formation of pollution cavity

areas, informing policymakers about effective strategies for reducing air pollution and protecting public health.

3. Economic Interest:

- **Cost Savings from Health Benefits:** Improving air quality in urban areas can lead to significant health benefits, resulting in cost savings associated with reduced healthcare expenditures and increased productivity. The research findings can help policymakers quantify the economic benefits of implementing measures to reduce air pollution, such as promoting green infrastructure, enhancing public transportation systems, and implementing stricter emissions standards.
- **Promoting Sustainable Development:** Sustainable urban development practices that prioritize air quality and environmental sustainability can contribute to long-term economic prosperity. By advocating for sustainable urban planning and design strategies, the research supports economic initiatives aimed at promoting green growth, attracting investment, and enhancing the quality of life for urban residents.
- **Fostering Innovation and Technological Development:** Addressing environmental challenges such as air pollution requires innovative solutions and technological advancements. The research stimulates economic interest by fostering innovation in areas such as green building design, renewable energy technologies, and smart urban planning solutions. By promoting investment in innovative technologies and sustainable development practices, the research contributes to economic growth and competitiveness in urban areas.

In summary, the research on the urban form's effect on pollution cavity areas is of significant interest to academia, politics, and the economy. By advancing knowledge in urban planning and environmental science, informing policy development, and promoting sustainable development initiatives, the research contributes to addressing contemporary environmental challenges and fostering holistic approaches to creating resilient and sustainable cities.

3. CHAPTER II: LITERATURE REVIEW AND THEORETICAL DISCUSSION

2.1. Critical discussion

While regulatory and technological interventions have led to improvements in air quality in many cities, challenges remain. One issue is the balance between economic development and environmental protection, particularly in regions where industrial activities are a major source of employment and income. Additionally, the global nature of air pollution, with pollutants traveling long distances, complicates efforts to address it at the local level (Anenberg, 2019). The impact of climate change on air quality further complicates the issue. Rising temperatures can increase the formation of ground-level ozone, while **changes in weather patterns affect the dispersion and deposition of pollutants** (Jacob, 2009). Moreover, the COVID-19 pandemic has highlighted the complex interplay between air pollution, public health, and societal behaviour. Lockdowns and reduced economic activity led to temporary improvements in air quality in many cities, suggesting that significant reductions in urban air pollution are possible with substantial changes in transportation and industrial practices (Venter, 2020). Air pollution reductions during COVID-19 lockdowns have an immediate and potential long-term health benefits, indicating the positive impacts of reduced human activities on air quality (Giani, 2019). The discourse around air pollution encompasses various credible academic arguments that highlight its causes, effects, and the necessity for comprehensive mitigation strategies. There is a consensus on the need for stringent air quality regulations and policies to reduce emissions from major sources, such as transportation, industry, and agriculture. Academics argue for the effectiveness of policies like emission standards, low emission zones, and renewable energy incentives in improving air quality (Anenberg, 2017).

It is imperative that the problem on air pollution is strongly interlinked with the development processes taking place nowadays. Even the lack of data during 18th – 19th centuries with regard to air pollution cannot dispose the hypothesis that those countries, today appearing as leading economies with a high socio-economic status, could have walked the same path most of the developing countries are doing today. Nonetheless, the environmental arguments of numerous academics have penetrated and influenced economy and political disciplines. There is a robust belief that only strong countries have nowadays been able and fit to manage and avoid degradation of their natural resources, urban environment and public health (Schlager, 2004)

Yet, considering today's know-how there is still a lack of willingness to mitigate air pollution in urban areas. It requires a major shift and transition from fossil fuels, from daily habits and an overall social

culture build and functioning around fossil emissions. Accepting pollution as an unintended consequence of the evolution and urbanization equals to the induced acceptance that “smoking” was considered as a medicine to health in the late 60’. This course of thought and actions is based on the 20th century notions that the world is in a state of dichotomy. Whereas public goods is leading to a significant decrease of interest on the public commons and goods. The tension between economic growth and environmental sustainability is a critical issue. Developing countries often prioritize industrialization and economic development over environmental protection due to immediate economic needs. However, this short-term gain can lead to long-term health costs and environmental degradation (Dasgupta, 2002). The concept of sustainable development aims to address this dichotomy by promoting economic growth without compromising environmental health, yet its implementation remains challenging due to varying national priorities and capacities. If referring to the Environmental Kuznets Curve (EKC), a hypothesized relationship between environmental degradation and economic development. Where suggestion that as an economy grows and income per capita increases, environmental degradation intensifies up to a certain point. Beyond this point, further economic growth leads to environmental improvements. (Visually the EKC is represented graphically as an inverted U-shaped curve, with environmental degradation on the vertical axis and income per capita on the horizontal axis) the hypothesis makes perfect sense if we observe that in the early stages of economic development, industries and economies prioritize growth over environmental protection, leading to increased pollution and resource depletion. However, as income levels rise, there is a growing demand for improved environmental quality, and more resources are allocated to conservation and pollution control efforts. This leads to a decrease in environmental degradation, even as the economy continues to grow. However, to EKC debate among economists and environmental scientists, critics argue that the relationship between economic growth and environmental quality is not universally applicable and can vary significantly across different pollutants, regions, and stages of development. Some pollutants may not follow the inverted U-shaped curve, and in some cases, economic growth can continue to exacerbate environmental degradation without the anticipated improvement. Drawing parallels with the situation in Western Balkans and moreover with Tirana as our case study. The stronger the economy grows and the income per capita the heavier are the environmental and public health impact, specifically to the point that institutions do not dare to monitor and provide data for public at large. But now we are at a turning point with regard to mitigating air pollution and that is due to the fact that global pandemic had its counter effects or unintended effects to the public perception on the

matter. Public awareness and changes in societal behaviour play a crucial role in combating air pollution. The COVID-19 pandemic, demonstrated how reduced human activity can lead to significant improvements in air quality. This suggests that lifestyle changes, such as increased use of public transportation, cycling, and remote work, could contribute to sustained air quality improvements (Venter, 2020). However, achieving widespread behavioural change requires comprehensive public education campaigns, infrastructure development, and policy support.

2.2. A unique case study:

Air pollution in Albania presents a significant environmental and urban health concern to its citizens. Even though there has been a decade of “silence” from authorities to abide the legal obligations of monitoring, inspecting and reporting, the overall situation is rather felt and sensed by all of Tirana’s inhabitants. The country faces severe health risks from ambient air pollution (AAP), which is responsible for approximately 5,350 premature deaths annually and an average loss of 184 days of life across the nation, as reported by the European Environmental Agency in 2019. This corresponds also to the last year that EEA included Albania into its report given that most of the conclusions came through interpolation of satellite monitoring rather than being feed by local site monitoring practices. The major health issues stemming from elevated pollutant levels include acute lower respiratory infections, heightened lung cancer risk, strokes, ischemic heart disease, chronic obstructive pulmonary disease, and increased stress levels. Additionally, air pollution adversely affects vegetation and natural habitats, particularly diminishing ecosystem services in areas near urban and industrial zones. The primary sources of air pollutants in Albania include vehicle emissions exacerbated by poor fuel quality, the construction and heavy industry sectors, small and medium-sized enterprises operating medium or low combustion plants, and the illegal burning of waste and agricultural crops.

Regulations require that pollutants such as Sulphur Dioxide (SO₂), Nitrogen Dioxide (NO₂), Ozone (O₃), Particulate Matter (PM), and Carbon Monoxide and Dioxide (CO & CO₂) are monitored for more than 75% of the time annually (6570 hours) to comply with the Ambient Air Quality Directive (European Commission, 2008). Since 2015, Albania has lacked accredited stations for monitoring and reporting on air pollution, rendering most data cited in reports from EU agencies, the World Bank, and WHO outdated by over five years. Between 2015 and 2020, unregulated emissions have notably increased, with pollution levels becoming a critical environmental health risk, especially in cities like

Tirana and Elbasan. Such finding can't be actually referenced given that no official monitoring and publication is available in any of the official web-sites of National Environmental Agency (NEA) nor of the Public Health Institute (PHI). It is rather the authors persistent work on voluntary and alternative monitoring practices that concludes this increasing incidence on the concentration of urban air pollutants.

Despite the lack of specific public information on urban air quality and general environmental health, citizen science initiatives have played a key role in highlighting air pollution as a primary concern in Tirana. Currently, three main sources offer accessible information to the public:

The "Green Lungs for Our Cities¹" project, conceptualized, managed and implemented by this thesis author. This project was initially funded by the EU Delegation in Albania (2017 – 2021) and further through the support of Sweden International Development Agency (Sida) (2022 – 2027). This project is being led by the team at Co-PLAN Institute for Habitat Development under the supervision of the author. Moreover, there are countless actors involved in this initiative, such as *Milieukontakt Albania, EPER Centre, GO2 Shkoder, Arhaus Centre Shkoder, Eko-Mjedisi Durres, Ecological Club Elbasan, and further more 4 universities in Albania, Polis University, Natural Sciences University, Durres University and Agricultural University of Tirana*. Green Lungs monitors eight different pollutants in the municipalities of Tirana, Durres, Elbasan, Korce and Shkoder. This initiative shares its findings through an online platform, covering 2,340 monitoring activities.

Air quality monitoring that evaluates eight components, a collaborative effort between Vodafone Albania and the Municipality of Tirana, operates three stations in Tirana. This project provides real-time data through the "Tirana lme" app. It only was operative from 2018 – 2019.

Five (5) IQ Air Visual program sensors privately and green-lungs supported are installed in Tirana offer real-time PM2.5 concentration data through a global online platform.

With no recent publications or reports on air quality from state institutions, civil society initiatives have filled this void, producing over 45 articles and broadcasts on this topic in 2019. Community awareness of the unhealthy urban air quality in Tirana and other major cities has significantly

¹ Official web page of Mushkeri te Gjelbra: <https://greenlungs.al/index.php?lng=en>

increased. The restrictions imposed in March 2020 due to the COVID-19 pandemic led to an immediate and noticeable reduction in pollution levels, highlighting the potential for improving air quality. For a period of 62 days, from March 11 to May 11, 2020, we implemented a comprehensive daily observation strategy to track variations in air quality levels in Tirana, specifically focusing on NO₂, PM_{2.5}, and PM₁₀ pollutants. This initiative aimed to assess the potential links between implemented measures and pollution levels. The study selected four sites based on findings from a 2019 project which indicated that these areas consistently surpassed acceptable pollution thresholds in both concentration levels and duration of exposure. The chosen locations, all positioned along the western segment of Tirana's ring road, include the Vasil Shanto intersection, the 21 Dhjetori cross-road, the Architecture and Civil Engineering cross-road, and the Zogu Zi roundabout. The monitoring effort encompassed a total of 681 observations.

Figure 3: Monitoring practices conducted by the author during COVID-19 period



Source: Author

Observational protocols were implemented to ensure coverage amounted to 10% of the total study period. A rigorous analysis was conducted to establish a linkage between the findings and the enforcement of restrictions by the central authorities. On March 11, measures including the cessation of public transportation, the construction industry, and public gatherings were introduced indefinitely. By March 13, a comprehensive quarantine was enacted, leading to a cessation of all

urban activity. A notable initial observation was a 12.7% reduction in pollution levels following the suspension of public transport and heavy vehicle circulation. Subsequently, within a week of halting vehicular traffic and construction activities, a significant decrease in the levels of NO₂, PM_{2.5}, and PM₁₀ was observed, bringing them below the European Union's standards for the Albanian capital.

An unexpected occurrence on March 14 involved a high smog concentration in the afternoon and evening, not detected by the monitoring instruments. However, the detection of sulphur odors prompted measurements of sulphur dioxide, revealing a peak concentration of 166 µg/m³ between 18:00 and 23:00. Despite sporadic media reports on this unusual pollution event, the exact source remained unidentified. It is speculated that this could have been due to waste burning in either Tirana or the Durrës Municipality, exacerbated by the surge in waste production from increased consumption during the early days of quarantine. The study documented a 14% daily reduction in pollution levels across the monitored sites.

Between April 5 and 7, pollution levels plummeted to record lows across all sites, with the following results:

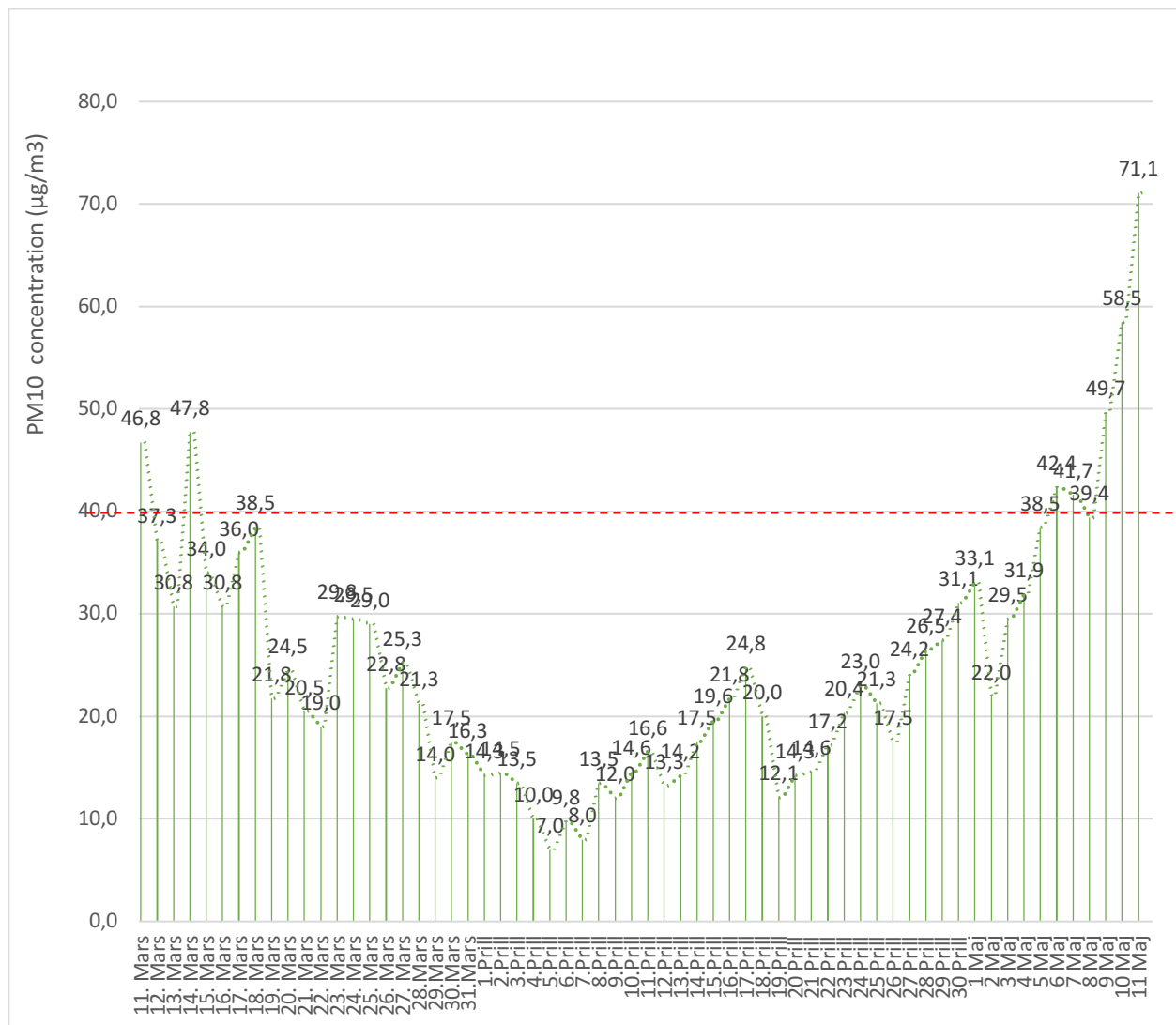
- PM₁₀ levels reached 6µg/m³, significantly below both EU and by World Health Organization (WHO) standards.
- PM_{2.5} levels were at 1.5µg/m³, surpassing EU and WHO standards by a considerable margin.
- NO₂ levels fell to 7µg/m³, well below the thresholds set by both the EU and WHO.

From the second week of April, coinciding with the resumption of construction activities and an increase in private vehicle use, a gradual rise in pollutant concentrations was observed, averaging a 9% day-to-day increase. Notably, the implementation of stringent weekend lockdowns contributed to a marked reduction in pollution. Remarkably, Tirana residents experienced 52 consecutive days of improved air quality, an unprecedented occurrence. Towards the end of April, despite a moderate relaxation of restrictions excluding public transport, which was projected to resume on June 15, pollution levels began to rise in the second week of May. This increase was attributed not solely to the reactivation of urban activities and transportation but also to meteorological phenomena affecting the entire Balkan Peninsula, including Sahara Sandstorms. The presence of fine dust particles in the atmosphere became more pronounced, eventually settling on both urban and natural surfaces following periods of rainfall.

On a more technical language, from all this monitoring practice during the most unique period ever perceived since 1989 for a city as Tirana, the finding could be summarized as below:

For PM₁₀, the data indicate an average concentration of 25.76 µg/m³, with the minimum recorded level being 6 µg/m³. This represents a significant decline of 41% compared to the annual average of 2019 and positions the levels at least 36% below the European Union (EU) standards. However, these levels failed to meet the World Health Organization (WHO) standards, with measurements in Tirana was reported to have a yearly average concentration of PM₁₀ = 50.6µg/m³ during 2016 (NEA National Environmental Agency, 2017) While the same source reported an increased concentration during 2017 PM₁₀ = 62.4µg/m³ which is also the last report on Air from the state authorities. On the other hand, form the Green Lungs project. on same component we registered an average yearly concentration of 43.8µg/m³ during 2019.

Figure 4: Daily concentration of PM₁₀ during the lock-down period in Tirana (11. March.2020 – 11. May.2020)

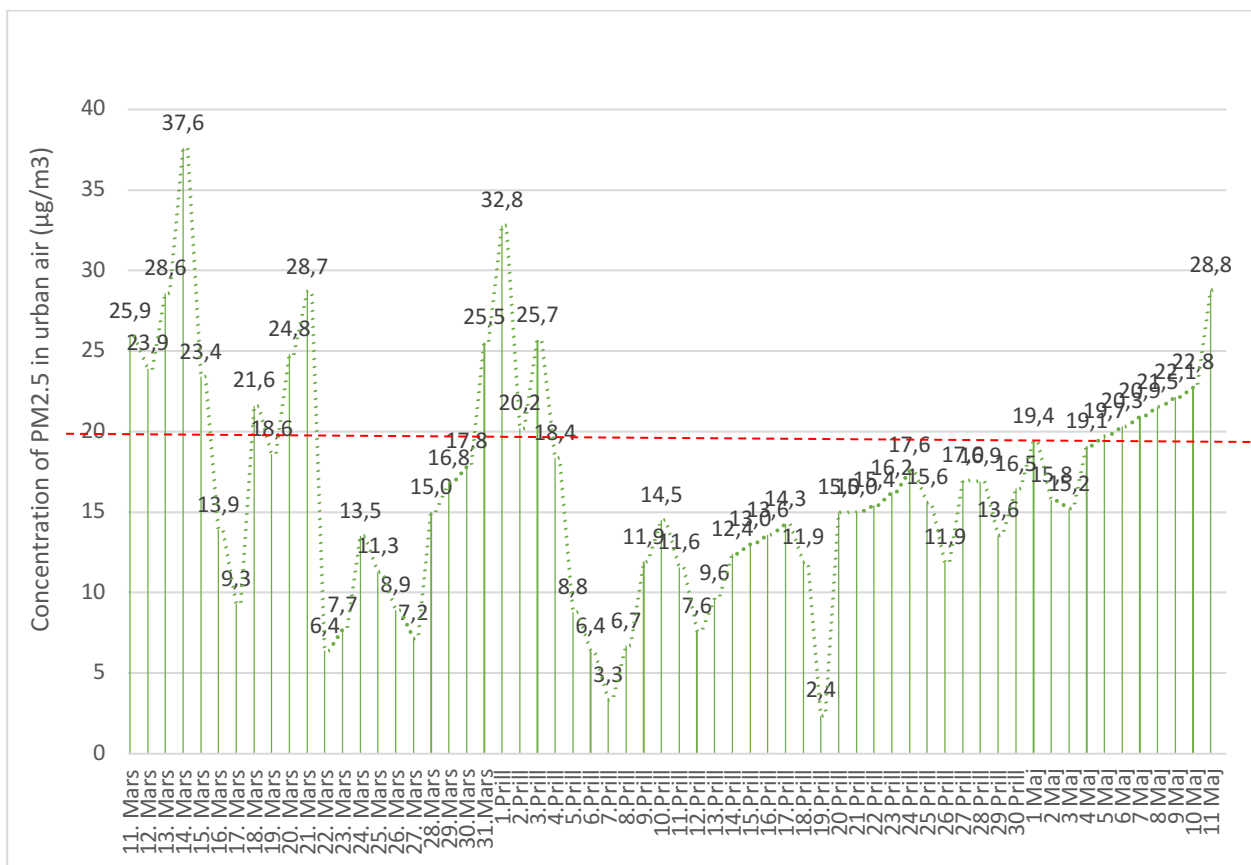


Source: Author calculation and findings

PM_{2.5} average from March 11th to May 11th 19.1µg/m³ and the lowest registered value 1.5µg/m³ (13 times lower than EU standard and 7 times lower than WHO standard)

Given the context where numerous researchers have cited direct link of fine particular matter to the aggravated effects of COVID-19, such pollutant in my case indicates a substantial decrease by 31% comparing to the 2019 yearly average and standing at least 25% below the EU standard but nevertheless it didn't reach to meet the WHO standard whereas even during COVID-19 in Tirana we were at least 91% above their exposure standard. Tirana has not reported a yearly average concentration of since 2015 therefore we can referee only to the data provided by Green Lungs project. During 2019 we registered an average yearly concentration of 27.8µg/m³. It is important to be noted that the second week of May was characterized by meteorological conditions caused by the Sahara Sand-storm that was present in the whole region.

Figure 5: Daily concentration of PM_{2.5} during the lock-down period in Tirana (11. March.2020 – 11. May.2020)

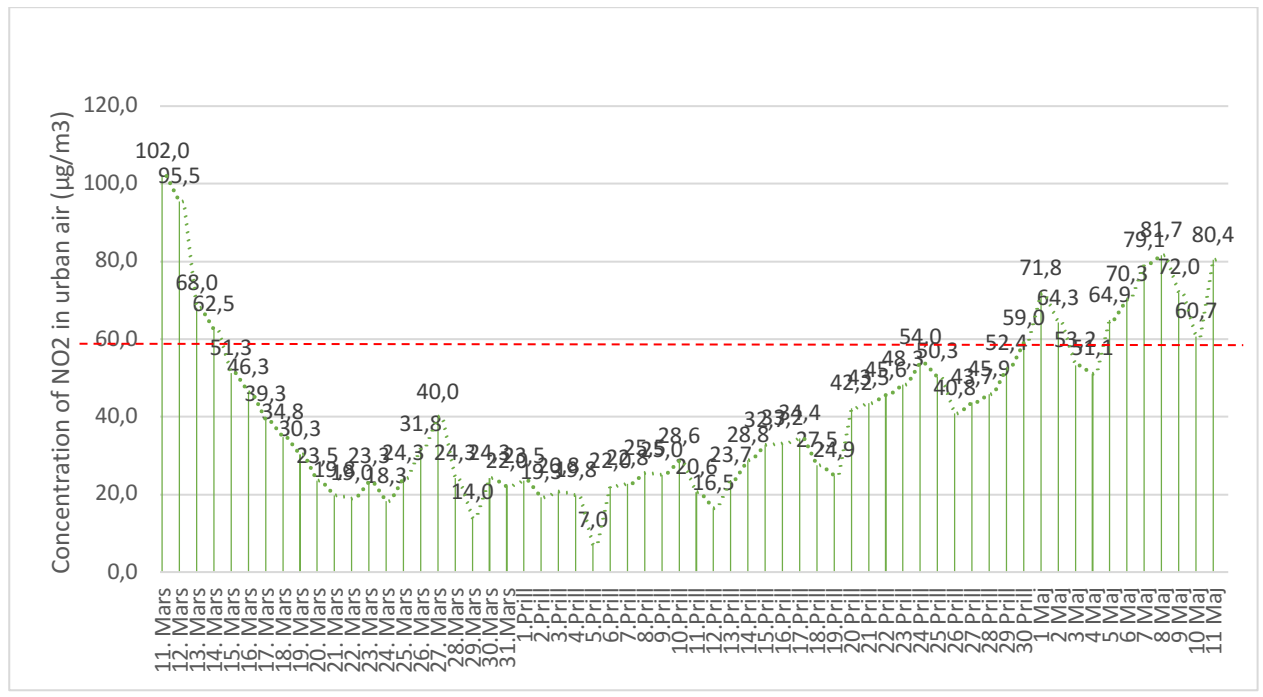


Source: Authors calculations and findings

NO₂ = average from March 11th to May 11th 42.1µg/m³ and the lowest registered value 7µg/m³ (6 times lower than EU and WHO standard). Nitrogen dioxide is considered to be the main problem in Tirana during the last 5 years now. It is directly linked with two acute problems that our city faces

on a daily basis. Low level of mobility within the city whereas traffic congestions constrict most of the drivers and passengers to endure 200hours of traffic per year and an average of 244 liters of fuel being burned in traffic (GJOKA, 2020). The second problem consist on a worst-scenario combination for a city as dense as Tiana, whereas the low quality of fuel is being burned in ICE vehicles that are part of one of the oldest fleets in the region. As a first finding it can be stated that even-though we experienced around 35 days in a row with NO₂ concentration below the EU AND who standard of 40µg/m³ the overall average of these monitoring campaign stands 5.3% above the EU and WHO standards. In terms of comparison with the concentration of previous years. Tirana was reported to have a yearly average concentration of NO₂ = 24.5µg/m³ during 2016 (RGJM, 2017). While the same source reported an increased concentration during 2017 NO₂ = 67.5µg/m³ which is also the last report on Air from the state authorities. On the other hand, form the Green Lungs project. on same component we registered an average yearly concentration of 112µg/m³ during 2019. Finally, we can state that enforced restrictions banning all transport means in Tirana contributed directly by reducing the NO₂ concentration in urban air by 62% from the previous year. Nevertheless, it should be mentioned that by the end of the monitoring campaign, when transport means were gradually open in full (beside public transportation) the concentration started to increase by an average of 1.47 µg/m³ per day.

Figure 6: Daily concentration of NO₂ during the lock-down period in Tirana (11. March.2020 – 11. May.2020)



Source: Author calculations and findings

Since the onset of the COVID-19 pandemic, the relationship between air pollution and the global health crisis has emerged as a focal point of environmental and public health research. Two principal observations were made early in the pandemic's course. The first observation highlighted a swift reduction in air pollution levels following the implementation of quarantine measures worldwide. This immediate environmental response to reduced human activity underscored the significant impact of transportation and industrial activities on air quality. Concurrently, the second observation established a linkage between the severity of COVID-19's clinical outcomes and the air quality of the affected regions. Research, such as the study conducted by Harvard University in 2020, suggests a marked increase in COVID-19 mortality rates among individuals residing in areas with elevated levels of fine particulate matter. Specifically, the study found an 8% increase in the likelihood of death from COVID-19 for individuals living in areas with just one microgram per cubic meter more of particulate pollution than less polluted areas. pollution (Harvard University, 2020).

In Europe, real-time data from the European Environment Agency (EEA), leveraging over 4000 monitoring stations, documented significant reductions in nitrogen dioxide (NO₂) concentrations during the pandemic—24% in Milan, 40% in Barcelona, and 56% in Madrid, compared to the same timeframe in 2019. This trend was visually corroborated by the Copernicus Atmosphere Monitoring Service through the Sentinel 5 satellite, which detailed a decrease in pollutants, particularly in densely populated urban regions. In contrast, Tirana reported a substantial 64% reduction in air pollution, highlighting the considerable influence of vehicular emissions and fuel standards on the city's air quality.

The Western Balkans face distinct challenges, with several cities at risk of experiencing heightened pollution levels due to reliance on thermal power plants for energy. The lockdown in spring 2020 led to a notable increase in household energy demand, raising concerns about the potential for increased emissions should a second wave of the pandemic necessitate further quarantine measures. In anticipation of such scenarios, it is crucial for local and central governments in cities like Prishtina, Belgrade, Skopje, and Sarajevo to devise strategies to mitigate this risk. For Albania, which does not rely heavily on coal for energy, the concern remains with the traditional use of wood, coal, and pellets for heating, which contributes to pollution without adhering to emission standards.

The World Bank's "Regional Note on Air Quality Management in the Western Balkans" underscores the need for proactive measures to prevent winter pollution spikes and acknowledges the transboundary nature of air pollution challenges. Despite Albania's non-coal-based energy system,

the country is braced for an uptick in pollution levels, particularly with NO₂ concentrations already exceeding national and international standards. The prevalence of dioxins and furans from waste incineration, along with emissions from public and private sector activities, underscores the urgent need for investment in pollution reduction strategies. (World Bank, 2020).

The COVID-19 crisis, while presenting numerous socio-economic challenges, also offers a vision for a sustainable and resilient future aligned with the Paris Agreement and the EU Green New Deal. The path towards decarbonization of the energy, transport, and industrial sectors is increasingly recognized as vital for achieving a socio-economic transformation that supports a climate-friendly and clean environment.

2.3. Policy and Novel Approaches on Air Pollution

The European Union (EU) has established a comprehensive framework of laws and policies aimed at combating air pollution, recognizing its significant impact on human health, the environment, and the economy. This framework is among the most ambitious globally, designed to reduce emissions of air pollutants and improve air quality. The EU's approach to air quality management and regulation can serve as a model for other regions, including the integration of environmental concerns into its member states' legal systems, such as Albania. Here's a detailed overview of the matter, taking into account both the EU and the Albanian context:

EU Framework on Air Quality

Directive on Ambient Air Quality and Cleaner Air for Europe (2008/50/EC)

This directive consolidates previous legislation and sets ambitious goals for reducing concentrations of air pollutants deemed harmful to human health and the environment. It establishes air quality standards for pollutants such as particulate matter (PM₁₀ and PM_{2.5}), nitrogen dioxide (NO₂), and ozone (O₃), among others. Member states are required to assess air quality in their territories, ensure public access to information, and develop Air Quality Plans to achieve and maintain the air quality standards.

National Emission Ceilings Directive (2016/2284/EU)

This directive sets national emission reduction commitments for five key pollutants: sulfur dioxide (SO₂), nitrogen oxides (NO_x), non-methane volatile organic compounds (NM_VOCs), ammonia (NH₃), and fine particulate matter (PM_{2.5}). The aim is to reduce air pollution and its impacts on human health and the environment by 2020 and 2030.

The European Green Deal is a set of policy initiatives with the overarching aim of making Europe climate neutral by 2050. Among its many goals, the Green Deal focuses on reducing pollution to levels no longer considered harmful to health and natural ecosystems, thereby directly addressing air quality.

On the other hand, it is imperative for Albania to invest in and establish a comprehensive Air Quality Monitoring and Reporting Network is underscored by the requirements set forth in the National Strategy for Air Quality (Decision of the Council of Ministers No. 594, dated September 10, 2015) and the National Plan for the Management of Air Quality (Decision of the Council of Ministers No. 412/2019). This initiative is crucial for ensuring the systematic observation and assessment of air quality across the nation, facilitating informed decision-making and policy development aimed at mitigating air pollution.

Moreover, there is a pressing need for Albania to fully integrate and enact the provisions of several critical European Union directives within its national legislation.

These directives encompass:

- *Directive 2008/50/EC on Ambient Air Quality,*
- *Directive 2016/2284/EC on the reduction of national emissions of certain atmospheric pollutants,*
- *Directive 2016/802/EC regarding the reduction in the sulfur content of certain liquid fuels,*
- *Directive 2009/126/EC which pertains to Stage II vapor recovery during refuelling of motor vehicles,*
- *Directive 2015/2193/EU on the limitation of emissions of certain pollutants from medium combustion plants, and*
- *Directive 2010/75/EU on industrial emissions (Integrated Pollution Prevention and Control).*

Furthermore, enhancing collaboration between the National Environmental Agency (NEA) and the Institute of Public Health (IPH) is essential. This collaboration should focus on the scientific analysis of pollution concentrations and the assessment of their economic impact based on a welfare-oriented approach to pollution exposure and the overall health of urban environments.

Transitioning towards a low-carbon economy is identified as a critical mid-term goal for significantly reducing reliance on fossil fuel combustion. This transition necessitates targeted investments and strategic decision-making at the national level, adopting a climate-neutral perspective. It is imperative that both public and private investments in Albania are evaluated for their immediate

and long-term environmental impacts, incorporating a thorough Benefit-Cost Analysis that encompasses Ecosystem Services, Air Pollution, and Urban Health considerations.

Local governance in Tirana, including the City Council, is urged to prioritize measures to curb air pollution emanating from public and private transportation, traffic congestion, and emissions from the construction and industrial sectors. These sources have been recognized as significant contributors to stationary air pollution over the past five years.

In Tirana, the distribution of pollution exposure disproportionately affects certain populations, necessitating the development of equitable solutions to air quality improvement efforts that do not unduly burden the economically disadvantaged or vulnerable groups. Public investments should be directed towards climate-friendly initiatives, setting a National Emission Target subsequent to the establishment of an Air Monitoring Network and the completion of a National Emission Analysis.

The renewal of Tirana's public bus fleet to meet EURO-6 standards or transition towards electric buses to reduce reliance on private vehicle use. Enforcement of emission standards for heavy vehicles, particularly those used in public service operations and construction, to meet at least EURO-5 emission standards. Technical control of emissions from private vehicles by certified companies, ensuring compliance with EURO-IV standards or higher.

Consideration of Low Emission Zones and Ultra Low Emission Zones in Tirana to regulate vehicle access based on emission standards. It is of utmost importance that environmental protection laws, particularly those relating to construction, transport, and industry sectors, are strictly adhered to. This includes rigorous monitoring and reporting of pollution emissions to ensure compliance with established standards. The provision of inaccurate or misleading data in self-monitoring reports undermines regulatory efforts and must be addressed to uphold the integrity of environmental governance. Through these comprehensive strategies and measures, Albania can make significant progress in improving air quality and advancing towards a sustainable and environmentally responsible future.

2.4. Low / Ultra Low Emission Zones

Low Emission Zones (LEZs) and Ultra Low Emission Zones (ULEZs) represent critical strategies in urban environmental management, aiming to reduce pollution levels and improve air quality. These zones restrict access to certain areas for vehicles that do not meet specified emission standards, effectively reducing the concentration of pollutants in urban environments.

Low Emission Zones (LEZs) are designated areas in cities where access by certain polluting vehicles is restricted to improve air quality. Ultra Low Emission Zones (ULEZs) represent a stricter version of LEZs, imposing more stringent emissions standards. Originating in several European cities, these zones aim to mitigate the environmental and health impacts of urban air pollution by encouraging the use of cleaner vehicles.

The Rationale Behind LEZ and ULEZ implementation relies on the fact that air pollution is a significant public health issue, contributing to respiratory diseases, cardiovascular conditions, and premature deaths. Vehicles, particularly diesel-powered ones, are a major source of urban air pollutants, including nitrogen oxides (NO_x) and particulate matter (PM). LEZs and ULEZs are implemented as part of broader urban air quality strategies to reduce these emissions.

Even though this appears rather as a policy initiative, academics have analysed the effectiveness and socio-economic impacts of LEZ and ULEZ policies. Studies in journals such as *Environmental Science & Policy* and *Transportation Research “Part D”* often highlight the positive environmental impact of these zones. For instance, in London's ULEZ found a significant reduction in NO_x emissions within the zone. However, there is also debate regarding the equity of these policies, with some researchers arguing that they disproportionately affect lower-income drivers who cannot afford newer, cleaner vehicles (Font, 2018). Evidence from cities that have implemented LEZs and ULEZs shows notable improvements in air quality. For example, after the introduction of the ULEZ in London in 2019, the city reported a 36% reduction in NO_x emissions within the zone. Similarly, Berlin's² LEZ led to a 20% decrease in diesel particulate matter. These statistics underscore the potential of emission zones to significantly mitigate urban air pollution. Critics argue that LEZs and ULEZs can lead to unintended consequences, such as increased traffic in areas just outside the zones and economic hardship for individuals and businesses reliant on older vehicles. There is also concern about the adequacy of public transport alternatives and the overall effectiveness of such zones in achieving long-term air quality goals.

LEZs and ULEZs are pivotal components of urban environmental strategies, offering a proven method to reduce vehicle emissions and combat air pollution. While challenges and criticisms exist, the positive impact on urban air quality cannot be understated. Future policies must consider equity and accessibility, ensuring that improvements in air quality benefit all residents without undue burden.

² Berlin's Low Emission Zone: An Evaluation, Senate Department for the Environment, Berlin

2.5. Environment and Urban Planning

Urban planning's roots can be traced back to ancient civilizations, where it was primarily concerned with the design and management of public spaces, roads, and buildings for functional and aesthetic purposes. However, it was not until the 19th century that urban planning began to emerge as a distinct professional field in response to industrialization and urbanization, which brought about significant environmental and social challenges.

Leonardo Benevolo provides an amazing prospect on the history of urban planning focusing on its architecture and form. Urban planning is a rich and multifaceted field that spans across several centuries, reflecting the evolution of human settlements from ancient times to the modern era (Benevolo, 1980). Urban planning, as a deliberate effort to shape cities and towns, has been influenced by a variety of factors including technological advancements, social reforms, and cultural shifts.

- Ancient Civilizations

Indus Valley Civilization (around 2600 BCE): One of the earliest examples of planned settlements. Cities like Mohenjo-Daro and Harappa featured grid layouts, sophisticated drainage systems, and standardized bricks for construction.

Ancient Egypt (around 3000 BCE to 30 BCE): Planning was evident in the layout of cities, the construction of the pyramids, and the creation of irrigation systems to support agriculture.

Ancient Greece (around 800 BCE to 146 BCE): Introduced the concept of urban centers (agoras) and public spaces. Hippodamus of Miletus is one of the first known urban planners, advocating for grid layouts and functional zoning.

- Medieval Period

During the medieval period, urban planning was less evident in Europe due to the feudal system, but Islamic cities continued to develop sophisticated urban designs, including central marketplaces, residential quarters, and intricate street patterns.

During the Medieval period, cartographic representations of the world were largely allegorical rather than factual, reflecting a Christian-centric worldview with Jerusalem often depicted at the centre. Furthermore, some maps employed the motif of Christ's body as the framework for incorporating geographical details, indicating a symbolic rather than an empirical approach to

cartography. This blend of theology and geography underscored the medieval conception of the world as a spiritual and moral landscape rather than a physical one. However, this approach underwent a significant transformation during the Renaissance, as empirical observation and a renewed interest in classical antiquity led to a more accurate and reality-based representation of the world in maps. This shift marked a departure from the religiously inspired cartographic practices of the Middle Ages, heralding a new era of exploration and discovery that prioritized accurate geographical depiction over religious symbolism.

- **Renaissance and Baroque Periods (14th to 17th Centuries)**

Renaissance Italy: Saw the return of grid patterns and the design of ideal cities, combining aesthetics with functional considerations. Figures like Leonardo da Vinci and Antonio di Pietro Averlino (Filarete), Mercator and Copernicus contributed to urban planning concepts. Blending art, science, and architecture to envisage city designs that were ahead of their time. Their work reflects a deep understanding of the importance of functionality, aesthetics, and human well-being in urban spaces.

Leonardo da Vinci, renowned for his wide array of talents, applied his genius to the realm of urban planning with innovative ideas that emphasized harmony between the natural and built environments. His contributions encompass

a) City Layout: Leonardo proposed the separation of pedestrian and vehicular traffic, which was revolutionary. He designed a multi-level city with the upper level for foot traffic and the lower level for goods transportation, aiming to reduce congestion and improve hygiene.

b) Water Management: Understanding the importance of water in cities, Leonardo devised advanced water systems for sanitation, navigation, and flood control. His designs included canals for transport and sewers to improve public health.

c) Urban Renewal: Although not implemented during his lifetime, Leonardo's sketches and notes reveal plans for reorganizing medieval cities according to principles of symmetry, functionality, and beauty. His ideas anticipated modern urban redevelopment concepts by centuries.

Da Vinci through applying math and measurement, created a beautiful and practical map of Imola accurate enough to navigate the Italian city today. In the case of Imola, da Vinci's first commissioned work from Cesare Borgia (son of Pope Alexander II) he was requested to create an accurate map of the city. Whereas by using compass, odometer and polar coordinates and his practical approach *sapere vedere*, da Vinci produced the first flattened city map, even accurate with today's cartography.

Figure 7: Leonardo da Vinci map plan of Imola



Source: National Geographic _ Transformation of mapping from art to science

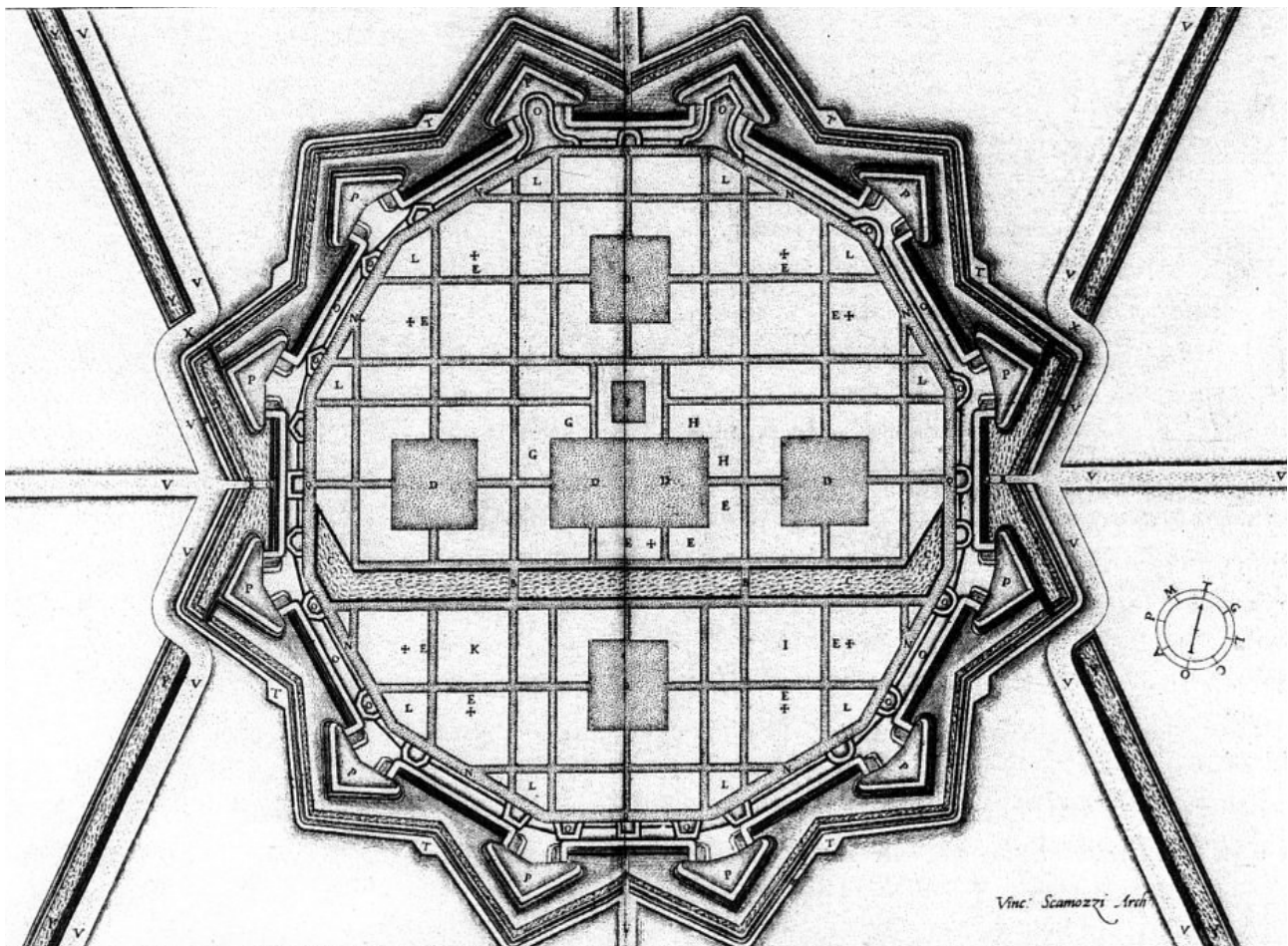
Various attempts at different cartographic representations were explored, leading to a notable milestone in 1569 with Mercator's introduction of his global map. Nonetheless, the prevailing cosmological perspective remained entrenched in the mistaken belief of Earth's central position in the universe, a view that endured until Copernicus's revolutionary work in 1543. Christian Norberg-Schulz describes how the Renaissance perspective integrated both empirical, uniform space and ideal, centralized space through these innovations. This integration is exemplified in the notion of the ideal city. Contrary to the medieval city, which was deemed ideal for its physical embodiment of the *Civitas Dei*, the Renaissance city sought after an ideal form. The era was characterized by scientific explorations into urban design, culminating in the construction of an exemplary ideal city, *Palma Nova*, in 1593 by Savorgnan and Scamozzi. Additionally, this period saw a proliferation of treatises by architects who meticulously analysed urban challenges with the intent of establishing exemplary urban designs. On the other hand, Filarete's ("the lover of excellence from ancient Greek"), was an architect, sculptor, and urban planner. His contributions are notably encapsulated in his architectural treatise, where he outlined the ideal city *Sforzinda*³. Filarete designed an ideal

³ *Tratto di Architettura* or known as *Codex Magliabechiano* 15th Century

city named Sforzinda in honour of Francesco Sforza, the Duke of Milan. This plan, detailed in his treatise, featured a star-shaped layout with radial streets emanating from a central point, reflecting principles of ideal Renaissance cities with emphasis on order, symmetry, and defensibility. Public Health, Hygiene and Protection were Filarete's pillars when designing wide streets for airflow and sunlight, public squares, and dedicated areas for markets, demonstrating an understanding of the social aspects of urban design and the well-being of inhabitants (Ruth, 2001).

He also envisioned mixed-use zones with residential, commercial, and civic buildings coexisting, aiming for a self-sufficient city that catered to the diverse needs of its residents. Always and everything projected within the ideal principles of exact geometry.

Figure 8: Ideal city plan by Vincenzo Scamozzi (1615)



Source: Utopianism and the (n) build environment

Their visionary ideas laid foundational principles that influenced the development of modern urban planning, highlighting the Renaissance era's profound impact on how cities could be organized for improved living conditions, efficiency, and beauty (Rosenau, 1983).

Baroque planning (17th Century): Focused on grandiose urban designs, emphasizing order, symmetry, and monumental axes. Paris, under the influence of planners like Baron Haussmann in the 19th century, is a notable example with its wide boulevards and uniform architectural styles. Baroque urban planning considered the natural environment as a backdrop and tool for enhancing the grandeur and theatricality of urban spaces. Planners and architects of the Baroque period skilfully manipulated landscapes to create dramatic vistas, direct sightlines to significant edifices, and design intricate garden spaces that reflected the era's fascination with control over nature. The relationship between built structures and the environment was carefully curated to achieve an effect of awe and splendour. Indeed, it appears that the Baroque planning period represents a critical phase in the history of urban development but moreover into the scholar proceedings of the time, where **the environment was ultimately transformed into a mere backdrop and tool to realize the architectural and urban planning goals of the period.**

Most of the landmarks that even nowadays inspire generations for their amazing human creativity indicate the period's control over natural landscapes. Most of the primitive and simplistic approaches on nature and environment from earlier eras were lost. A streamline of academic discussions on Baroque influence in urban planning and cities often focus on the intricate relationship between urban design and the political, social, and aesthetic aspirations of the Baroque era. These discussions highlight the use of urban planning to project power, control, and a sense of divine order, transforming cities into theatrical spaces that both reflect and reinforce the values of their creators. (Mayerik, 2018). Alongside to Mayerik arguments, one significant aspect of Baroque urban planning is its emphasis on creating dramatic vistas and direct sightlines to significant edifices, a strategy that serves to emphasize the power and grandeur of ruling authorities. The planning of Rome under Sixtus V is frequently cited as a pivotal example of how urban planning and architecture were harnessed to serve both functional and symbolic purposes during the Baroque period. The implementation of grand boulevards, open squares, and strategically placed monuments facilitated not just the physical reorganization of the city but also aimed to manifest the church's and monarchy's influence in the physical and social landscape of the city (Filali-Ansary, 2018).

Baroque cities were designed as microcosms of the world, embodying a blend of political means directed towards analogical ends, where the ephemeral and the permanent structures coexisted to animate the city in a manner that aligned with the era's cosmological and theological views. The layout of cities like Rome, Paris, and Versailles during this period exemplifies how urban spaces were

meticulously curated to achieve an awe-inspiring effect, making the city itself a spectacle of power and divine order thus planting and nurturing among public at large that man is above nature.

- **Industrial Revolution (18th to 19th Centuries)**

Fossil fuel era, utilization of this product potential shaped the whole world faster than any other resource ever used by humans. Initially Abraham Darby I, an Englishman ironmaster was the first to practically refine fossil fuels in order to obtain higher calorific input for his daily iron smelting processes. Through his invention during the first decade of 1700s, he contributed to decreasing iron production costs. Later in the 19th century, masterminds of thermodynamics, geology and chemistry like Joule, James Prescott, Dmitri Mendeleev unlocked the full potential of all fossil fuel by-products thus laying the foundations of understanding embodied energy of fossil fuel, its efficiency and economic perspective.

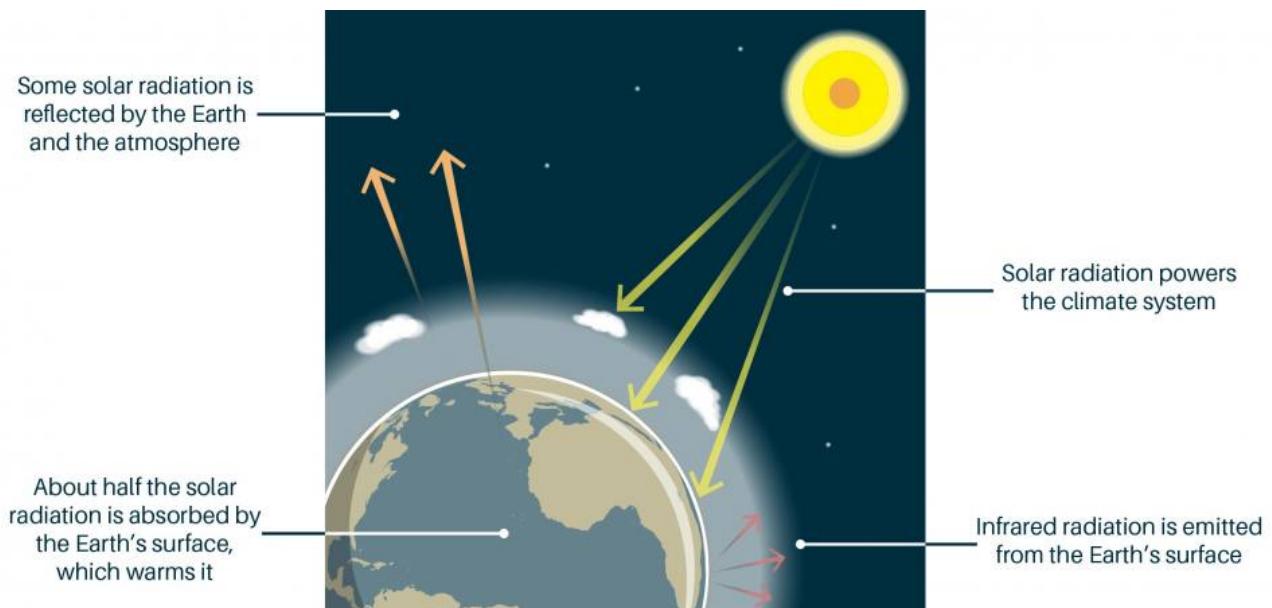
Such understanding led the modernization of all sectors, economy, army, industry, power, art and social behaviour. It was an imposed and rather fast transition for anyone in the world to catch up. Whilst industry and economies were expanding their bites on natural resources it was obvious that common knowledge on environment, nature resources and climate deriving from ancient time to 18th century masterminds was deliberately neglected.

First concerns arose as early as 1856, when Foote demonstrated that carbon dioxide (CO₂) and water vapor could trap heat, suggesting a warming effect on the Earth's atmosphere (Foote, 1856). Although her work did not directly address climate change as we understand it today, it laid the groundwork for the greenhouse effect theory. Eunice Newton Foote contribution was not recognized at the time due to a male predominant scientific community but her early contribution may pose the largest positive contribution to nature protection in world's history.

Later on, 1986 the Greenhouse Gas (GHG) Theory (Arrhenius, 1896) was quantitatively described by the Swedish author Svante Arrhenius. Explicitly he posits those gases in Earth's atmosphere, such as carbon dioxide, methane, and water vapor, trap heat from the sun, preventing it from escaping back into space, and thus warming the planet.

Despite some misunderstandings, Arrhenius's paper does not directly claim that fossil fuel combustion will lead to global warming. However, he acknowledges the significant potential of fossil fuels to increase atmospheric carbon dioxide levels (as mentioned on page 270), and in subsequent work, he more clearly proposes that such emissions could warm the Earth.

Figure 9: Solar radiation heating the atmosphere and earth.



Source: British Geology Survey Society

Nevertheless, Industrial revolution required human work-force nearby the resources being exploited or processed. Herby rapid, urbanization and industrialization highlighted the need for urban planning to address overcrowded cities, sanitation issues, and public health crises. The introduction of public parks, wider streets, and zoning laws began to take shape, certainly at a cost. Poor areas were forcibly displaced and such transition was far from being just to many.

- **20th Century to Present**

Early 20th Century: Saw the emergence of the Garden City Movement by Ebenezer Howard, aiming to combine the best of urban and rural environments to create self-contained communities.

Mid-20th Century: The modernist movement led by architects and planners like Le Corbusier emphasized functionality and introduced the concept of the Radiant City, with large-scale, centralized urban planning focusing on high-rise buildings and separation of functions.

Late 20th Century to Present: Urban planning has increasingly focused on sustainability, community involvement, and the integration of new technologies. Concepts such as Smart Cities, green infrastructure, and mixed-use developments reflect a move towards more environmentally friendly and socially inclusive urban environments.

Throughout its history, urban planning has been shaped by the challenges and needs of the times. Today, it continues to evolve, incorporating lessons from the past and innovations for the future, aiming to create liveable, sustainable, and resilient urban environments.

Urban planning literature emphasizes the necessity of integrating ecosystem services into the urban fabric to enhance resilience and sustainability. The European Commission's 2050 Green Agenda and the United Nations' recommendations underline the importance of including nature in urban development plans. Studies suggest that urban green spaces, such as parks and green roofs, can significantly improve air quality and reduce the urban heat island effect (Connop, 2016). These green infrastructures play a crucial role in filtering air pollutants and providing cooler urban environments.

Research on climate change impacts on urban areas highlights the increasing vulnerability of cities to extreme weather events and the need for adaptive urban planning strategies. The Intergovernmental Panel on Climate Change (IPCC) reports indicate that urban areas, particularly in the Western Balkans, face significant risks from climate change, including increased temperatures and altered precipitation patterns (United Nations, 2014). Building urban resilience, therefore, necessitates a focus on sustainable urban forms that can mitigate these impacts and enhance the quality of life.

2.6. Urban Form and Air Pollution

Urban form refers to the physical layout, design, and organization of urban areas. It encompasses the arrangement and distribution of buildings, public spaces, transportation networks, infrastructure, and other urban elements.

Urban form has a significant impact on the way people interact with and experience cities. A well-designed urban form can encourage social interactions, promote walkability and active transportation, reduce the negative impacts of car dependence, and support a sustainable urban environment. In contrast, poorly designed urban form can result in social isolation, urban sprawl, and environmental degradation.

Different urban forms can be identified, such as the grid pattern found in many American cities, the concentric rings of urban development in European cities, or the mixed-use development common in many Asian cities. Urban form can also vary within cities, depending on the neighbourhoods, land use patterns, and historical development patterns. Urban planners and designers play a critical role in shaping urban form, considering factors such as population growth, transportation needs, environmental concerns, and social equity. Effective urban form planning can create liveable, equitable, and sustainable cities that meet the needs of their residents.

Urban form epistemology refers to the study of how knowledge about urban form is produced, acquired, and applied. It explores the ways in which knowledge is created and disseminated within the fields of urban planning, design, and related disciplines, and how this knowledge shapes the development of urban form.

Urban form epistemology is a complex and interdisciplinary field, drawing on knowledge and methodologies from fields such as geography, sociology, architecture, and urban planning. It examines the theoretical frameworks and models used to understand and analyse urban form, as well as the empirical data and methods used to collect and analyse information about urban areas. However, one of the earliest theories on urban form in the mid-19th century were presented the ideas about the layout and design of cities that influenced modern urban planning. Of a crucial importance are the grid layouts, open spaces, and infrastructure in promoting healthier living conditions and addressing the challenges of urban growth. (Cerdá, 1867).

Ildefonso Cerdá concluded that urban form should prioritize broad, grid-patterned streets to facilitate movement and reduce congestion, incorporating large, open spaces for public use. He emphasized the importance of integrating infrastructure for transport, sewage, and utilities into city planning. Cerdá advocated for urban development that considered social and environmental well-being, aiming to create liveable cities that catered to the health and needs of their inhabitants. His work laid foundational principles for modern urban planning, focusing on functionality, accessibility, and sustainability.

On the other hand, the discourse on urban morphology necessitates a profound comprehension of its multifaceted nature, transcending mere physicality to encompass social dynamics and sustainability within a given milieu. Urban form embodies a complex interplay of architectural and infrastructural elements, fostering diverse human interactions.

Alexander's seminal critique of conventional urban planning posits a 'semi-lattice' model, advocating for an organic, interconnected urbanism that mirrors the complexity of human societies (Alexander, 1956). This approach underlines the imperative to reconceptualize sustainability, urging a holistic examination beyond environmental determinism to include socio-economic and cultural dimensions within urban ecosystems.

The link between urban air pollution and public health is well-documented in environmental health literature. Studies show that pollutants like Nitrogen Dioxide (NO₂) and Particulate Matter (PM_{2.5} and PM₁₀) are associated with respiratory and cardiovascular diseases (World Health Organization,

2013). Urban areas, especially in Central and Eastern Europe, are identified as hotspots for air pollution due to dense population, industrial activities, and vehicular emissions. This research underscores the importance of monitoring and reducing air pollution levels to protect public health while accepting that our both urban, technological and engineering knowledge at the moment does not indicate a realistic scenario where an urban area shall be completely depolluted. Herby alternative solutions alongside monitoring and mitigation measures relate to enabling urban form in a certain way that it can allow and further facilitate natural dispersal of air pollution through the wash-out effect. This is a necessity to avoid unintended increased concentration of pollutants in specific areas whereas urban form and wind interaction create cavity areas.

By examining the epistemology of urban form, the candidate knowledge in the field of urban planning combined with his environmental senior profile have come to identify opportunities for improving the effectiveness and equity of urban form practices. Nevertheless, before jumping to conclusions there are many authors who have made significant contributions to the study of urban form.

For instance, there is a strong argument that the quality in a physical object which gives it a high probability of evoking a strong image in any given observer Kevin Lynch: An American urban planner and author of the classic book "The Image of the City," which introduced the concept of mental mapping and helped to establish the field of urban design. focuses on how people perceive and navigate urban environments, introducing the concept of mental mapping. He identified five elements crucial to the legibility of cities: paths, edges, districts, nodes, and landmarks. Lynch argued that a well-designed city should be easy to navigate, with distinctive features that help people form mental maps of their surroundings. His work has significantly influenced urban design, emphasizing the importance of user-friendly urban environments that cater to human cognitive processes in city planning. The environmental image is the result of a process of selection and organization, a process based not only on optical stimuli but also on the entire past experience of the observer. We must be able to see where we are, not just in a physical sense but in relation to the larger environment. Given that urban inhabitants do not simply 'see' a space; they view it from a particular standpoint and are influenced by their past experiences, desires, and intentions. Herby to Lynch city is a dynamic entity, continually evolving and reshaping itself, and our mental images of it must similarly adapt and evolve (Lynch, 1960). Lynch emphasizes that people create mental maps or "images" of the cities they inhabit, influenced by both physical characteristics and personal experiences. He argues that cities should be legible, meaning that they should be easily understood

and navigable by their inhabitants. By studying these mental images and the factors that shape them, urban planners and designers can create more liveable, accessible, and visually coherent cities.

Jane Jacobs: An American-Canadian journalist and activist, whose book "The Death and Life of Great American Cities" challenged the prevailing ideas about urban planning and argued for a more organic, community-oriented approach to urban development. Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody. She continues her prologue by stating that cities are full of endless and varied human stories—many of them touching, some of them triumphant, and a few of them tragic. To her designing a dream city is easy; rebuilding a living one takes imagination (Jacobs, 1961)

Her argumentation challenges prevailing urban planning theories of the time, particularly those advocating for large-scale urban renewal projects and highway construction. She argues that vibrant, diverse neighbourhoods are essential for the vitality of cities and that the organic, bottom-up growth of communities should be prioritized over top-down planning. Jacobs emphasizes the importance of mixed-use development, walkability, and the preservation of historic buildings in creating liveable urban environments. Her book appears even nowadays as a sharp critique of the prevailing approach to urban planning, which emphasized large-scale demolition and redevelopment as a means of revitalizing urban areas. Jacobs as many today argued that this approach was misguided and counterproductive, and that the key to creating vibrant, liveable cities was to focus on the needs and desires of the people who live and work in them. She identified four key principles of successful urban neighbourhood's:

Mixed primary uses: Successful neighbourhood should have a mix of different types of buildings and uses, including residential, commercial, and cultural activities.

Short blocks: Short blocks allow for more frequent intersections and more direct routes, which in turn encourage pedestrian activity and make it easier for people to get around.

Buildings of varying ages and states of repair: A mix of old and new buildings, and buildings in different states of repair, creates visual interest and encourages a diversity of uses.

A density of people and buildings: A high density of people and buildings creates a vibrant, active environment that supports a range of social and economic activities.

Jacobs' ideas about the importance of mixed-use neighbourhoods and pedestrian-friendly streets have had a lasting impact on urban design and planning. They have contributed to the development of new urbanism, a movement that seeks to create walkable, mixed-use communities with a human scale and a strong sense of place. Her focus on the needs and desires of people in the design of cities has also helped to shift the emphasis in urban planning from large-scale infrastructure projects to more human-centred, community-oriented approaches.

Jan Gehl: A Danish architect and urban designer, whose books "Life Between Buildings" and "Cities for People" emphasize the importance of designing cities for people rather than cars, and advocate for a human-centered approach to urban design. Gehl draws on his extensive experience as an urban planner and designer to offer a range of practical solutions for creating more liveable, sustainable cities. He emphasizes the importance of designing streets and public spaces that are safe and comfortable for pedestrians and cyclists, and advocates for reducing the dominance of cars and other motorized vehicles in urban areas.

His statement that the quality of urban spaces is defined by their ability to induce social encounters, to invite people to sit and linger, to enjoy the city remains accurate and actual even in the today's context of cities such as Tirana. Cities must urge urban planners and architects to reinforce pedestrianism as an integrated city policy to develop lively, safe, sustainable, and healthy cities. Therefore, a good city is like a good party, people stay longer than really necessary because they are enjoying themselves (Gehl, 2011)."

To Gehl the most sustainable thing is a good city, and that means a city with a high density of people but his most eloquent statement is: "First life, then spaces, then buildings – the other way around never works." (Gehl, 2010). TO Gehl argument designing cities for people is far more important rather than automobiles or buildings. He argues that successful urban spaces prioritize human interaction, walkability, and public life. Gehl's approach advocates for creating cities that promote social interaction, physical activity, and environmental sustainability. By prioritizing the needs and experiences of pedestrians, cyclists, and public transit users, Gehl's vision aims to create vibrant, inclusive, and liveable urban environments.

Gehl also stresses the importance of creating public spaces that are welcoming and inclusive for people of all ages, backgrounds, and abilities. He argues that cities should prioritize the creation of public spaces that promote social interaction and community engagement, and that are designed to accommodate a variety of activities and events.

William H. Whyte: An American urbanist and author of "The Social Life of Small Urban Spaces," which analysed the behaviour of people in public spaces and helped to establish the importance of urban design in creating vibrant, liveable cities. He argued that social perception of their urban morphology is key to happiness. "What attracts people most, it would appear, is other people." (Whyte, 1980) "On city streets, in city squares, in city parks, people want to be where other people are" demonstrates the significance of human behaviour and social interaction in shaping the design of public spaces. Whyte highlights the importance of factors such as seating, pedestrian traffic flow, and opportunities for spontaneous encounters in creating vibrant and engaging urban environments. Whyte's work underscores the notion that successful public spaces are those that facilitate social connections and community engagement, ultimately contributing to the liveability and vitality of cities.

Richard Florida: An American urban studies theorist and author of "The Rise of the Creative Class," which argued that cities that attract and retain creative workers are more likely to be economically successful. On his other publication "Cities for People" is a call to action for creating urban environments that prioritize the needs and desires of people over cars and other vehicles. Gehl argues that cities should be designed to encourage walking, biking, and public transportation, and that urban spaces should be designed with human scale in mind. Human creativity is the ultimate economic resource. A place that has high concentrations of technology, talent, and tolerance will attract creative people. Creativity is not just about technology or the arts. It's about every facet of human activity (Florida, 2002). His theory revolves around the concept of the "creative class," a group of highly skilled professionals, including scientists, engineers, artists, and entrepreneurs, whose creative talents drive economic growth and urban revitalization. According to Florida, cities that foster a supportive environment for creativity, characterized by diversity, openness, and tolerance, are better positioned to attract and retain members of the creative class. These individuals, in turn, contribute to innovation, entrepreneurship, and cultural vibrancy, thereby fuelling economic prosperity.

Florida argues that the presence of a thriving creative class can transform cities into dynamic hubs of innovation and prosperity. He emphasizes the importance of investing in amenities, such as cultural institutions, green spaces, and vibrant urban neighbourhoods, to attract and retain creative talent. Additionally, Florida advocates for policies that promote inclusivity, diversity, and social equity to ensure that the benefits of urban development are shared by all residents. Florida's theory

highlights the potential for cities to harness the power of creativity to foster innovation, drive economic growth, and enhance quality of life for residents.

Edward Glaeser's book "Triumph of the City" is a provocative and influential work that argues that cities are the engines of economic growth and innovation in the modern world. Glaeser, a Harvard economist, draws on a wide range of data and research to make the case that cities are the most efficient and effective way to organize human activity. He argues that cities are hubs of creativity and innovation, with concentrations of people and ideas that foster new business ventures and drive economic growth. He also contends that cities offer a range of benefits to their residents, including access to better jobs, cultural amenities, and social networks. Cities are the absence of physical space between people and companies. They are proximity, density, closeness. They enable us to work and play together, and their success depends on the demand for physical connection. The most successful cities are those that attract and retain the most talented and ambitious people. (Glaeser, 2011) However, Glaeser also acknowledges the challenges of urban life, including issues of inequality, crime, and environmental degradation. He argues that these challenges can be addressed through smart urban policies that prioritize investments in infrastructure, education, and public safety. Overall, his argument for the importance of cities in the modern world, and has helped to shape the way that policymakers and urban planners think about the role of cities in driving economic growth and fostering social progress.

These authors and many others have contributed to our understanding of the complex and multifaceted nature of urban form, and have helped to shape the way we think about and design cities.

On the other hand, **Air pollution** refers to the presence of harmful substances, such as particulate matter, nitrogen oxides, sulphur dioxide, ozone, and carbon monoxide, in the air we breathe. These substances can have a range of negative impacts on human health, as well as on the environment.

Sources of Knowledge upon Air pollution can be disintegrated into:

Empirical Observation: Direct observation of air quality, pollutant emissions, and their effects on human health and ecosystems.

Scientific Research: Rigorous studies conducted by atmospheric scientists, environmental engineers, epidemiologists, and other experts to investigate the sources, distribution, and impacts of air pollution.

Monitoring and Measurement: Data collected from air quality monitoring stations, satellite imagery, and sensor networks to quantify pollutant concentrations and assess spatial and temporal trends.

Indigenous and Traditional Knowledge: Insights from indigenous communities and traditional practices that offer holistic perspectives on air pollution and environmental stewardship.

While the theories and models used to address air pollution could be grouped as following:

Atmospheric Chemistry: The study of chemical reactions and processes that occur in the atmosphere, informing our understanding of pollutant formation, transformation, and dispersion.

Dispersion Modelling: Mathematical models that simulate the transport and diffusion of pollutants in the atmosphere, helping to predict air quality levels and identify sources of pollution.

Health Effects: Epidemiological and toxicological studies that investigate the health impacts of air pollution exposure, including respiratory diseases, cardiovascular disorders, and neurological effects.

Environmental Justice: Theoretical frameworks that examine the disproportionate burden of air pollution on marginalized communities, highlighting social inequalities in exposure and vulnerability.

Data are considered the most important part when studying air pollution, whereas its methods of Inquiry can be grouped into:

Quantitative Analysis: Statistical techniques, data analysis, and mathematical modelling used to quantify pollutant concentrations, estimate emission sources, and assess health and environmental impacts.

Qualitative Research: Interviews, surveys, and case studies conducted to understand the social, cultural, and behavioural dimensions of air pollution, including perceptions, attitudes, and mitigation strategies.

Interdisciplinary Approaches: Collaboration across scientific disciplines, policy fields, and community engagement efforts to address the complex and interconnected nature of air pollution and its drivers.

Finally, as to any other sensitive research topic, there are critical ethical considerations:

Environmental Ethics: Ethical principles and values that guide decisions about air pollution control, environmental justice, and sustainable development, including considerations of equity, responsibility, and intergenerational justice.

Precautionary Principle: The ethical principle that calls for precautionary measures to be taken in the face of uncertain but potentially serious risks, such as those posed by air pollution, even in the absence of conclusive scientific evidence.

Environmental Rights: Legal and moral rights to clean air, environmental health, and a safe living environment, which underpin efforts to protect vulnerable populations from the harmful effects of air pollution.

Last but not least, the outcome is reflection into Policy Development. More specifically the translation of scientific findings and public awareness into policy interventions, regulations, and standards aimed at reducing air pollution emissions, improving air quality, and safeguarding public health. Followed by dissemination of scientific information, health advisories, and public outreach campaigns to raise awareness about air pollution risks, promote behaviour change, and empower communities to advocate for cleaner air, all these in the most ease and digestible way for public at large.

Sources of air pollution include transportation (cars, trucks, and airplanes), industrial activities (factories and power plants), agriculture (livestock and fertilizer use), and natural phenomena (dust and wildfires). In urban areas, traffic congestion and the burning of fossil fuels for heating and electricity generation are major contributors to air pollution.

Exposure to air pollution can cause a range of health problems, including respiratory and cardiovascular diseases, as well as cancer. Children, the elderly, and people with pre-existing health conditions are particularly vulnerable to the effects of air pollution. Air pollution also has environmental impacts, such as contributing to climate change, acid rain, and the degradation of ecosystems.

To address air pollution, governments and communities have implemented a range of strategies, including regulations on emissions from industry and transportation, investment in public transportation and cycling infrastructure, and public education campaigns to promote awareness of

the health impacts of air pollution. Advances in technology, such as electric vehicles and renewable energy sources, also offer promise for reducing the sources of air pollution in the future.

Urban form can have a significant impact on air pollution levels in cities. The layout of a city, the density and height of buildings, the transportation infrastructure, and the location of industrial and commercial activities can all affect air quality.

One of the key factors affecting air pollution in cities is transportation. Cities that are designed around automobile use, with wide roads and sprawling suburbs, tend to have higher levels of air pollution than cities with compact, walkable urban cores and efficient public transportation systems. In car-oriented cities, the high volume of traffic, particularly during rush hour, can lead to significant emissions of pollutants such as nitrogen oxides and particulate matter.

The density and height of buildings can also affect air quality. Tall buildings can create "urban canyons" that trap air pollutants, leading to higher concentrations in certain areas. Buildings can also affect wind patterns and air circulation, which can impact the dispersion of pollutants.

The location of industrial and commercial activities can also contribute to air pollution in urban areas. Industrial facilities that emit pollutants such as sulphur dioxide, nitrogen oxides, and particulate matter can have a significant impact on air quality, particularly in low-income neighbourhoods and communities of colour that are often located near these facilities.

To address air pollution in urban areas, planners and policymakers can implement a range of strategies, including promoting sustainable transportation options, incentivizing green buildings and green infrastructure, and regulating emissions from industrial facilities. Additionally, increasing public awareness of the health impacts of air pollution can help to build support for these strategies and create a sense of urgency around the need to improve air quality in cities.

The study of air pollution is a multifaceted field encompassing various disciplines, methodologies, and research approaches. While it's challenging to identify the "ultimate" studies on air pollution due to the vastness of the topic and ongoing research, several seminal studies have significantly advanced our understanding of this critical environmental issue. Some key studies that have had a substantial impact on the field of air pollution research could be listed as below:

London Fog Study (1952):

One of the earliest and most influential studies on air pollution, the London Fog event of 1952 resulted in thousands of deaths attributed to severe air pollution episodes. This event spurred

scientific inquiry into the health effects of air pollution and led to the development of air quality regulations and standards worldwide. (Smith, 2010)

Harvard Six Cities Study (1993):

This landmark epidemiological study, conducted by researchers at the Harvard School of Public Health, investigated the long-term health effects of air pollution exposure on residents of six U.S. cities. The study provided robust evidence linking fine particulate matter (PM_{2.5}) pollution to increased mortality rates from cardiovascular and respiratory diseases (Dockery, 1993).

National Morbidity, Mortality, and Air Pollution Study (NMMAPS):

NMMAPS, conducted in the United States in the 1990s, analysed the association between air pollution levels and daily mortality and morbidity rates in multiple cities. This study provided valuable insights into the acute health effects of air pollution exposure, including short-term increases in cardiovascular and respiratory hospital admissions and mortality rates (Samet, 2000).

Global Burden of Disease (GBD) Studies:

The GBD studies, coordinated by the Institute for Health Metrics and Evaluation (IHME), quantify the health impacts of air pollution on a global scale. These studies estimate the burden of disease attributable to various pollutants, including particulate matter, ozone, nitrogen dioxide, and sulfur dioxide, highlighting the significant contribution of air pollution to global morbidity and mortality. (GBD 2019 Risk Factors Collaborators. , 2020)

Intergovernmental Panel on Climate Change (IPCC) Assessments:

The IPCC assessments comprehensively evaluate the scientific literature on climate change, including the role of air pollutants such as carbon dioxide, methane, and black carbon in driving global warming and influencing atmospheric chemistry. These assessments inform international climate policy and mitigation strategies aimed at reducing greenhouse gas emissions and improving air quality (Meyer, 2014) .

Satellite-Based Studies:

Satellite-based studies, such as those conducted by NASA and other EU-Copernicus, provide valuable insights into the spatial and temporal patterns of air pollution at regional and global scales. These studies use remote sensing techniques to monitor pollutant concentrations, track pollution transport pathways, and assess the impacts of air pollution on public health and ecosystems (van Donkelaar, 2010) .

Long-Term Observational Studies:

Long-term observational studies, including air quality monitoring networks such as the U.S. Environmental Protection Agency's Air Quality System⁴ (AQS), provide continuous measurements of air pollutant concentrations over extended periods. These studies contribute to our understanding of air pollution trends, sources, and variability, supporting the development of effective air quality management strategies.

Aside of ivory-league research authorities dealing with air pollution, even individual authors and researchers have contributed to our understanding of air pollution:

John Bellamy Foster - an environmental sociologist who has written extensively on the social and ecological dimensions of air pollution, including its effects on public health, ecosystems, and climate change. To him air pollution is not just an environmental issue but rather a social justice one. Disproportionately affecting marginalized communities and exacerbating public health. Further to his research he added that health implications are tip of the iceberg given the acute and cumulative nature the pollutant. Beyond that relies the fact that air pollution impact extends to ecosystem degradation, biodiversity loss and climate change. "The fight against air pollution is inseparable from broader struggles for social and environmental justice, as both are rooted in the same system that nurtures inequalities to obtain power control" (Foster, 2011). While Foster may not explicitly focus solely on-air pollution, he surely provides valuable insights into the broader environmental challenges faced by contemporary societies and the underlying socio-economic systems driving environmental degradation. Foster's work contributes to a critical understanding of the complex relationships between capitalism, ecology, and environmental justice, which are essential for addressing issues such as air pollution in a holistic manner but also to be kept into consideration are his Marxist Ecological perspectives that do collide his political perspectives with the issues itself.

Michael Brauer, an epidemiologist renowned for his research on the health effects of air pollution, particularly its associations with respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD), has contributed significantly to our understanding of the impacts of air pollution on public health. While specific quotes from him may not be widely available, his research findings and conclusions have been extensively cited in academic literature. Brauer's research has demonstrated that exposure to air pollution, particularly fine particulate matter (PM_{2.5}) and nitrogen dioxide (NO₂), is associated with an increased risk of respiratory diseases, including asthma

⁴ <https://www.epa.gov/aqs/air-quality-system-data-mart>

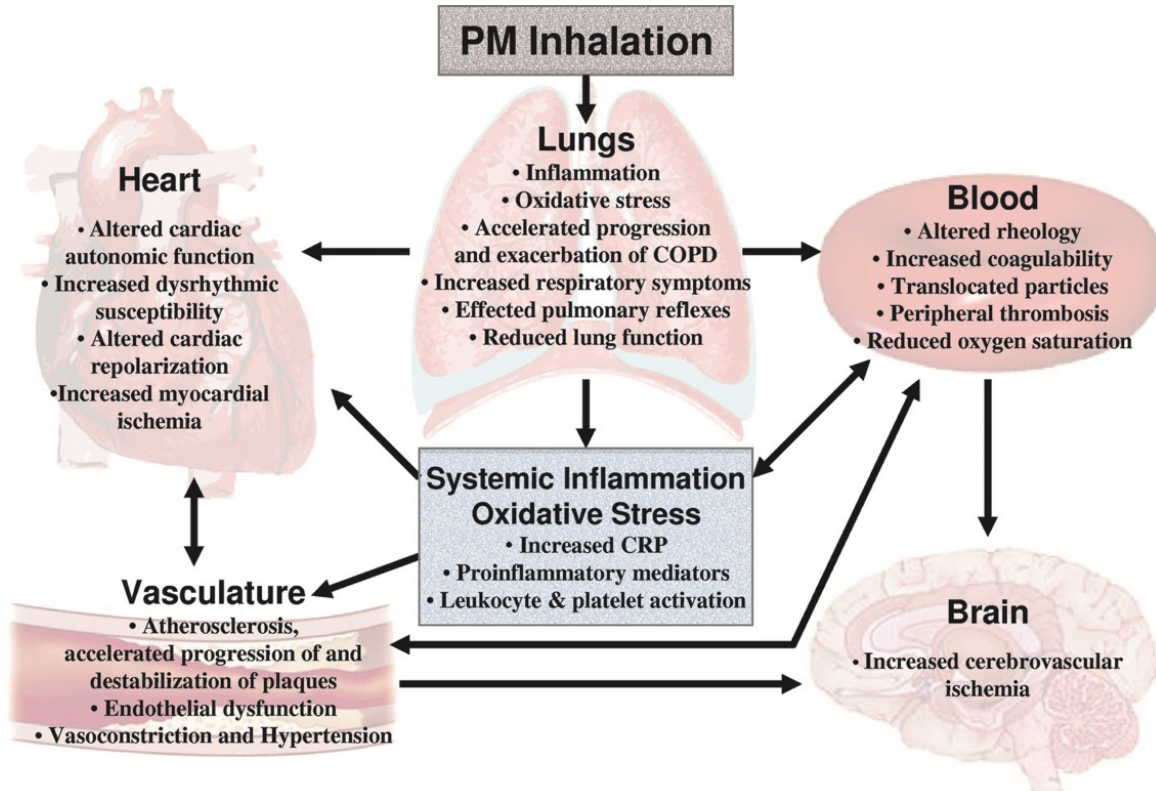
and COPD. On his research it is indicated that long-term exposure to PM_{2.5} is linked to exacerbations of asthma symptoms, decreased lung function, and increased mortality from respiratory causes (Brauer, 2019) . Brauer's research has also highlighted the disproportionate burden of air pollution-related respiratory diseases on vulnerable populations, including children, the elderly, and individuals with pre-existing respiratory conditions. According to his research, outdoor air pollution, including PM_{2.5} and NO₂, is a leading environmental risk factor for respiratory morbidity and mortality, contributing to millions of cases of asthma exacerbations, COPD exacerbations, and respiratory-related deaths annually (Brauer, 2020) .

Arden Pope - an economist who has conducted research on the economic costs of air pollution, including the costs of health care and lost productivity associated with exposure to air pollutants. Pope has made significant contributions to understanding the broader societal impacts of air pollution. While specific quotes from him may not be widely available, his research findings and conclusions have been extensively cited in academic literature. Pope's research has highlighted the substantial economic burden of air pollution on society, including healthcare expenditures, lost productivity, and other indirect costs (Pope, 2017). Pope's research has also quantified the economic costs of air pollution-related mortality and morbidity, including the value of premature deaths, lost workdays, and reduced quality of life (Pope, 2006).

Pope considered elders and chronic-ill groups as the most vulnerable and an ample amount of evidence has taken into consideration their participation. Whereas for Infants, Neonates and Birth Outcomes evidence that PM exposure impacts them is of a high sensitivity.

PM exposure in children has been associated with deficits in lung function , (Pope, et al., 1991) lung function growth, (Peters, et al., 2004) increased respiratory illness and symptoms, increased school absences, and hospitalizations for respiratory disease (Peters, et al., 1999)

Figure 10: Pathophysiological pathways linking PM exposure with cardiopulmonary morbidity and mortality.



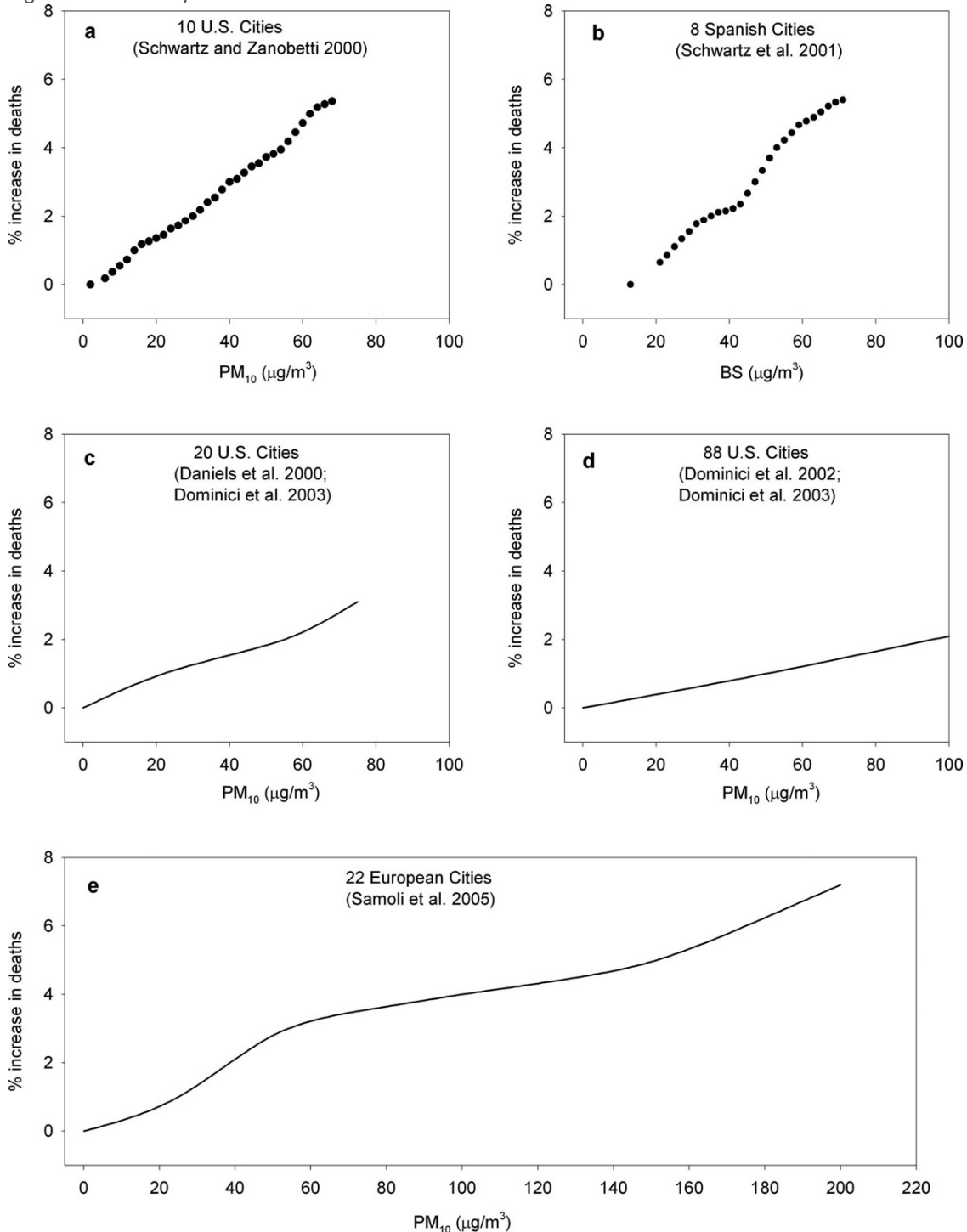
Source: Pope and Dockery (page 729)

There is also substantial and growing evidence that air pollution is a risk factor for increased mortality in infants and young children. Relatively large increases in infant mortality were observed during the London smog episode of 1952 (Ministry of Health, London, 1954). Contemporary studies have observed PM-infant mortality associations (Lin, et al., 2004) There have also been several recent reviews of these studies that generally conclude that PM exposure is most strongly and consistently associated with post neonatal respiratory mortality with less compelling evidence of a link between PM and SIDS (Sram, et al., 2005).

The effects of air pollution on various other birth outcomes are substantially less well established and understood. Nevertheless, there are a growing number of contemporary studies that have evaluated potential links between air pollution and birth weight, (Wilhelm & Ritz, 2005) premature birth, (Sagiv, et al., 2005) fetal growth, (Jedrychowski, et al., 2004) intrauterine mortality, birth defects, (Ritz, et al., 2002) and lymphocyte immunophenotype in cord and maternal blood at delivery. Recent reviews of the literature dealing with air pollution and these various birth outcomes (Maisonet, et al., 2004) generally suggest that there may be effects of ambient PM air pollution on these outcomes but that these effects are not well understood. Although the evidence is reasonably compelling that PM exposure increases the risk of infant mortality, especially post neonatal respiratory mortality, there remain serious gaps in our knowledge regarding the potential

effects of ambient PM on fetal growth, premature birth, and related birth outcomes. Moreover, on the impact that air pollution has on children Jonathan Grigg a paediatrician has conducted research on the effects of air pollution on their health, including in his work concrete links between air pollution and asthma, low birth weight, and cognitive development. Pope's research on effects of fine particles of Air Pollution to human health is a repository of more than 500 references to other relevant studies from the last 4 decades.

Figure 11: Mortality increase vis a vis the concentration of PM10



Source: Pope, approximate adaptations from original publications rescaled for comparison purposes

Herby we can point out the research on “10 U.S Cities” from Shwartz and Zanobeti whom later replicated the same approach on “8 Spanish cities”. Danielas and Dominici conducted research on the matter including 20 U.S cities and further 88 U.S Cities. To conclude with Samoli’s research on 22 European cities. Their conclusions upon the linkage of exposure to air pollution (PM10) and premature deaths sets the ground for a thorough comparative analysis.

These authors and researchers have helped to build our understanding of the complex social, economic, and health impacts of air pollution, and have contributed to the development of policies and strategies to address this critical environmental issue.

However, one of the most widely cited reports on air pollution is the Global Burden of Disease (GBD) study, which was conducted by an international team of researchers and published in The Lancet medical journal in 2019. The GBD study estimates the health impacts of air pollution in different regions of the world, and provides important data on the mortality and morbidity associated with exposure to air pollutants such as fine particulate matter (PM_{2.5}) and ozone. The lead authors of the GBD study are Christopher J.L. Murray and Michael Brauer, both of whom are prominent researchers in the field of air pollution and public health.

One theoretical gap in the study of urban form is the need for a more nuanced understanding of the complex interactions between physical, social, and cultural factors that shape the built environment. While many studies have identified the ways in which urban form can influence a range of outcomes, including air pollution, public health, and social equity, these studies often rely on simplified models that do not fully capture the complexities of urban systems.

Another theoretical gap is the need to consider the role of power dynamics and political economy in shaping urban form. Urban planning and design are often influenced by a range of actors, including developers, politicians, community groups, and other stakeholders, each with their own interests and priorities. These power dynamics can shape the outcomes of planning and design processes, and can lead to outcomes that reinforce existing inequalities and power structures.

A third theoretical gap is the need to consider the temporal dimension of urban form. Urban systems are constantly evolving, and the outcomes of planning and design decisions may not be fully realized for many years. This means that it is often difficult to assess the long-term impacts of urban form decisions, and to make informed decisions that take into account the likely outcomes of different planning and design scenarios over time.

Finally, there is a need for more research on the potential unintended consequences of urban form interventions. While sustainable urban design and planning interventions may have positive impacts on a range of outcomes, such as reducing air pollution, they may also have unintended consequences that are not fully understood. For example, interventions that prioritize bike lanes and pedestrian walkways may have the unintended consequence of displacing low-income residents or exacerbating existing transportation inequalities.

Addressing these theoretical gaps will require interdisciplinary approaches that draw on a range of theoretical frameworks and methodological approaches, and that prioritize a holistic understanding of urban systems and the complex factors that shape them.

2.7. Urban Form & Architectural Influence on Air Quality

Urbanization and architectural design play significant roles in shaping the quality of air within cities. This theoretical review aims to explore the intricate relationship between urban form, architectural design, and air quality. By examining existing literature, this review identifies key factors influencing air quality in urban environments, such as building density, street layout, green spaces, and building materials. Furthermore, it discusses various architectural strategies and urban planning approaches that can mitigate air pollution and promote healthier living environments. Through a comprehensive analysis, this review elucidates the importance of considering urban form and architectural design in air quality management strategies for sustainable and liveable cities.

Urbanization is a defining characteristic of modern civilization, with an increasing majority of the global population residing in urban areas. However, rapid urban growth brings about various environmental challenges, among which air pollution stands out as a pressing concern. The quality of air in urban environments is influenced by a multitude of factors, including vehicular emissions, industrial activities, and urban form. In this regard, the design of cities and buildings plays a crucial role in shaping air quality. This theoretical review aims to delve into the relationship between urban form, architectural design, and air quality, elucidating key factors and strategies for creating healthier urban environments.

Building density refers to the concentration of structures within a given area of land. High-density urban environments often experience increased air pollution due to factors such as traffic congestion and limited ventilation. Tall buildings can impede airflow and create urban canyons, trapping pollutants at street level. Conversely, low-density developments may promote dispersal of pollutants but can lead to increased vehicle usage and urban sprawl. Achieving an optimal balance

in building density is essential for mitigating air pollution while ensuring urban functionality and efficiency.

The layout of streets and roads influences air quality by affecting traffic flow and dispersion of pollutants. Gridiron street patterns facilitate efficient movement of vehicles but may lead to congestion in certain areas. On the other hand, curvilinear street layouts can enhance aesthetic appeal and reduce traffic speeds, thereby lowering emissions. Additionally, the design of pedestrian-friendly streets and bike lanes promotes alternative modes of transportation, reducing reliance on automobiles and improving air quality.

Incorporating green spaces into urban environments has proven benefits for air quality and public health. Trees and vegetation act as natural filters, capturing airborne pollutants and releasing oxygen through photosynthesis. Moreover, green spaces provide shade, mitigate urban heat island effects, and enhance aesthetic quality. Integrating parks, gardens, and green corridors into urban planning initiatives can help mitigate the adverse effects of air pollution while fostering biodiversity and recreational opportunities.

Architectural Influence on Air Quality

The orientation of buildings and their design features significantly impact indoor air quality and thermal comfort. Proper building orientation can maximize natural ventilation and daylighting, reducing the need for mechanical heating and cooling systems. Cross-ventilation strategies, such as operable windows and atriums, facilitate airflow and improve indoor air circulation. Additionally, incorporating passive design principles, such as shading devices and thermal mass, enhances energy efficiency and indoor environmental quality.

Building Materials and Indoor Air Quality

The selection of building materials plays a crucial role in determining indoor air quality levels. Volatile organic compounds (VOCs) emitted from paints, adhesives, and furnishings can contribute to indoor air pollution and adverse health effects. Choosing low-emission materials and finishes, such as low-VOC paints and formaldehyde-free wood products, reduces indoor air contaminants and enhances occupant well-being. Furthermore, promoting sustainable building practices, such as using recycled and locally sourced materials, minimizes environmental impacts and supports circular economy principles.

Sustainable urban design principles prioritize environmental stewardship, social equity, and economic viability in urban planning initiatives. Implementing compact, mixed-use developments reduces vehicle miles travelled and promotes active transportation options. Additionally, incorporating green infrastructure, such as green roofs and permeable pavements, helps manage stormwater runoff and mitigate air pollution. By fostering walkable neighbourhoods and accessible public transit systems, sustainable urban design enhances air quality while enhancing overall urban liveability.

Passive design strategies emphasize harnessing natural resources and climatic conditions to create comfortable and healthy indoor environments. Orienting buildings to optimize solar exposure and prevailing winds reduces reliance on mechanical systems and minimizes energy consumption. Passive solar design techniques, such as daylighting and solar shading, enhance visual comfort and thermal performance while reducing carbon emissions. Moreover, incorporating natural ventilation strategies, such as stack ventilation and night flushing, improves indoor air quality and occupant comfort levels.

Transport:

Decarbonizing the transportation sector emerges as a pivotal endeavour essential for effectuating the transition toward a low-carbon society, aligning with the objectives outlined in the Paris Agreement (UNFCCC Secretariat, 2015) and the overarching aspiration of stabilizing the average global temperature increase at 1.5 degrees Celsius (Rogelj, 2015). The epoch between 2007 and 2009 marked a significant juncture as urban populations exceeded rural populations for the first time in recorded history, intensifying pressures on urban infrastructures and services. Consequently, burgeoning transportation demands precipitated a trajectory of carbon dioxide (CO₂) emissions, amplifying their global imprint. To address and mitigate such impacts, an array of studies and initiatives have been undertaken, including the notable publication of the International Transportation Forum (ITF) in 2018 titled "Policy Priorities for Decarbonising Urban Passenger Transport." The ITF serves as both a technical and policy-oriented platform, comprising 59 member nations, including Albania. Through its policy recommendations, the ITF has delineated a roadmap toward a climate-neutral transportation sector, steering strategic investments to facilitate this transition. The report adopts an inclusive approach, aligning its proposed measures with those outlined in the Paris Agreement and the EU 2050 Strategy for Achieving Climate Neutrality. Embracing a nuanced perspective, the document addresses technological challenges, economic

ramifications, and distinct country profiles categorized by income levels (high, medium, and low). The overarching global objective is the complete phasing out of fossil fuel utilization in the transportation sector. International efforts aimed at mitigating emissions from the transportation sector have gained traction, with the Paris Agreement translating into tangible actions, led prominently by the European Union (EU) on a global scale. Notably, the European Parliament on Transport and Tourism (TRAN) and the Environmental Committee of the European Parliament (EVI) have proposed a mandate for 100% Electric Vehicles (EVs) for new European car sales. This initiative has the potential to significantly penetrate the market, offering an alternative that fosters economic and job sustainability across Europe (International Transport Forum, 2018)

Furthermore, in November 2018, the European Commission unveiled the EU 2050 long-term vision, outlining aspirations for a prosperous, modern, competitive, and climate-neutral economy. Emphasizing the imperative of transitioning the transport sector towards zero-emissions, the Commission articulated the transformative impact of urban planning, safe cycling and walking paths, clean local public transport, and the integration of innovative delivery technologies such as drones and mobility services. These measures, coupled with the adoption of carbon-free transport technologies, are envisioned to mitigate air pollution, noise, and accidents, thereby enhancing the quality of urban living (European Commission, 2018)

In alignment with the overarching goal of limiting global warming to below 1.5 degrees Celsius, the European Commission has enacted new CO₂ standards for cars and vans as part of the Mobility Package, extending these standards to trucks and heavy-duty vehicles for the first time. Additionally, in 2017, the EC launched the 'European Battery Alliance,' aimed at promoting the deployment of low-emission vehicles, enhancing infrastructure for alternative fuels, and fostering innovation in the transport sector to accelerate the transition towards a sustainable and climate-resilient future transportation sector by 2050.

Another detailed research from the author, measuring the emission footprint from public transport sector fleet in Tirana:

The overall status of Tirana's Public Health is of great concern as it faces considerable daily jeopardy due to several factors, including the reluctance of central government institutions and agencies to acknowledge the presence of climate change, inadequate monitoring and documentation of leaks and emissions across various sectors by competent authorities such as the National Environmental Agency (NEA) and the Institute of Public Health (IPH), resulting in an severely biased and often ill-

informed public opinion lacking evidence-based analyses on the matter. Moreover, central government entities like the Civil Emergencies and notably the Ministry of Tourism and Environment persist in addressing climate-related emergencies in an ad-hoc manner (Duro, 2015).

Despite Albania's adoption of 75% of the Clean Air for Europe⁵ (CAFE) EU program into national legislation, the implementation thereof in terms of monitoring, control, and reporting stands at a mere 5%, as indicated by the latest findings from the State Agency for Nature and Environment⁶ (SANE). Regarding the transport sector, Albania aims to elevate the share of renewable combustion fuels to 7% of the gross annual fuel consumption, surpassing the baseline share of 3% reported for 2017 (GoA , 2018). However, the electrification of public transport remains challenging, primarily due to financial constraints and the requisite technical expertise.

Nevertheless, specific responsibilities and obligations are incumbent upon local governments to initiate air quality management planning in accordance with Law no.162/2014⁷ 'On the Protection of Air Quality.' Additionally, significant potential exists to reduce transport emissions by 11.5% through the adoption of appropriate measures aligned with the EU Urban Agenda approach and the integration of renewable energies into the mobility sector.

In November 2016, Albania adopted the National Transport Strategy and Action Plan, supplemented by the National Plan for Air Quality Management endorsed through Decision of Council of Ministers (DCM) No. 412 in June 2019 (GoA, 2019). These national initiatives aim to synergize efforts and implement common measures to mitigate environmental impacts from public transport in urban areas. Furthermore, the plans underscore the importance of all municipalities developing Local Air Quality Management Plans (LAQMP) and Local Sustainable Transport Plans (LSTP) to promote low carbon emitting systems and facilitate the phased transition of the existing public transportation fleet to new Electric Vehicles (EVs) or Low Emitting Vehicles compliant with Euro VI emission standards

In conclusion, urban form and architectural design play integral roles in shaping air quality within cities. By considering factors such as building density, street layout, green spaces, and building materials, urban planners and architects can develop strategies to mitigate air pollution and create healthier living environments. Sustainable urban design principles and passive design strategies

⁵ <https://www.consilium.europa.eu/en/policies/clean-air/>

⁶ <https://sane27.com>

⁷ https://turizmi.gov.al/wp-content/uploads/2018/09/FZ-198-2014_ligji-162-date-04.12.-2014_-per-mbrojtjen-e-cilesise-se-ajrit-ne-mjedis.pdf

offer promising approaches for improving air quality while enhancing overall urban sustainability and liveability. Moving forward, interdisciplinary collaboration and innovative solutions are essential for addressing the complex challenges of urbanization and air pollution in the pursuit of healthier and more resilient cities.

Acknowledging the severe impact, Municipality of Tirana embraced an integrated approach to address air quality and transportation challenges by formulating and endorsing a Green City Action Plan (EBRD, 2018), funded by the European Bank for Reconstruction and Development (EBRD) and the Sustainable Development Solutions (SDS) in 2018. Both the GCAP and SDS recognize that Tirana's ambient air contains concentrations of PM₁₀, PM_{2.5}, and CO₂ that exceed daily exposure thresholds compared to national and EU standards, registering at 44%. Identified primary sources of pollution include transportation, substandard fuel quality, unregulated waste incineration, and construction activities (Municipality of Tirana, 2018). Since 2018 the governor and council members Tirana aspired to transition its transportation systems toward a more sustainable mobility form, with a particular focus on enhancing public transit, cycling infrastructure, and implementing intelligent transport solutions (Municipality of Tirana, 2018). Nevertheless, the SDS does not align with the EU's trajectory toward decarbonizing the transport sector at large or specifically targeting urban passenger transport. While it potentially hints at decarbonization through intelligent transport solutions, there is no explicit indication of emission reduction goals for the public transport fleet. This is a common oversight in rapidly growing urban areas like Tirana, which prioritize addressing congestion, transport mode diversity, and safety over emissions reduction measures or setting targets for achieving a carbon-neutral transportation sector as indicated in the International Transport Forum of 2018. Moreover, the Municipality of Tirana developed and approved its Sustainable Urban Mobility Plan (GIZ, Bashkia Tirane, TRT, 2020) generously funded by the German Ministry for Economic Cooperation and Development and executed by GIZ⁸. This plan is envisaged to contribute to reducing the city's carbon footprint by strategically planning mobility interventions to alleviate traffic congestion and enhance motorized transport flow. Notably, the local administration has made significant strides in establishing a network of over 30 kilometres of dedicated cycling lanes and more than 35 kilometres of exclusive bus/taxi and emergency lanes within Tirana's urban road network. To evaluate the impact of these infrastructure enhancements on societal behaviour and bicycle usage rates, GDi-Albania is facilitating real-time

⁸ <https://www.giz.de/en/worldwide/294.html>

data monitoring through Closed Circuit Television (CCTV), revealing preliminary evidence of a slight uptick in bicycle ridership and a minor decrease in urban cycling accidents (Daci, 2019).

While the introduction of dedicated bike lanes has enhanced cycling safety, its implementation has incurred ancillary costs beyond lane construction. The conversion of pedestrian and parking spaces along roadways into bike lanes has diminished pedestrian mobility space and intensified demand for parking. Unfortunately, the installation of bike lanes has not curbed private car usage or alleviated parking and traffic congestion issues, despite recent municipal efforts to introduce a new parking system. Consequently, in a city boasting 225,000 private cars, there are only 7,600 physical public parking spaces available along roadways, with an additional 17 public parking lots comprising a total capacity of over 1,850 spots according to Tirana Parking⁹. Consequently, less than 5% of the private vehicle fleet has access to public parking, while the majority either struggles to rent a private parking facilities or in most of the cases occupy even the most necessary public spaces, particularly within Tirana's neighbourhoods whereas children cannot even walk freely nevertheless organize any sport activity. These mobility dynamics have compromised the convenience and allure of walking and cycling, not only along major thoroughfares but also within residential areas.

The pedestrian and cycling experience in Tirana are significantly affected by a confluence of factors including urban air pollution, noise pollution, limited urban green spaces, and extensive construction activities with the presence of an overwhelming number of old heavy-duty trucks. As the city undergoes increased mobility for motorized vehicles and bicycles, pedestrian activity has been marginalized due to heightened exposure to environmental hazards and safety risks. Despite assertions by the Municipality of Tirana in support of the compact city concept, which advocates for city densification and infill development, the implementation of such policies has resulted in the loss of public green areas. Between 2010 and 2023, infill development within the urban core led to the disappearance of 61 hectares of public green spaces (Gjoka, 2023). This reduction in green areas, coupled with intensified infill development, has contributed to elevated concentrations of air pollutants, thereby diminishing the city's air quality and consequently, citizens perception on walkability. This correlation is further corroborated by measurements of nitrogen dioxide (NO₂) particular matter (PM_{2.5} & PM₁₀) which concentration was monitored as part of the Green Lungs¹⁰.

⁹ <https://tiranaparking.al>

¹⁰ Green Lungs is a project conceptualized and implemented by the author during his work as Environment Unit Leader of Co-PLAN Research Institute (2016-2023) <https://www.greenlungs.al/#>

The provision of public transportation services in Tirana is facilitated through contracts between the municipality and private operators, utilizing a fleet predominantly composed of vehicles powered by fuel combustion engines. Notably, the absence of alternatives such as trains, metro systems, or electric and hydrogen-powered vehicles exacerbates the sector's contribution to air and noise pollution within urban areas.

The combustion process inherent to these vehicles results in elevated emissions, compounded by the utilization of locally sourced, inadequately refined fuel and an aging fleet. Notably, the quality of fuel available in Albania has been flagged as substandard (Supreme State Audit, 2015), further exacerbated by its comparatively high-cost relative to neighbouring countries (Autotraveler, 2019). The Albanian government has implemented a notably stringent tax regime on fuel, with taxes accounting for 60% of the final fuel price (Kondi, 2019) moreover they do tax carbon emission to an extend of 3 Albanian Lek per each litter of fossil fuel pumped into the consumers tanks. Such tax has been applied for over than 18 years now and it is estimated to generate an overall income to budget state of over 17 million Euro annually. However, there has been no discernible progress in enhancing fuel quality or implementing effective monitoring and marking practices.

Nor any slight investment on air monitoring or reporting, even the today's outdated equipment¹¹ used by NEA and IPH were a donation from European Union and World Health Organization. Given that the national transport sector's annual fuel consumption in 2017 stood at approximately 828 thousand tons of oil equivalent (NANR: Annual Report of Energy Balance in Albania, 2018), it can be extrapolated that fuel traders have contributed approximately 20 million Euros to the state budget through carbon taxes levied on fuel prices. Remarkably, this sum mirrors the allocation to the Ministry of Tourism and Environment by the central government for implementing various environmental mitigation programs and projects during 2019. However, this funding allocation proves inadequate for investment in urban air quality enhancement or the monitoring of air emissions from industrial and transport sectors. Also, according to Albania's Environmental Status Report (AESR)¹² for the fourth consecutive year fails to provide concrete figures on air quality due to the absence of on-site monitoring practices. The dearth of monitoring and public information on ambient air quality, particularly annual emissions from industry and transportation, underscores

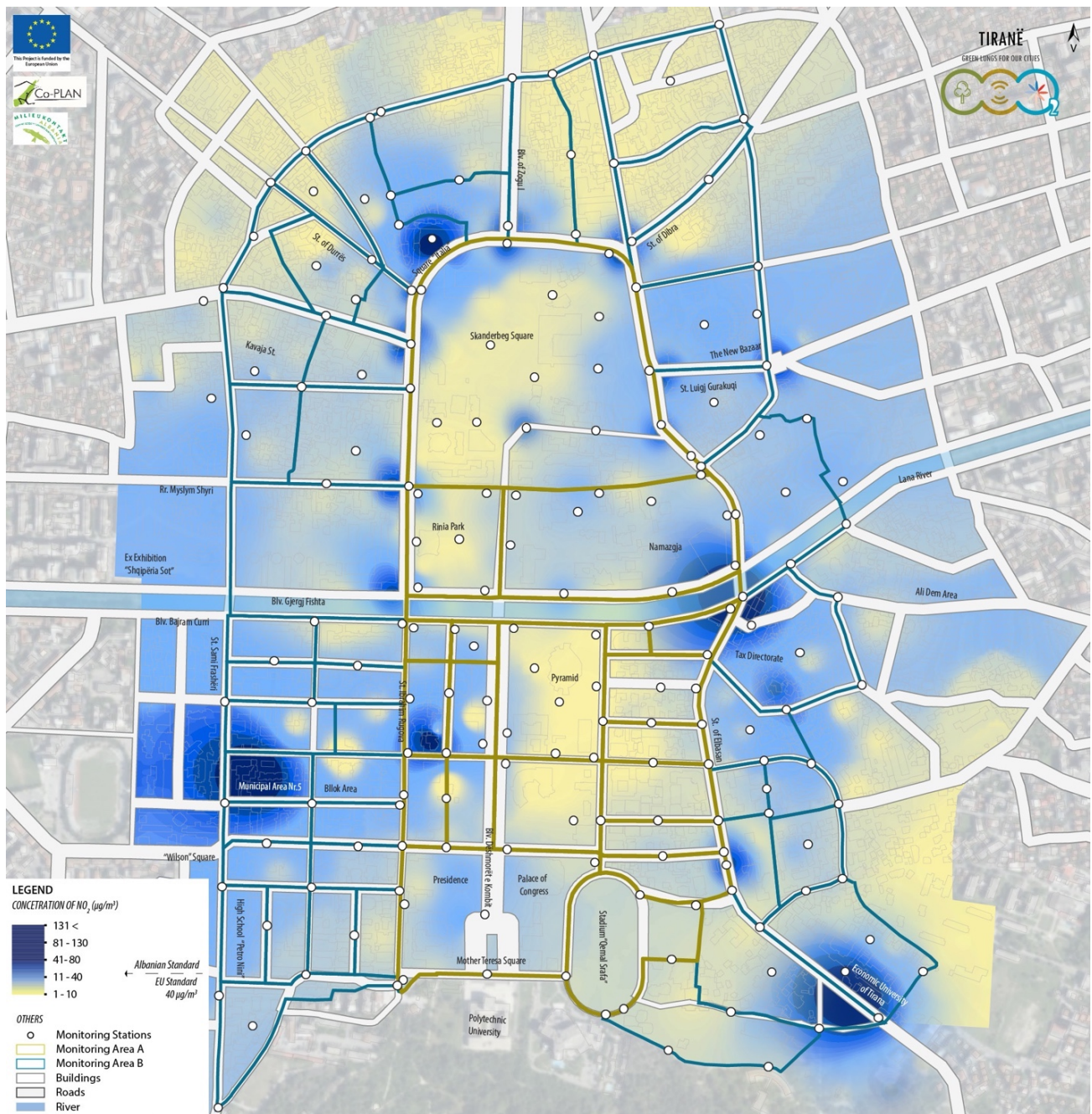
¹¹ <https://portavendore.al/2021/11/15/monitorimi-dhe-minimizimi-i-ndotjes-se-ajrit-sfida-e-qeverise-shqiptare-qe-su-be-asnjehere-realitet/>

¹² https://akm.gov.al/ova_doc/raporti-per-gjendjen-e-mjedisit-2022/

deficiencies in budgetary planning and human resources allocated to maintain and operate a national laboratory.

Policy improvements aimed at controlling and reducing emissions from the transport sector are imperative, necessitating the establishment of specific targets for phasing out high-emission vehicles from the public transport fleet at the local and regional levels. Presently, the sole monitoring initiatives recognized by the municipality are those facilitated through private sponsorship by Vodafone Albania at four key monitoring stations in Tirana.

Figure 12: Concentration of NO₂ in Tirana during 2020



Source: Author work on Green Lungs project, Co-PLAN

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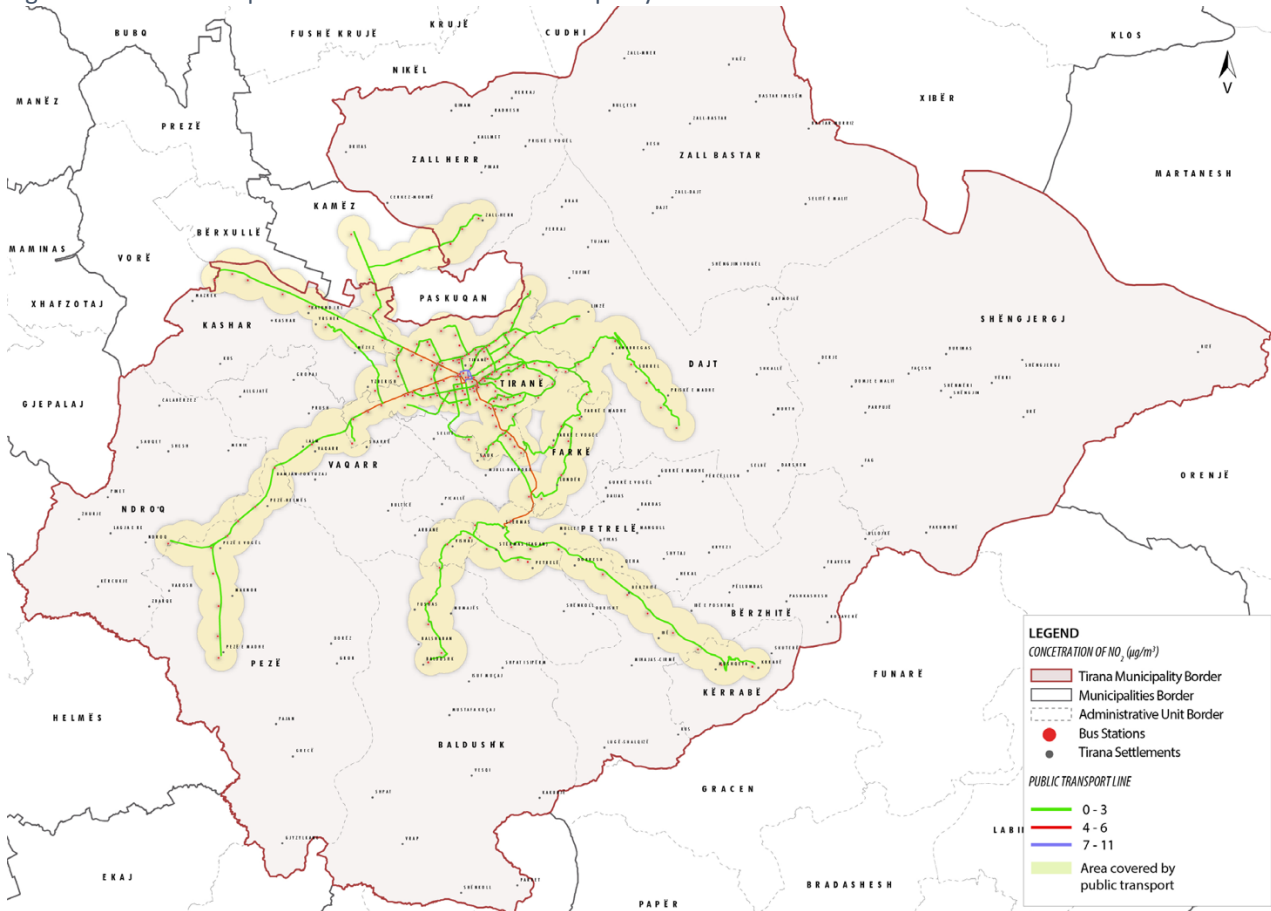
According to the Green City Action Plan (GCAP) and Sustainable Development Solutions (SDS), over 18.5 million passengers utilize public transport within the Municipality of Tirana annually. Eight registered private operators administer a flat fare of 40 Lek per person, irrespective of the distance travelled, provided there is no line change. Approximately 280 bus stations are dispersed along the serviced routes. Additionally, the average age of the public transport fleet hovers between 13 and 14 years.

To ascertain the pollution load attributed to public transportation, relevant data and sources were analysed. Statistics from Tirana's SDS indicate that 36% of residents utilize public transport, while 27% opt for private cars, with the remainder categorized as utilizing alternative modes such as bicycles, motorcycles, or walking (Municipality of Tirana, 2018a). Rural areas, encompassing an approximate population of 17,000 individuals, lack access to such services. Presently, the public transport fleet comprises 305 buses, of which only 65 adhere to Euro-V/VI standards for combustion emissions.

The total capacity of the public transport fleet, accounting for seating and standing volume, amounts to 30,365 passengers, with only 31% of this capacity attributed to seated passengers. Consideration of the estimated daily volume and the 332 buses currently operational in Tirana equates to approximately 55,000-62,000 passengers.

¹³ https://akm.gov.al/ova_doc/raporti-per-gjendjen-e-mjedisit-2022/

Figure 13: Public transport cover area in Tirana Municipality



Source: Co-Author Delli. G., Gjoka. R., Co-PLAN (GIS analysis of buss accessibility in Tirana)

The entire fleet of public transport vehicles in Tirana operates using Ignition Combustion Engines (ICE), with diesel fuel powering the whole 305 buses while 27 buses are hybrid version. Based on calculations, it has been determined that each litter of diesel burned in open air emits approximately 2,640 grams of CO₂ (Directive 70/220/EC¹⁴ and Regulation 715/2007¹⁵).

The Euro standards (II-VI) delineate the degree of particulate filtering and processing within the ICE exhaust system, with higher Euro classifications correlating to lower carbon dioxide emissions from the engine exhaust.

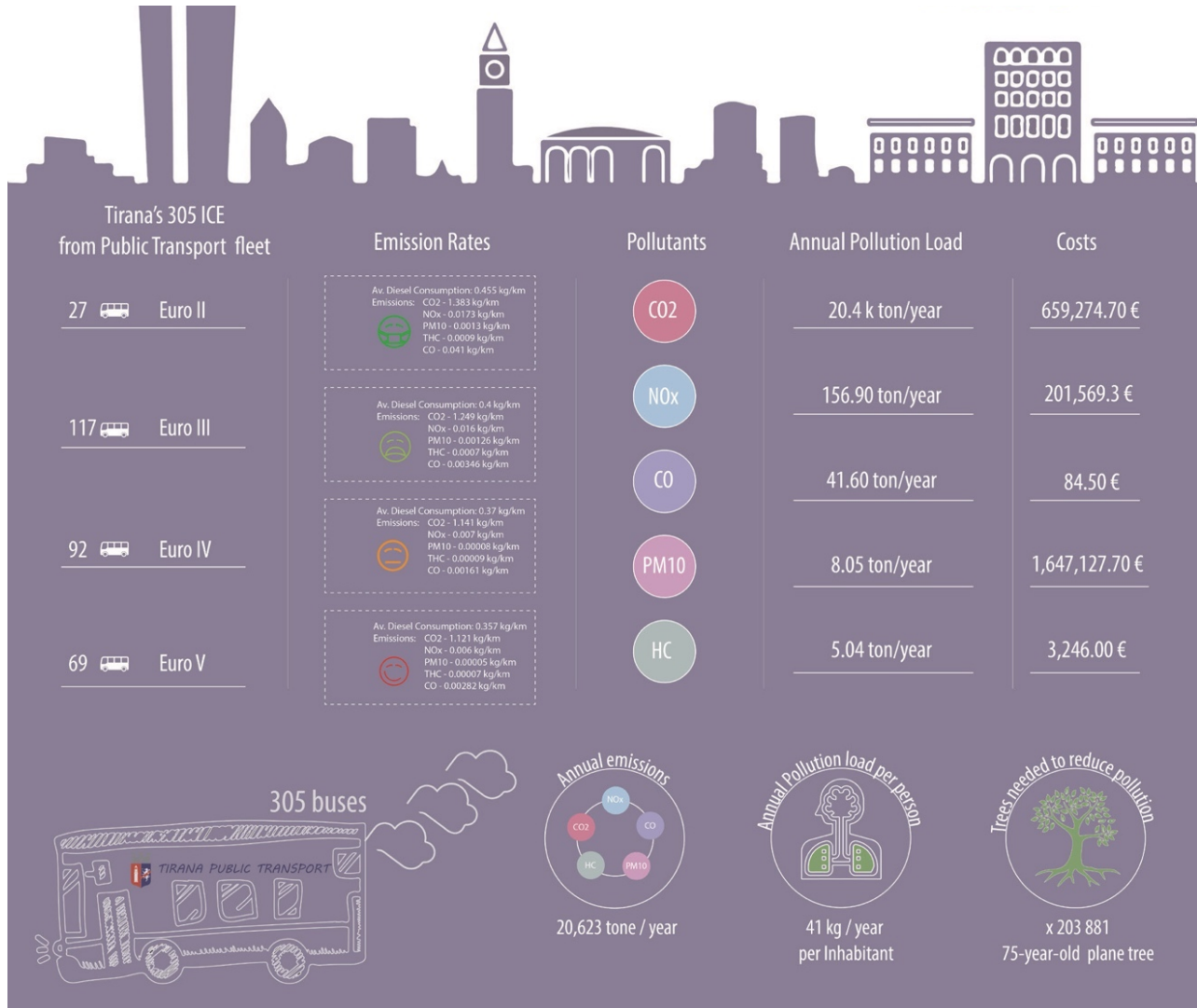
Data pertaining to vehicle type, brand, year of first registration, engine power, fuel type, and daily operating cycles were sourced officially from the Municipality of Tirana. Utilizing GIS analysis, the distances of designated routes were identified, enabling the calculation of fuel consumption for each bus. In accordance with regulatory standards, including Directive 70/220/EC and Regulation

¹⁴ <https://www.eea.europa.eu/policy-documents/directive-70-220-ec>

¹⁵ <https://eur-lex.europa.eu/eli/reg/2007/715/oj>

715/2007, fuel consumption rates (lt/km) and emission rates for PM10, CO, CO2, NOx, and HC (gr/km) were determined for an average speed range of 20-45 km/hr. The amortization factor of the ICE was omitted from this analysis, as the objective was to provide indicative results rather than an exhaustive breakdown for each vehicle.

Figure 14: Emissions from Tirana's Public Transport fleet



Source: Author's calculation on the pollution load from public transport vehicles (Co-PLAN)

Initially, buses were classified based on their emission category, determined by technical specifications provided by the municipality. Subsequently, the specific routes traversed by each bus were evaluated to ascertain the exact number of kilometres travelled per vehicle. Finally, the overall fuel consumption for each bus was computed, taking into consideration their ICE Euro classification and specific emissions of PM10, CO, CO2, NOx, and HC on an annual basis.

Once the calculations were generated to provide a yearly overview of each pollutant component, data from the European Union Emission Trading Register (EU ETS¹⁶) was consulted to ascertain the prevailing costs of these pollutants on global markets. If Albania were to align with EU standards, the public transport sector alone within the Tirana Municipality would incur an estimated cost of 2.5 million Euros, derived from the national state budget as a tax on the overall emissions contribution to the atmosphere.

In conclusion, the analysis of emissions stemming from the public transport fleet of the Tirana Municipality reveals an annual generation of approximately 21 kilotons (kt) of pollutants. Addressing this issue through natural means, such as the absorption of pollutants by trees, would necessitate the planting of approximately 203,881 Platanus trees, each at least 75 years old, within the city centre to mitigate the pollution load from CO₂ and PM₁₀.

However, if the age of the public transport vehicles and the amortization factor were recognized and taken into the equation, the quantity of pollutants could potentially escalate to as much as 141kt. For instance, a direct monitoring exercise was undertaken to assess the pollution load emitted by two typical buses falling under the Euro-IV category. This monitoring revealed that the age factor contributes to an increase of approximately 67% in total emissions of PM₁₀, CO₂, and NO_x compared to the Euro-IV baseline. The monitoring was conducted by deploying an AeroQual Series500 monitor at a bus station near the '21-Dhjetori' area. However, it's important to note that the age and amortization factor have been excluded from the overall emissions calculation for the purpose of this article.

2.8. Climate Change and Urban Air Pollution

The advancements in 21st century technologies have expanded the avenues for energy acquisition and production. However, despite these advancements, there remains a significant reliance on fossil fuels. Presently, the atmospheric concentration of CO₂ stands at approximately 555 ppm, with projections indicating a surge to levels ranging between 750 and 1300 ppm by 2100 (United Nations, 2014). Such escalation is poised to elevate the global average temperature by 2.2 to 3.7 degrees Celsius above pre-industrial levels (ibid.). By the years 2030 to 2052, it is anticipated that global warming will breach the critical threshold of 1.5 degrees Celsius above pre-industrial averages. Limiting the ascent of global temperatures to this threshold is imperative to avert irreversible

¹⁶ https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/union-registry_en

repercussions on Earth's ecosystems. This looming peril was underscored by participants of the Talanoa Dialogue¹⁷ during the Conference of Parties (COP-24) in Katowice. They warned that the forthcoming generation faces a climate emergency of global proportions, with no transitional respite or adaptation avenues available.

The vast majority of climate change impact will land on those most vulnerable that for decades now have now exploited and counter-developed their resources vis-à-vis sustainability and resilience. This is a characteristic especially for developing countries. The future of hundreds of millions of people in urban areas across the world will be affected and the overall disaster risk factor will increase (UN-Habitat, 2009). In light of the increasingly severe climatic conditions affecting major economies and sectors, numerous countries have transitioned from mere prevention strategies to encompassing mitigation and adaptation measures within their policy frameworks (Leuthard, 2018). A majority of nations have instituted financial and legal mechanisms in alignment with international agreements such as the Rio Convention, Stockholm Convention, and the pivotal Paris Agreement (COP21). These concerted efforts underscore a global recognition of the urgent need to safeguard the fundamental underpinnings of life itself (ibid).

Contemporary discourse surrounding climate change predominantly revolves around the development and identification of political and legal remedies aimed at addressing and mitigating the issue. As such, significant emphasis is placed on proactively averting the impacts of climate change, implementing mitigation strategies, and ensuring the adaptation of various countries and economic sectors to the existing changes or potential exacerbations of circumstances.

According to the IPCC sixth assessment report¹⁸ from March 2023, global climate change has become an undeniable reality, with temperatures rising by approximately +1.09°C during the period of 2011-2020 compared to 1850-1900. This occurrence poses an amplified danger to countries like Albania, particularly due to the increased frequency of extreme weather events such as floods, prolonged droughts, heat waves, and forest fires. Approximately 55% of Albania's population, primarily residing in the Western Lowlands, is projected to experience significant exposure to climate-related risks. This figure surpasses the previous global estimate of 40-45%. In the span of just three months this winter, certain communities in Shkodra County experienced three instances

¹⁷ *Author attended in person the dialogue during COP-24 in Katowice, Poland. Talanoa is a concept from Pacific countries based on the idea that story-telling leads to consensus building and decision making. Introduced by the Republic of Fiji.*

¹⁸ <https://www.ipcc.ch/report/ar6/syr/>

of flooding due to the overflowing waters of the Drin and Buna rivers. Additionally, during the summer, areas of forests and burned regions posed a significant threat, jeopardizing even the tourist season in several instances. Prolonged droughts have also placed substantial strain on the energy and agricultural sectors.

The assumed reference temperature is anchored to the average temperature of 1990 (GoA, Ministry of Tourism and Environment, 2022) . According to temperature rise projections, by 2050, an average temperature increases of 1.7°C is anticipated based on existing simulation data, with a maximum forecasted rise of 2.2°C in the worst-case scenario ((United Nations , 2015). By 2080, the temperature is estimated to elevate by 2.8°C, with a maximum potential increase of 3.5°C. Looking further ahead to 2100, the average annual temperature is projected to escalate by 2.4°C, reaching up to 4.1°C under the worst-case scenario.

Table 1: Forecast of rainfall change (in %) for different periods in relation to 1931-1965-1990

Years Vitet	1931-1965 (avg. mm)	1951-1980 (avg. mm)	2030	2050	2080	2100
Annual Vjetore	1415	1271.5	-3.84 (-35.4 to 27.7)	-8.46 (-56.0 to 47.4)	-14.37 (-78.6 to 81.1)	-18.13 (-89.7 to 94.9)
Winter Dimër	455	422.5	-5.96 (-15.9 to 4.0)	-10 (-27.9 to 7.7)	-14.3 (-44.6 to 16.1)	-18.1 (-55.8 to 19.6)
Spring Pranverë	337	324	-2.45 (-11.9 to 7.0)	-7.26 (-25.3to 10.75)	-14.26 (-45.1to 16.6)	-17.7 (-55.3 to 19.8)
Summer Verë	141	157.4	-10.4 (-12.8 to -7.9)	-19.7 (-24.1 to -15.3)	-41.9 (-49.2 to -34.5)	-50.4 (-59.4 to -41.3)
Autumn Vjeshtë	482	367.6	0.5 (-10.1 to 11.1)	-2.5 (-21.3 to 16.3)	-6.9 (-38.1 to 25.2)	-9.5 (-48.1 to 29.1)

Source: Ministry of Environment, 2016 and (Academy of Science in Albania, 1985)

In tandem with rising temperatures, an escalation in the number of consecutive days featuring extreme weather phenomena, such as temperatures exceeding 35°C or dipping below 0°C, is anticipated. Moreover, a diminishing trend in rainfall and an increasingly erratic, unpredictable distribution of precipitation throughout the year constitute another pivotal consequence of climate change in Albania. In the forthcoming years, a reduction of approximately 14.37% in rainfall is expected by 2080, escalating to over 18% by 2100. This surge in drought periods and a

corresponding over 50% decrease in summer season precipitation pose significant challenges for the agricultural, energy, and forestry sectors. According to AQUACORP and CLIRUN models, staple crops such as corn, alfalfa, and various domestic vegetables and fruits are forecasted to endure a productivity decline ranging from 20% to 50% by 2050 (Sutton, 2013).

Furthermore, sea levels may experience an elevation of 5 cm to 14 cm by 2030, and potentially up to 49 cm by 2100 (Frehner, 2011). Notably, the Adriatic Sea is profoundly impacted by global warming, evidenced by a yearly rise in its level by one centimetre and a corresponding temperature increase of half a degree Celsius annually since 1970.

The consequences of these phenomena directly affect the economy, particularly in terms of hydroelectric energy production, increased energy consumption, water utilization, and agricultural and livestock output. These factors have a direct impact on the well-being and safety of the population. Urban infrastructure, including transportation, water and sewage systems, and energy supply networks, face mounting pressure from extreme weather events, compromising the quality of services and supplies and potentially leading to disruptions. These disruptions result in economic losses and have a more pronounced effect on impoverished sections of the population. According to the Energy Community reports, the energy crisis in 2022 has elevated the percentage of Albanian citizens facing energy poverty to 37%.

The rise in temperatures, accompanied by climatic changes, has resulted in alterations to natural habitats and biodiversity. This has placed increased pressure on the most vulnerable habitats and species, particularly lagoon and coastal ecosystems, and has led to a rise in the presence of alien and invasive species. Notably, urban areas bear the brunt of these phenomena, as three decades of transition, urbanization, and construction have led to the paving over of more than 90% of their surface area. The loss of natural elements within cities exposes many citizens, often unwillingly, to higher temperatures than those recorded by meteorological centres. These areas also experience high concentrations of pollutants in the air, posing risks to public health.

Climate change and urban air pollution are two interconnected environmental challenges that pose significant risks to human health, ecosystems, and global sustainability. This theoretical review explores the intricate relationship between climate change and urban air pollution, elucidating the underlying mechanisms, shared drivers, and mutual impacts. It examines how climate change influences air quality through various pathways, including meteorological factors, atmospheric chemistry, and emission patterns. Additionally, it discusses how urban air pollution contributes to

climate change through the release of greenhouse gases and aerosols. By synthesizing existing literature, this review highlights the importance of integrated mitigation strategies and interdisciplinary approaches for addressing both climate change and urban air pollution in the quest for sustainable urban development.

Climate change and urban air pollution are among the most pressing environmental challenges of the 21st century, with far-reaching consequences for human health, ecosystems, and socio-economic well-being. While they are often studied and addressed separately, there exists a complex interplay between the two phenomena, with implications for both global and urban scales. This theoretical review aims to explore the relationship between climate change and urban air pollution, examining their interconnectedness, shared drivers, and mutual impacts. By synthesizing existing literature, it seeks to provide insights into the underlying mechanisms and pathways linking these two environmental challenges and to identify potential synergies in mitigation and adaptation strategies.

- **Meteorological Factors**

Climate change influences air quality through various meteorological factors, such as temperature, precipitation, and wind patterns. Rising temperatures can accelerate the formation of ground-level ozone (O₃) and other secondary pollutants through photochemical reactions. Changes in precipitation patterns affect the distribution and transport of airborne pollutants, leading to localized variations in air quality. Alterations in wind patterns can influence the dispersion of pollutants, exacerbating pollution hotspots in urban areas. Understanding the interactions between climate dynamics and air quality is essential for predicting future trends and developing effective mitigation strategies.

Inversion of wind speed, often discussed in the context of atmospheric or weather phenomena, refers to a situation where the wind speed increases with altitude, contrary to the typical pattern where wind speed decreases or remains constant with height. This phenomenon is closely related to temperature inversions in the atmosphere.

Normally, the air near the Earth's surface is warmer than the air above it, largely due to the heating effects of the sun on the ground. This warmer air at the surface tends to rise, and cooler air from above replaces it, creating what is known as a normal lapse rate, where temperature decreases with altitude. However, during a temperature inversion, this typical pattern is reversed—the temperature increases with altitude, leading to a layer of warmer air sitting above cooler air.

When a temperature inversion occurs, it can also lead to an inversion of wind speed. This happens because the inversion layer acts as a cap that stabilizes the lower atmosphere, suppressing vertical air movement. As a result, the winds at the surface become weaker due to friction and lack of vertical mixing, while at higher altitudes, above the inversion layer, winds can be stronger due to less friction and the presence of stronger pressure gradients.

Inversion of wind speed is significant because it can lead to the trapping of pollutants near the ground, resulting in poor air quality and visibility conditions. This is because the stable layer formed by the inversion inhibits vertical mixing of air, preventing pollutants from dispersing upwards and away from the surface.

Temperature inversions and associated wind speed inversions are common in certain meteorological conditions, such as on clear, calm nights or in areas with geographical features that enhance the stability of the air, like valleys surrounded by mountains.

- **Urban Vortex and Air Pollution**

Pollution dispersal in the air is affected mainly by these factors:

- meteorological conditions (especially wind speed, wind direction and atmospheric stability)
- emission altitude (e.g. ground level sources such as road traffic or high level sources such as tall chimneys)
- local and regional geographical / morphological features (topography, presence of strong natural patterns such as rivers, mountains etc)
- emission source (e.g. fixed point, such as a chimney, or a diffuse number of sources such as cars and solvents).

Urban Wind Vortexes, also known as urban wind funnels or urban wind canyons, are localized wind patterns and phenomena that occur within urban areas. They are primarily caused by the complex interactions between buildings, streets, and the surrounding environment.

Fluid Dynamics studies natural ventilation to stimulate and solve issues related to fluid flow of air and wind. Focused on urban ventilation, energy efficiency design, management of urban vortexes, funnels, aerodynamic performance and resistance as well as for the creation of wind canyons effects.

Urban vortex causes relate with topography, meteorology, seasonal variations but at a city scale it is prone to urban morphology/form such as:

Complex Layout (vis a vi the local wind patterns)

Buildings Height

Buildings Form

Mobility Infrastructure Layout etc.

Urban vortex phenomena linkage with air pollution is practically acknowledged but there are no practical studies indicating the effect of this phenomena on the creation of Air Pollution Cavity Areas APCA.

- **Atmospheric Chemistry**

Changes in atmospheric chemistry driven by climate change can significantly impact air quality. For instance, increased concentrations of greenhouse gases, such as carbon dioxide (CO₂) and methane (CH₄), can indirectly influence the formation of secondary pollutants, including ozone and particulate matter (PM). Additionally, alterations in atmospheric circulation patterns and atmospheric stability can affect the distribution and transport of pollutants, leading to regional disparities in air quality. The complex interplay between climate-induced changes in atmospheric chemistry and air pollution dynamics underscores the need for integrated modelling approaches and interdisciplinary research efforts.

- **Emission Patterns**

Climate change can influence emission patterns through various mechanisms, including changes in energy consumption, land use, and industrial activities. For example, shifts towards renewable energy sources and energy efficiency measures can reduce emissions of traditional air pollutants, such as sulphur dioxide (SO₂) and nitrogen oxides (NO_x), as well as greenhouse gases. Conversely, changes in land use, such as deforestation and urbanization, can alter emissions of biogenic volatile organic compounds (BVOCs) and aerosols, impacting both air quality and climate dynamics. Understanding the synergies and trade-offs between mitigation strategies targeting climate change and air pollution is critical for achieving co-benefits and avoiding unintended consequences.

- **Urban Air Pollution and Climate Change: Greenhouse Gas Emissions**

Urban areas are significant sources of greenhouse gas emissions, primarily from energy consumption, transportation, and waste management. Combustion of fossil fuels for heating, electricity generation, and transportation releases CO₂, CH₄, and other greenhouse gases into the

atmosphere, contributing to global warming and climate change. Additionally, urban sprawl and land-use changes associated with urbanization can lead to deforestation and degradation of carbon sinks, further exacerbating climate change. Mitigating urban greenhouse gas emissions requires comprehensive strategies that promote energy efficiency, renewable energy deployment, and sustainable urban planning.

- **Aerosol Pollution**

Urban air pollution also influences climate change through the emission of aerosols, which can have both warming and cooling effects on the climate. Fine particulate matter (PM_{2.5}) and black carbon (BC) emitted from combustion processes absorb solar radiation and contribute to local warming, known as the urban heat island effect. On the other hand, sulphate aerosols from industrial activities and transportation have a cooling effect by reflecting sunlight and enhancing cloud albedo. The complex interactions between aerosols, clouds, and radiation represent a key uncertainty in climate modelling and underscore the need for improved understanding of aerosol-climate feedbacks.

Addressing both climate change and urban air pollution requires integrated mitigation strategies that leverage co-benefits and synergies between the two phenomena. For example, transitioning to cleaner and more efficient energy sources, such as renewable energy and electrified transportation, can reduce both greenhouse gas emissions and air pollution levels. Similarly, promoting sustainable urban planning and transportation policies, such as compact development and public transit expansion, can mitigate emissions while improving urban air quality and liveability. Adopting a co-benefits approach enables policymakers to maximize the effectiveness and cost-effectiveness of mitigation efforts.

Achieving meaningful progress in addressing climate change and urban air pollution necessitates interdisciplinary collaboration among scientists, policymakers, urban planners, and community stakeholders. Integrating knowledge from atmospheric science, environmental engineering, urban planning, and public health enables a holistic understanding of the complex interactions between climate dynamics, air quality, and human well-being. Furthermore, engaging local communities in decision-making processes and fostering partnerships between government agencies, academia, and civil society enhances the effectiveness and equity of mitigation strategies. By fostering collaboration and knowledge exchange, interdisciplinary approaches can drive innovation and accelerate progress towards sustainable urban development.

In conclusion, climate change and urban air pollution are closely interconnected environmental challenges that pose significant risks to human health, ecosystems, and global sustainability. Understanding the relationship between these two phenomena is essential for developing effective mitigation and adaptation strategies that address their shared drivers and impacts. By integrating knowledge from atmospheric science, environmental engineering, urban planning, and public health, interdisciplinary approaches can unlock synergies and co-benefits that enhance the effectiveness and resilience of urban climate action. Moving forward, concerted efforts and collaborative initiatives are needed to tackle both climate change and urban air pollution in the pursuit of sustainable and equitable urban development

2.9. Public Health Implications of Air Pollution

Air pollution poses significant public health risks, affecting millions of people worldwide and contributing to various adverse health outcomes. This theoretical review explores the complex relationship between air pollution and public health, examining the physiological mechanisms, epidemiological evidence, and societal impacts of exposure to airborne pollutants. By synthesizing existing literature, this review highlights the diverse health effects associated with different air pollutants, including particulate matter, nitrogen dioxide, sulphur dioxide, ozone, and volatile organic compounds. Furthermore, it discusses vulnerable populations, such as children, the elderly, and individuals with pre-existing health conditions, who are disproportionately affected by air pollution. Through an in-depth analysis of the public health implications of air pollution, this review underscores the urgent need for comprehensive mitigation strategies and policy interventions to protect human health and promote environmental justice.

Air pollution is a pervasive environmental problem with profound implications for public health. Exposure to airborne pollutants is associated with a wide range of adverse health effects, including respiratory diseases, cardiovascular disorders, and premature mortality. Despite advances in air quality management, millions of people worldwide continue to suffer from the health consequences of air pollution, particularly in urban and industrialized areas. This theoretical review aims to elucidate the public health implications of air pollution, exploring the physiological mechanisms, epidemiological evidence, and societal impacts of exposure to airborne contaminants. By synthesizing existing literature, this review seeks to raise awareness of the urgent need for

comprehensive mitigation strategies and policy interventions to safeguard human health and promote environmental justice.

Physiological Mechanisms of Air Pollution

- **Particulate Matter (PM)**

Particulate matter is a complex mixture of solid and liquid particles suspended in the air, varying in size, composition, and sources. PM can penetrate deep into the respiratory system, causing inflammation, oxidative stress, and cellular damage. Fine particles (PM_{2.5}) are of particular concern due to their ability to bypass the body's defence mechanisms and reach the bloodstream, leading to systemic effects on cardiovascular health. Additionally, ultrafine particles (PM_{0.1}) have been implicated in adverse neurological outcomes, including cognitive decline and neurodegenerative diseases.

- **Nitrogen Dioxide (NO₂)**

Nitrogen dioxide is a common air pollutant primarily emitted from combustion processes, such as vehicle emissions and industrial activities. NO₂ can irritate the respiratory tract, exacerbate asthma symptoms, and increase susceptibility to respiratory infections. Prolonged exposure to NO₂ is associated with reduced lung function, increased risk of respiratory hospitalizations, and cardiovascular mortality. Furthermore, NO₂ reacts with other pollutants in the atmosphere to form secondary pollutants, such as ozone and particulate matter, exacerbating air quality issues.

- **Sulphur Dioxide (SO₂)**

Sulphur dioxide is a gaseous air pollutant emitted from burning fossil fuels, industrial processes, and volcanic eruptions. SO₂ can irritate the respiratory system, leading to respiratory symptoms, bronchoconstriction, and exacerbation of asthma and chronic obstructive pulmonary disease (COPD). Long-term exposure to SO₂ is associated with increased mortality from respiratory and cardiovascular diseases, particularly among vulnerable populations. Moreover, SO₂ can react with other pollutants to form fine particulate matter, further compromising air quality and human health.

- **Ozone (O₃)**

Ozone is a secondary pollutant formed through complex photochemical reactions involving precursor pollutants, such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs). Ground-level ozone can trigger respiratory inflammation, worsen asthma symptoms, and decrease

lung function. Prolonged exposure to ozone is associated with increased risk of respiratory hospitalizations, cardiovascular events, and premature mortality. Vulnerable populations, such as children, the elderly, and individuals with pre-existing respiratory conditions, are particularly susceptible to the health effects of ozone exposure.

- **Volatile Organic Compounds (VOCs)**

Volatile organic compounds are a diverse group of chemicals emitted from various sources, including vehicle exhaust, industrial processes, and consumer products. VOCs can contribute to the formation of secondary pollutants, such as ozone and fine particulate matter, through photochemical reactions in the atmosphere. Additionally, certain VOCs, such as benzene and formaldehyde, are classified as carcinogens and are associated with increased risk of cancer and other adverse health outcomes. Indoor sources of VOCs, such as building materials and household products, can also contribute to indoor air pollution and pose health risks to occupants.

Epidemiological studies have provided compelling evidence of the adverse health effects of air pollution, linking exposure to airborne pollutants with increased morbidity and mortality rates. For example, a systematic review and meta-analysis conducted by (Pope III, 2002) found consistent associations between long-term exposure to PM_{2.5} and cardiovascular mortality, respiratory mortality, and lung cancer incidence. Similarly, studies examining the health impacts of nitrogen dioxide exposure have reported associations with asthma exacerbations, hospital admissions for respiratory diseases, and cardiovascular mortality (Brunekreef, 2002). Furthermore, research on the health effects of ozone exposure has demonstrated associations with respiratory symptoms, emergency department visits, and premature mortality (Bell, 2004).

Collectively, these studies underscore the importance of reducing air pollution levels to protect public health and prevent adverse health outcomes.

Air pollution disproportionately affects vulnerable populations, including children, the elderly, low-income communities, and individuals with pre-existing health conditions, exacerbating health disparities and social inequalities. Children are particularly susceptible to the health effects of air pollution due to their developing respiratory systems and higher levels of outdoor activity. Exposure to airborne pollutants during pregnancy is associated with adverse birth outcomes, such as low birth weight and preterm birth, with long-term implications for child health and development. Similarly, elderly individuals and individuals with pre-existing respiratory and cardiovascular conditions are at

increased risk of morbidity and mortality from air pollution exposure, highlighting the importance of targeted interventions and protective measures for vulnerable populations.

Addressing the public health implications of air pollution requires comprehensive mitigation strategies and policy interventions at the local, national, and global levels. These may include regulatory measures to limit emissions from industrial sources, transportation, and power generation; investment in cleaner technologies and renewable energy sources; promotion of sustainable transportation modes, such as public transit, cycling, and walking; urban planning initiatives to reduce exposure to air pollution, such as green spaces, tree planting, and pedestrian-friendly infrastructure; public education and awareness campaigns to inform communities about the health risks of air pollution and empower individuals to take action to protect their health and the environment. Additionally, international collaboration and cooperation are essential to address transboundary air pollution issues and mitigate the global impacts of air pollution on public health and the environment.

In conclusion, air pollution poses significant public health risks, affecting millions of people worldwide and contributing to various adverse health outcomes, including respiratory diseases, cardiovascular disorders, and premature mortality. Particulate matter, nitrogen dioxide, sulfur dioxide, ozone, and volatile organic compounds are among the key pollutants of concern, with diverse physiological mechanisms and epidemiological evidence of health effects.

2.10. Previous Studies on Pollution Cavity Areas

Studies on pollution cavity areas, also known as pollution hotspots or pollution sinks, have gained significant attention in environmental research due to their implications for air quality management and public health. Pollution cavity areas refer to locations where atmospheric conditions, topographical features, and human activities converge to trap pollutants, resulting in elevated concentrations of airborne contaminants. These areas may include urban street canyons, industrial zones, valleys, and enclosed spaces with limited ventilation. Previous studies have investigated various aspects of pollution cavity areas, including their formation mechanisms, spatial distribution, pollutant dynamics, and impacts on human health and the environment. Below are summaries of some key studies in this field:

"Characterization of Air Quality in Urban Street Canyons: Implications for Urban Air Quality Management" (Ho, 2015)

This study focused on characterizing air quality in urban street canyons, which are notorious pollution cavity areas due to limited air exchange and high vehicular emissions. The researchers conducted field measurements of air pollutants, including nitrogen dioxide (NO₂), particulate matter (PM₁₀), and volatile organic compounds (VOCs), in different street canyon configurations. They found that pollutant concentrations were significantly elevated within street canyons compared to nearby open areas, with variations depending on street orientation, traffic density, and meteorological conditions. The findings of the study reveal elevated concentrations of air pollutants within urban street canyons compared to surrounding areas, indicating the significant impact of canyon geometry on air quality.

Furthermore, the study discusses the implications of these findings for urban air quality management strategies, emphasizing the need for targeted interventions to mitigate pollution hotspots in urban environments. In conclusion, the study underscores the importance of understanding and addressing air quality issues within urban street canyons to effectively manage urban air pollution and safeguard public health.

"Identification of Air Pollution Hotspots in the UK" (Beever, 2005)

Beever and Carslaw aimed to identify air pollution hotspots in the United Kingdom using a combination of air quality monitoring data and dispersion modelling techniques. The researchers analysed spatial patterns of nitrogen dioxide (NO₂) concentrations across urban areas and identified hotspot locations with consistently elevated pollution levels. They found that traffic-related emissions were the primary contributors to air pollution hotspots, particularly in busy road junctions and street canyons. The study provided valuable insights into the spatial distribution of air pollution and informed targeted mitigation measures to reduce exposure in vulnerable communities. The findings of the study reveal the existence of distinct air pollution hotspots in urban, industrial, and transportation-heavy areas, where concentrations of pollutants exceed regulatory limits or guidelines. Furthermore, the study discusses the potential sources and drivers of air pollution hotspots, including vehicular emissions, industrial activities, and atmospheric conditions conducive to pollutant accumulation.

The implications of these findings for air quality management and policy are also discussed, emphasizing the need for targeted measures to mitigate pollution hotspots and protect public health. In conclusion, the study underscores the importance of proactive identification and

characterization of air pollution hotspots to inform evidence-based decision-making and prioritize interventions for air quality improvement in the UK.

"Air Pollution in Industrial Zones: Current Status, Health Impacts, and Mitigation Strategies" (Zhang, 2020)

This particular study examined air pollution in industrial zones, which are often pollution cavity areas due to emissions from industrial activities and limited dispersion of pollutants. The researchers conducted a comprehensive review of literature on air quality monitoring, health impacts, and mitigation strategies in industrial areas worldwide. They found that industrial emissions contributed to elevated levels of particulate matter (PM), sulphur dioxide (SO₂), and other pollutants in surrounding communities, leading to respiratory diseases, cardiovascular disorders, and premature mortality. The study emphasized the importance of stricter emission controls, pollution monitoring, and community engagement to address air pollution hotspots in industrial zones.

Furthermore, the study examines various mitigation strategies employed to reduce air pollution in industrial zones, including technological advancements in emission control, regulatory measures, and implementation of green and sustainable practices. The findings of the study highlight the effectiveness of certain mitigation measures in reducing air pollution levels and improving air quality in industrial zones, while also acknowledging the challenges and limitations associated with their implementation.

In conclusion, the study emphasizes the importance of adopting holistic approaches and collaborative efforts among stakeholders, including government agencies, industries, and local communities, to effectively mitigate air pollution in industrial zones and protect public health.

"Characterization of Air Quality in Mountain Valleys: Implications for Pollution Control Strategies" (Jiang, 2018)

Jiang investigated air quality in mountain valleys, which are natural pollution cavity areas characterized by limited air circulation and topographical trapping of pollutants. The researchers conducted field measurements of air pollutants, including ozone (O₃), nitrogen oxides (NO_x), and volatile organic compounds (VOCs), in several mountain valley locations. They found that pollutant concentrations were often elevated in valley bottoms compared to surrounding upland areas, particularly during stable atmospheric conditions and stagnant weather patterns. The study highlighted the need for targeted pollution control strategies, such as emissions reductions and land

use planning, to improve air quality in mountainous regions and protect human health and ecosystems. One potential technical finding from this study could be the characterization of specific air pollutants and their concentrations in mountain valleys. For example, the study might reveal elevated levels of particulate matter (PM), nitrogen oxides (NO_x), sulfur dioxide (SO₂), or ozone (O₃) in mountain valley environments compared to surrounding areas.

Additionally, the study may uncover the sources of air pollution in mountain valleys, such as vehicular emissions, industrial activities, biomass burning, or natural sources like pollen or dust. Understanding the sources of pollution is essential for developing effective pollution control strategies tailored to the unique characteristics of mountain valley environments.

Furthermore, the study might evaluate the effectiveness of different pollution control measures in reducing air pollution in mountain valleys. This could include assessing the impact of emission reduction policies, technological interventions, land use planning, or natural interventions such as afforestation or green infrastructure. These studies illustrate the diverse nature of pollution cavity areas and their significant implications for air quality management, public health, and environmental protection. By understanding initially, the cause of Air Pollution Cavity Areas and further identifying its cause and exact locations where these phenomena is occurring, researchers could explore into details the dynamic relationship between local microclimate, wind patterns, landcover, land use and the natural dispersal of air pollution urban planners can develop effective mitigation strategies to reduce exposure and safeguard the health and well-being of communities living in these vulnerable areas.

4. CHAPTER III: EMPIRICAL STUDY

4.1. Conceptual Framework

Humans started to build cities to support life and growth, based always on the services that ecosystem and key natural cycles (water, fire, earth and air) had to offer. Mankind seems to have mastered and further perfected such cycles. It is in our perception that the local, regional and global alternations we made to natural landscape, cycles and resources have been “natural” to the extent that exploiting for development was not generating any externalities or even any irreversible effect. Such denial approach outlived all power systems, regimes and historical developments vis a vis the fact that environment and nature was always the source to our intellectual knowledge. Just imagine that air pollution has been tackled since the ancient times whereas Babylonia, Egyptian, Roman and Greek manuscripts indicate the issue of dust if quarries were to be exploited nearby their mighty cities.

Figure 15: Aristotelis principles of weather phenomena understanding & afresco of Francis of Asissi



Source: Internet

Moreover, from an academic perspective, natural phenomena were key to knowledge development. While predating the specified time frame, Aristotle's contributions to natural

philosophy profoundly influenced subsequent generations of scholars and thinkers. In his work *Meteorology* (Lee, n.d.), Aristotle explored the principles governing the Earth's atmosphere, including weather patterns, climate variations, and atmospheric phenomena. Although Aristotle's understanding of meteorology was based on philosophical speculation rather than empirical observation, his writings laid the groundwork for early theories of climate and environmental dynamics. Further, *Gaius Plinius Secundus* wrote 55BC *Naturalis Historia* Theophrastus: 400bc Botany Hippocrates: Air and Water influencing Health / Environment and Health. Even from the religious perspective Egyptians, Maya and Babylonia tried to take advantage of predicting natural phenomena to indicate their linkage with gods. Aborigens, Buddhism, Hinduism, Taoism, Shintoism base their ideology on the importance of cycle continuation therefore indicating strong ethics when dealing with nature and biodiversity. The Bible (Garden of Eden) and Kuran (filtra – responsibility) on the other hand give more dominance to man as a custodiae of nature until *Giovani di Pietro di Bernandone* or also known as Francis of Assisi (founder of Franciscans) 12th Century clearly nurtured a more realistic perspective on the matter. Later, Al Kindi & Ibn al Haytham during the Islamic School from 8th to 13th Century observed meteorology and set the foundations for that during European Renaissance scientist on 1350 invented and used the first meteorological monitoring instruments. From renaissance until 17th century was a period that witnessed significant developments in environmental thought, scientific understanding, and technological innovations that laid the groundwork for contemporary discourse on climate and the environment. While the concept of climate change as we understand it today was not articulated until much later, several key authors, inventions, and theories contributed to shaping early perceptions of the environment and its interactions with human society.

Leonardo da Vinci, renowned for his multifaceted talents as an artist, inventor, and scientist, made noteworthy contributions to early environmental thought. His observations of natural phenomena, including weather patterns, water flow, and geological formations, provided valuable insights into the interconnectedness of the environment. Da Vinci's sketches (Ritcher, 1970) and writings on subjects such as hydrology, geology, and ecology exemplify his holistic approach to understanding the natural world.

Further Johannes Kepler considered a pioneer astronomer and mathematician, introduced groundbreaking theories on planetary motion and celestial mechanics. His work, particularly his laws of planetary motion, laid the groundwork for understanding the Earth's position in the cosmos and its relationship to broader astronomical phenomena (Donahue, 1992) that also affected the climate

and meteorology. While Kepler's focus was primarily on astronomy, his insights into the mechanics of the solar system contributed to early understandings of Earth's climatic variations.

Francis Bacon, an English philosopher and statesman, emphasized the importance of empirical observation and experimentation in understanding the natural world. His seminal work, *Novum Organum* (Urbach, 1994) advocated for a methodical approach to scientific inquiry, laying the foundation for modern scientific methodology. Bacon's emphasis on systematic observation and induction contributed to early efforts to study environmental phenomena and their underlying causes.

Later, during the timespan from 1650 to 1950 numerous authors, inventions, and theories emerged, contributing to the development of environmental science and influencing societal attitudes towards nature. For instance, Alexander von Humboldt, a German naturalist and explorer, made pioneering contributions to the study of ecology and environmental science. His comprehensive approach to scientific inquiry emphasized the interconnectedness of nature and the importance of understanding ecosystems (Otte, 1849) as complex systems. Humboldt's seminal work, "Kosmos," explored the unity of nature and laid the groundwork for modern environmentalism. James Hutton, a Scottish geologist often regarded as the father of modern geology, proposed revolutionary theories on the Earth's geological processes and the concept of deep time. In his seminal work, "Theory of the Earth," Hutton argued that geological formations were shaped by gradual, natural processes over vast periods, challenging prevailing notions of a young Earth (Hutton, 1788). Hutton's ideas laid the foundation for understanding Earth's environmental history and the long-term dynamics of climate change. John Tyndall, an Irish physicist, conducted pioneering research on the greenhouse effect and the role of atmospheric gases in regulating Earth's climate. In his experiments, Tyndall demonstrated the absorptive properties of gases such as carbon dioxide and water vapor, elucidating their influence on the Earth's thermal balance (Tyndall, 1863). Finally to Rachel Carson, an American marine biologist and conservationist, catalysed the modern environmental movement with her seminal work, "Silent Spring." Published in 1962, "Silent Spring" exposed the detrimental effects of pesticides, particularly DDT, on the environment and human health. Carson's eloquent prose and meticulous research raised public awareness about the interconnectedness of ecosystems and the need for environmental stewardship (Carson, 1962).

For over two centuries, carbon has served as the cornerstone of global economies, initially utilized for the production of materials and goods, and subsequently meeting the escalating demand for

energy in industrial and urban contexts, primarily in the form of electricity and heat generation. However, the pervasive use of carbon has engendered a formidable challenge for humanity, chiefly due to its pronounced influence on climate patterns. The emissions of greenhouse gases, predominantly carbon dioxide, have experienced a parallel ascent alongside burgeoning economies and the expansion of energy provision, constituting anthropogenic activities as the foremost catalyst for climate change.

Following the dissolution of the Berlin Wall, a discernible shift occurred within Western societies and economies, catalysing a heightened consciousness regarding their environmental footprint. This paradigm shift fostered a propensity towards critical examination and proactive measures aimed at mitigating adverse environmental impacts. Conversely, in the Eastern Hemisphere, while the recognition of environmental concerns is acknowledged, concerted efforts towards addressing carbon dependency and curtailing emissions have been notably lacking. Countries spanning from Poland, Russia, the Balkans, India, to China have exhibited a propensity for minimal to negligible strides in reducing carbon-based reliance and per capita emissions.

Cities although occupying just 2.2% of the earth surface, are responsible for 2/3 of global energy usage thus accounting to 79% of global anthropogenic emission of GHG. (International Energy Agency (IEA), 2008). Cities are the most complex organism but it's not the urban areas to be blamed for the emissions of GHG and several pollutants, its rather the design and form of the urban areas. Hereby lies also the solution, through design and changes in urban morphology and its form we can reduce the critical exposure of citizens to air pollution and decrease emissions contribution to climate alternation.

Evolving and growing are two different concepts, but the jargon of the 21st century on urban growth has generally used the evolving terminology hindering the actual problems arising from a consumerist behaviour and economy. Sustainability requires evolution and the process of evolving does not necessarily mean growth. However, this contested term (sustainability) indicates the characteristics of particular activities that do generate economic, social and environmental benefits. In the spectrum of urban planning, as complex as it might get is the perfect context to elaborate and define in practical terms "sustainability". How can cities generate environmental benefits alongside the pursuit of economic growth. This paradigm has led many authors convene on a new approach, green growth or ecological modernization¹⁹.

¹⁹ Murphy and Gouldsoon (2000), Mol and Sonnenfeld (2000), Young (2000) Lundqvist (2004) Barret (2005)

As intriguing and utopic it might appear, the ideal approach lies on the ability of local and regional economies imposing their behaviour to the global one by identifying market niches that target ecological behaviour of consumer so that environmental protection becomes a source of profit (Rydin, 2013).

Growth dependent planning is the key argument addresses by Yvone Rydin whereas she points out three main aspects supporting this idea: a) new development to bear considerably higher environmental standards since planning and design phase, b) conceive planning gain being used for environmental ends and c) urban development to contribute to the broader restructuring of local and national economies by providing demand for ecosystem services.

If we look closely into the environmental impact that nowadays growing cities are experiencing (herby referring to capital cities of Western Balkans like Tirana, Belgrade, Pristina, Skopje) the so called or proclaimed green infrastructure or green standers applied in planning, questions have been raised of whether there should have been limits to the overall quantum developments of urban morphology. More and more public spaces and old quarters even historical ones in these cities are being demolished for large-scale developments.

For instance, only in Tirana more than 56ha of public space including parks, green areas, sport fields have been lost forever due to individual rights to develop property. City council failed to protect these urban assets in face of growth dependent planning and thus they conceal such ecosystem services loss with the claim that new urban developments have increase property value and they are with high environmental standards. Such example from an environmental perspective does not at least meet the concept of Factor Four or even Factor Ten (Lovins, 1997) which argues that greater economic output can be achieved with considerably less resources use per unit, so that the annum resource use can be reduced even as growth is maintained.

Demolition in urban areas of Tirana applied only once the material reuse of the existing dwelling. The reference here is with the demolition of “Qemal Stafa” national stadium, part of the historical centre of the city. Given the enormous opposition from public to this project the authorities managed to satisfy “nostalgic feelings” of the concerned communities just by re-using the old stone façade of the entrance and stairs from the old stadium whereas everything else is completely transformed.

Figure 16: Entrance facade of Albania's national stadium "Qemal Stafa"



Source: Internet, Blogu Urban.

Figure 17: Entrance of the Air Albania national Stadium



Copyright: Pietro Savorelli

Not in any other case materials from previous building were reused within the new developments. On contrary, historical and public dwelling as well as historical villas, and moreover the damaged objects from the Earthquake of Nov.2019 were demolished aggressively even with explosion and further the inert were "chopped" within the working-site, undermining the fact that heavy duty vehicles, air pollution from dust, pneumatic hammers noise and all other disturbing processes were happening within the densest inhabited area of Albania. Exposing citizens to a certain daily stress and health risks just because the growth-demand planning did not take any environmental impact

into consideration due to high costs. Well in the end, such cost was politically absorbed by the city council, mayor and government authorities as they continue to pollute and communities continue to absorb the pollution in their lungs.

Whilst principles of circular economy and environmental standards to mitigate pollution were not even applied on the Faculty of Civil Engineering of Tirana, where these concepts are being taught since 1996 from the Environmental Department to all new students, imagine the exacerbated situation in other private construction sites throughout Tirana.

Hereby in the case of Tirana it can be concluded that the regulatory powers of the planning regime have intentionally traded off environmental impact mitigation to maximize private economical over social and public health gain from development process.

Figure 18: PM concentration exceeding 10 times the standard due to demolition of the Faculty of Civil Engineering



Source: Author monitoring practices

Given that as an author of this thesis and also due to previous research work on pollution, noise and ecosystem monitoring, i have come to conclude that: *Since the approval of the new administrative-territorial division with law no. 115, dated 31.07.2014, "On the administrative-territorial division of local government units in the Republic of Albania." Where the local government units in the Republic of Albania were merged from 335 to 61 municipalities and 12 districts. All the following bylaws, administration restructuring and general local plans led to the dismantling at an unprecedented scale of the environmental monitoring practices. For that the expenses of investors were feasible and viable enough to support the development public health and ecosystem services were exposed to alienation and destruction.*

At this modern era of planning, especially in developing economies, where simple principles are overridden. It appears that urban communities have broadly accepted that the social, cultural and environmental footprint of urban planning decision are a cost to be absorbed in order to maintain economic growth. Either they react weak in front of a system that blocked most of the participatory processes envisaged by planning instruments or quite dormant and self-complaining through a cup of coffee. The way out through this Gordian knot would be to finally understand that greater purchasing power operating in Albania's economy are actually decreasing the values of all community's resident before the 90' by worsening the uneven distribution of urban benefits such as access to fresh air, water, clean environment, recreational public space, and an overall healthy and qualitative life. This through an incremental change by gentrification of city centre and selected plots while densifying all the surrounding areas to an extent that disparities could be acknowledged by preschool kids.

4.2. Urban Form in Tirana

During the doctoral studies, several workshops and research activities were carried by the candidate to explore the notion of urban form and its sustainability vis a vis the temporal effect of various indicators such as decision making power, planning approaches, climate etc. My research in this particular case endeavours to produce analytical tools and architectural/urban compositions, predominantly conveyed through visual representations, to signify the sustainability of existing urban sites and propose visions for future sustainable development. Collaboratively, this research seeks to identify and prioritize sustainable elements within urban settings while distinguishing them from unsustainable counterparts at both individual and city-wide scales.

The significance of locality, identity, and belonging emerges as a product of collective memory and history rather than as a result of individual and centralized architectural interventions (Rossi, 1984). He argued that the significance of urban artifacts and their role in shaping the identity and character of cities over time is unequivocal whilst he critiques modern architectural practices for their disregard of urban context and historical continuity. He contends that cities are constructed layer by layer through incremental additions and modifications, resulting in a rich tapestry of urban fabric. According to Rossi, urban artifacts such as squares, streets, and landmarks are enduring elements that define the essence of a city and provide a sense of place and belonging to its inhabitants.

Central to Rossi's argument is the concept of "collective memory," which refers to the shared experiences and historical narratives embedded within urban spaces. He believed that cities should be viewed as repositories of collective memory, where past, present, and future coexist in a dynamic continuum. Rossi advocated for an architectural approach that respects and celebrates the historical layers of the city while accommodating contemporary needs and aspirations. His ideas underscore the importance of preserving and interpreting the built environment as a means of fostering cultural identity, social cohesion, and urban resilience.

Drawing from case studies conducted in Polis and Ferrara, along with theoretical insights from architectural scholars such as Rossi (1984) and Sitte (1945), the research explores the evolution of urban spaces over time. Rossi emphasizes the importance of cherishing cities as historical artifacts, while Sitte's examination of ancient towns highlights the significance of public spaces in urban design. By analyzing Tirana as a case study, the research assesses the alignment of urban development with theoretical frameworks and practical considerations.

Sustainability is conceptualized as a dynamic process rather than a fixed outcome, shaped by urban elements and phenomena that evolve over time. Through systematic analysis in architecture, urban planning, and environmental studies, the research aims to provide comprehensive insights into sustainable urban development practices. The findings, derived from the analysis of Tirana's historical maps spanning from 1921 to 2020, reveal shifts in urban morphology and land use patterns.

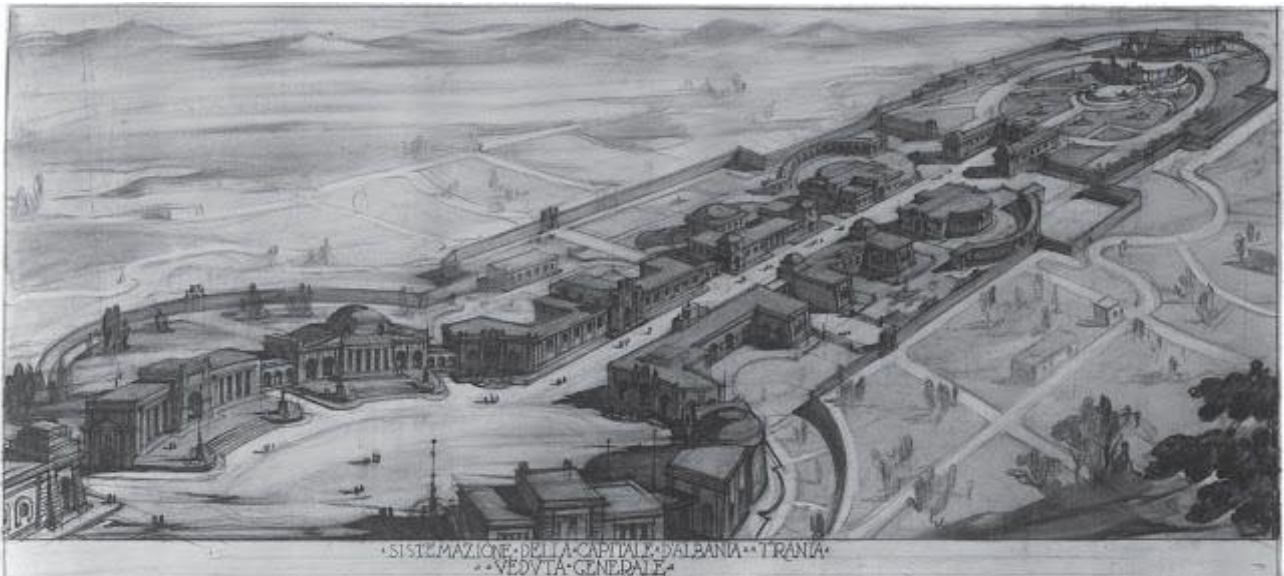
For instance, Tirana prior to being the capital city of Albania in 1925 did not pose any particular or historical urban layout rather than groupings of small villas.

Whereas cities such as Durrës, Shkoder, Berat, Gjirokaster, Lezha and Korca had magnificent urban layouts inheriting cultural and historical backgrounds since ancient times. In the early 20th century, Tirana, like other south-eastern European cities emerging from the Ottoman era, underwent a transition from its oriental roots to a more modern and Europeanized identity.

This transformation paralleled the nationalist movements of the late 19th and early 20th centuries, coinciding with the establishment of independent nation-states. The first layout of Tirana was put into map by the Austro-Hungarian army experts.

A pivotal moment in Tirana's urban evolution occurred with the introduction of a master plan by the renowned Italian architect Armando Brasini in 1925. This plan envisioned the construction of a new city centre featuring administrative institutions, the parliament, and governmental offices, anchored by a grand boulevard running from north to south. While Brasini's vision was ambitious, much of it remained unrealized. Nonetheless, the north-south axis outlined in his plan has continued to shape subsequent urban development initiatives in the city. Brasini was selected for this job from the Italian Authorities "*Societa per lo sviluppo Economico dell'Albania*" who reached an agreement between King Zog I and Credito Italiano Bank on an overall amount of 50 million gold franc loan. Brasini's historicist approach to Italian fascist design where an eclectic mix of baroque, renaissance and classical elements played an intricate part. As it can be envisaged on the layout he proposed for Tirana, its similarity with Saint Peter square in Vatican City. Even though this was the second proposal of Brasini, none of them was executed until the third proposal came from Florestano di Fausto who's layout on city centre and the main boulevard have shaped today's façade of Tirana's most wanted area.

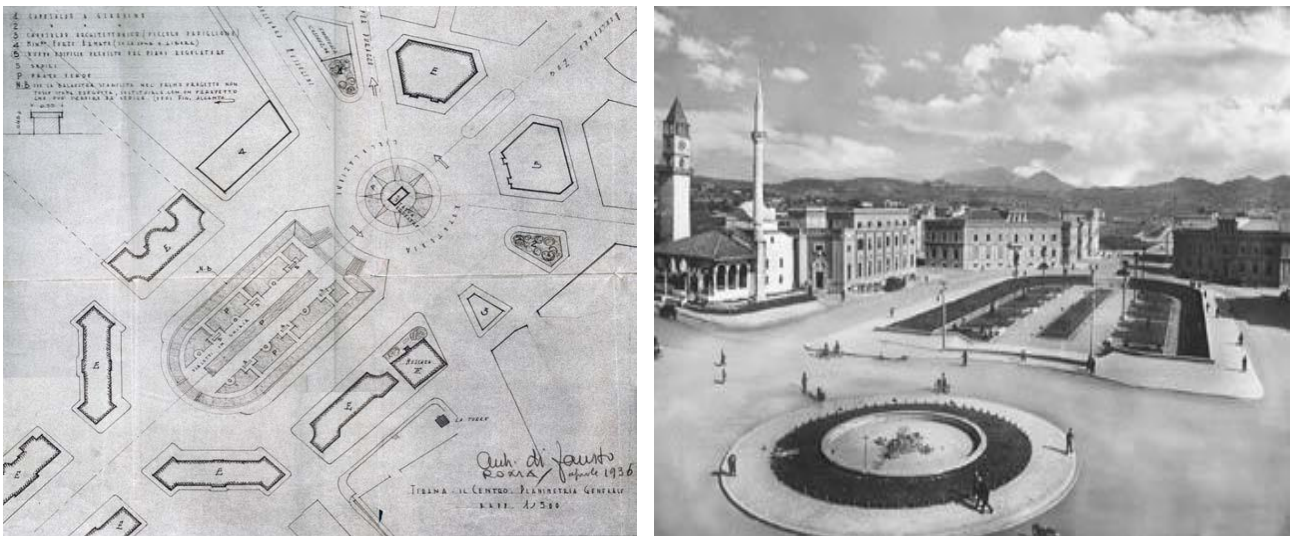
Figure 21: Brasini conceptual layout of Tirana



Source: tiranatimes.com

In Florestano's revision of Brasini's plan, the Presidential Palace to the south was omitted, and the square was simplified. Additionally, a thoughtfully designed sunken garden was introduced to enhance the appearance of the buildings, allowing them to appear taller while still providing shade without obstructing the overall complex. However, only two-thirds of the original plan were ultimately executed. In the northern-facing square, a post office was later constructed, but the northeast corner remained undeveloped.

Figure 22: Florestano's layout of Tirana city centre (plan and execution)



Source: tiranatimes.com

Fascist government sends in Tirana a group of young architects led by Gherardo Bozio, which will deal with the Regulatory Plan of Tirana. Studies for the plan began in September 1939 with the design and later the realization of the square and the boulevard of the fascist ideology. In October of the same year, the work began for the plan idea of the regulatory plan which ended with a project plan approved by Law 71, on 7 March 1940 (Vokshi, 2013)

Most of the reviewers of Bossio's work argue that the proposals made by Bosio for the preservation of the existing old quarter of Tirana are based on evidence that the architect himself will present in relation to the Regulatory Plan. He views this area, referred to as the "garden city," as needing to be preserved in its entirety. Firstly, he emphasizes the importance of maintaining the aesthetic factors and architectural forms that contribute to the strong local scenic environment. According to Bosio, these forms should serve as a testament to the historical significance of the old city of Tirana, and the integration of the old Ottoman texture with the new primary road system and the logic of mini-centres and small quarters with corresponding squares should be prioritized across the territory. Bosio's second argument in favour of preservation revolves around the relationship that the citizens of Tirana have with their homes and their unique way of life, viewing the issue from a social perspective as well. He believes that it would be challenging for citizens to quickly adapt to new conditions if significant changes were made to their living environment.

However, my research on the sustainability of the urban form starts with the analysis of the 1917-1921 cartography whereas the most predominant layers of the city appear to be road network and very few notable build landmarks as the most predominate element is the nature.

A noticeable clustering of small, familiar villas alongside a limited number of major public, military, and religious landmarks characterizes the urban landscape of early Tirana. However, despite this sparse urban fabric, streets such as Elbasani, Kavaja, Durrsi, and Dibra emerge as pivotal axes within the city. The directional naming of these streets towards prominent destinations suggests that these areas held greater significance as urban centers compared to the nascent city of Tirana during that era. Remarkably, these nomenclatures have not only endured over time but also exhibit a striking similarity of over 88% when compared to the 1917 map, underscoring their enduring legacy.

Figure 23: Sketch of Tirana's 1917-1921 main urban layers.



Source: Authors hand-sketching

Moreover, the formation of the first urban blocks in the eastern part of Tirana, particularly along Dibra Street, marks the earliest stages of urban development. This trend is further evident on both sides of Dibra Street, extending south to Tabaku's stream and Lana. Similar indications are observed between Durrsi Street, Kavaja Street, and Lana, albeit with more organized block formations emerging later in the eastern part of the city. These developments signify Tirana's initial emergence as a slowly evolving urban centre.

For the first time on the map, it becomes evident that a cluster of settlements, known henceforth as the Bregu Lumit community, emerged, comprising marginalized groups and Roma individuals.

Although these landmarks will be permanently displaced due to the construction of the new boulevard and the alteration of Lana, they will resurface in similar configurations, albeit in varying locations in subsequent years, notably in 1937, 1966, 1985, 2001, and 2022. An additional noteworthy aspect is the presence of four small surface water streams, namely "Perroi Tabakeve," "Lana," "Perroi Staneve," and "Perroi Jugor," in the eastern part of Tirana. Interestingly, these streams converge precisely at the location where the axis of the new boulevard would later be constructed, as depicted in yellow and orange in the figure below. This convergence highlights the interconnectedness of natural features and urban planning strategies in shaping the city's spatial layout and development trajectory.

As previously noted, the analysis proceeded with a reflection on the data provided by the 1937 map. Initial alterations indicated significant transformations, including the channelling of all streams into Lana's riverbed and the subsequent "disciplining" of the area, which spurred efforts to develop vacant spaces within the newly established buffer zone. This area was perceived as exclusive, with rumours circulating about the potential for major investments, including the construction of a boulevard and public buildings.

The development of public spaces and significant landmarks such as the American Embassy signifies the dynamic evolution of the urban landscape. Similarly, changes in road configurations and the emergence of cultural and administrative structures reflect the city's ongoing socio-economic evolution. These elements not only influence the physical environment but also play a crucial role in shaping the cultural and societal identity of a nation. During the communist era, Tirana held significant political sway and served as a focal point for all citizens across Albania, further enhancing its importance within the urban context. By 1937, it is evident that the upper part of the city had already adopted a block-based structure, delineated by major and connecting roads.

This grid layout appears to have influenced the development of urban blocks, with spaces quickly filled in, suggesting that the concept of urban form sustainability had become ingrained in the mindset of those involved in the area's development. Upon examining the present-day location, the blocks bordered in the north by Kavaja Street, with connecting roads serving as vehicular north-oriented corridors (*such as Islam Alla Street, Hajdar Hidri, and Shyqyri Berxolli streets*), retain the same footprint as they did a century ago.

Figure 24: Areal view from Hajdar Hidri str. with villas dating from 1930



Source: Author drone photo.

Figure 25: Sketch of Tirana's 1937 main urban layers.



Source: Authors sketching

Outcome of Second World War saw Tirana being a city of dual visages: on one hand, it showcased the historical charm of the old bazaar and Ottoman-style edifices; on the other, it bore the hallmarks of Italian fascist influence, which at that juncture was synonymous with modernity. Yet, the advent of communism introduced a new ideological paradigm aimed at reshaping the city's architectural and urban landscape. This period sought to imprint its distinct "similarity ideology" onto Tirana, further complicating the city's eclectic aesthetic. This transition not only represented a shift in political power but also a profound transformation in the city's identity, as it began to incorporate elements that reflected the prevailing communist ethos, thereby adding another layer to its complex urban tapestry.

The dichotomy between theoretical constructs and empirical realities often manifests starkly in the realm of political ideologies. Despite the divergence in ideological underpinnings, the pragmatics of governance and economic considerations necessitated that the transition to communism in Italy did not fundamentally alter the architectural and urban planning ethos inherited from previous regimes. This phenomenon was manifested through a process of rebranding - a mere substitution of insignias and renaming of edifices, underscoring the universality of symbols of dominion. The elements of monumentalism, axial symmetry, and expansive boulevards conducive to military parades were retained as quintessential markers of power. Notably, the Communists' adoption of architectural motifs reminiscent of fascist paradigms in The Cultural Palace at Skënderbej Square, with its rectilinear columns, eighteen years subsequent to its fascist prototypes, exemplifies this trend.

The urban development of the city underscored a stringent Eastern methodology, where political affiliations not only influenced urban planning theories but also dictated construction practices. This led to the creation of uniform blocks, replicating throughout the city as it rapidly expanded to triple its original size. Initially influenced by the Russian school of urban planning and architecture, the city later adopted the practicalities inherent in Chinese methodologies, culminating in its distinction as one of the most isolated and automobile-free cities of the period. Historical sites, including the Old Bazaar of Tirana and landmarks from the era of King Zog, were razed to make way for new symbols of communism.

This era's architectural ethos is vividly reflected in the current structures that populate the square and flank the boulevard. An emphasis on public spaces was paramount, as the communal domain

became a central element of the era, intended to be ingrained in the collective consciousness of the populace.

Through the analysis I conducted with the military cartographic maps of 1972 and that of 1985, the urban fabric of the city exhibited a distinct approach in its spatial organization. The northern sector was primarily characterized by its alignment along arterial routes and pathways that held significant value for the locals whilst the southern sector was notable for its grid-like layout, predominantly occupied by square configurations and buildings serving social and supplementary functions absent in the northern domain. As latter was the “neighbourhood” of couminist leadership. Even got the name BLOK. Furthermore, we can note that notable structures such as the Pyramid, Rinia Park, the New Ministry buildings, the National Theatre, the Queen's Park adjacent to the Palace of Pioneers, the National Assembly, the Prime Minister's office, the Palace of Congresses, the Academy of Arts, the University Rectorate, the Army Headquarters, the Polytechnic University, and the Qemal Stafa Stadium, all of which underwent significant conceptual transformations.

Figure 26: Sketch of Tirana's 1985 main public green areas in the city centre.



Source: Authors sketching

At a cursory examination, the southern part appeared to have been systematically populated with structures that addressed the emergent needs spurred by demographic expansion, encompassing

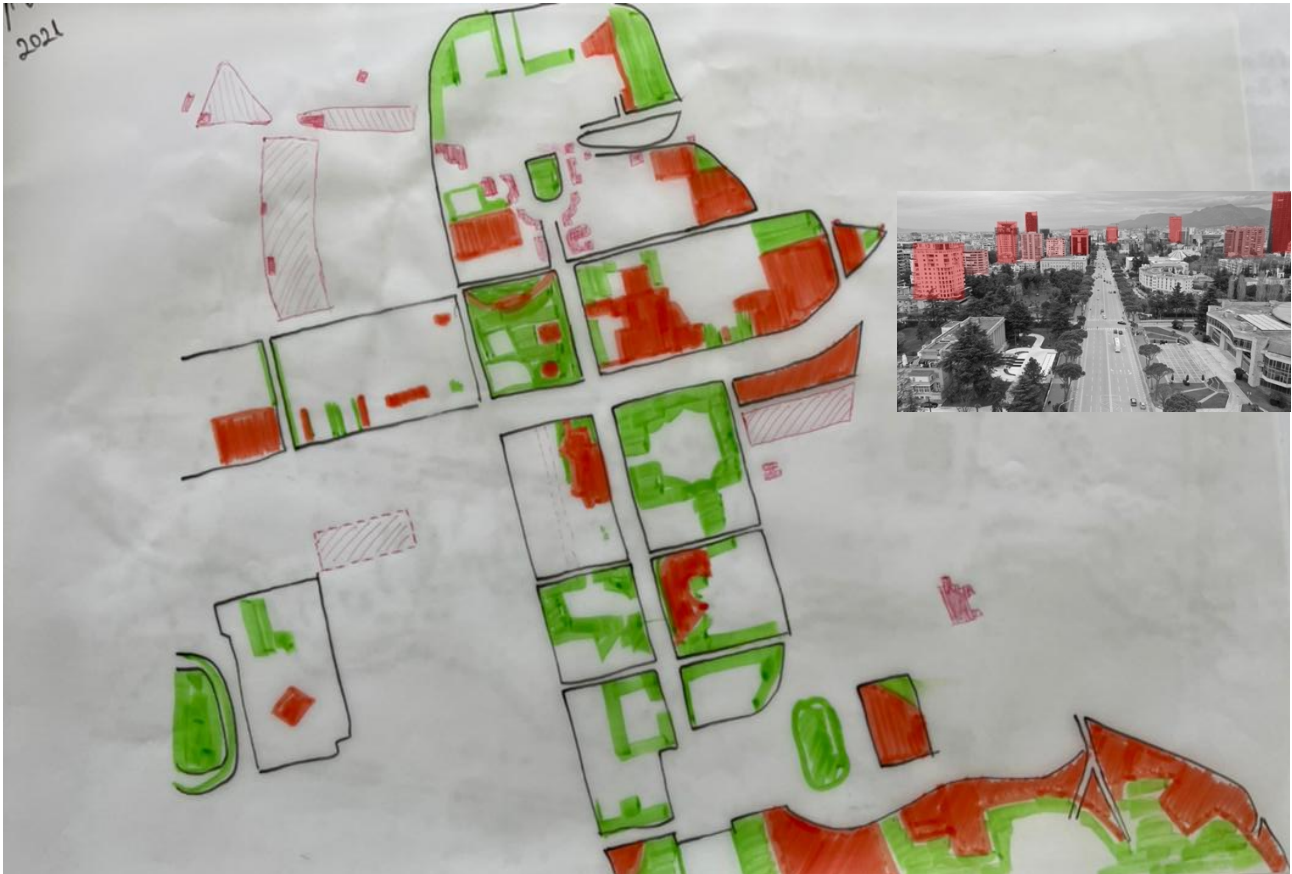
social, cultural, sports, and administrative facilities. Subsequent to the erection of these edifices, the remaining undeveloped plots were progressively occupied by constructions catering to evolving urban demands, including residential units and commercial complexes.

Planning and development from 1945-1985 seem to be a reflection of a broader urbanistic philosophy where the initial positioning of key structures influences subsequent urban layering, growth, and in some instances, the consolidation or disintegration of city blocks. During that time a lot of attention was paid to functionality, spaces and also natural ventilation. The proximity and arrangement of these entities significantly impact urban vitality, fostering a sense of rootedness and potential for expansion. Instances of strategic juxtaposition have led to coherent urban morphologies, whereas deviations from this principle have occasionally resulted in unsustainable spatial configurations. In the delineated schematic, I have deliberately highlighted, using a green coloration, all public spaces that would subsequently succumb to the forces of urban development, thereby diminishing the city's aggregate verdant expanses. In the concluding illustration, I have employed a red hue to denote all zones that underwent a transformation from green public spaces into constructed edifices and residential areas.

This transition contributed to the intensification of urban density, thereby impeding the city's inherent capacity for natural ventilation and curtailing the provision of essential ecosystem services to its inhabitants. This analysis led to the identification of small block units within the urban fabric, each exhibiting varying degrees of stability. The foundational reasons and outcomes of these spatial dynamics are elucidated in subsequent diagrams. Among the determinants of these areas' stability or lack thereof were the open angles between blocks and structures—observed through field visits, photographic documentation, and contemporary analysis—as well as the practice of constructing buildings directly at the block's perimeter without any intervening space.

During the course of site visits, a notable observation was made regarding the urban blocks that were characterized by a limited number of openings, restricted to one or two entrances per perimeter. These blocks exhibited significantly compromised natural ventilation, leading to an atmosphere that felt markedly more polluted compared to the air quality observed in the surrounding external environment.

Figure 27: Sketch and GIS register of Tirana's loss of public green areas.



Source: Authors sketching

This phenomenon piqued my interest and motivated a return to the site, this time equipped with appropriate tools to monitor air pollution levels, wind speed and direction, humidity, and to employ drone technology for an aerial perspective of these areas. These preliminary investigations enhanced my initial comprehension of various issues that were distinct across similar urban patterns, even though they had similar exposure to micro-climatic conditions and sources of pollution.

In Albania, land scarcity and territorial constraints are linked to the existence of a high percentage of mountains and numerous hills (almost 70% of the territory). Such conditions limit the cities from expanding in width, thus leading to the densification that supports development at higher floors. However, this cannot be done by harming the public, green and sports spaces that ensure the revival of community spirit and health. The emergence of pandemics and the number of deaths proved that Tirana is no more a healthy and sustainable city (Aliaj, 2023).

In response to these challenges, and moreover to the fact that the pollution cavity phenomena was caused by urban form in a time when in Tirana predominates a tendency to infill all available spaces. While addressing immediate spatial needs, Tirana homogenized its form and further engraved a whole new level of urban challenges, notably social, health and environmental issues that proliferated across the city. It could have gone high or even sprawl, but densification and occupation of every public space could have never been the feasible solution.

Nevertheless, at the conclusion of this analysis, the geometric shape of the block, the interconnected network of blocks and thoroughfares, as well as the topography of the terrain, appears quite evident as the most sustainable urban form. These configurations, quite applied at a large scale between 1950-1980 across Tirana and less during the period 1990-2023 are characterized by their inclusivity of mixed-use or multifunctional spaces, promoting a harmonious blend of activities and uses that contribute to the urban environment's resilience and adaptability.

4.3. Air Pollution in Albania, Tirana

The concept of urban pollution in Albania is clearly linked to the emission of harmful substances, which naturally and unnaturally enter and persist in cities and urban areas. Emissions associated with human activities such as construction, transportation, housing, industry, etc., are considered the largest pollutants in these urban areas due to the high concentration of people and activities in urban centres. The impact of these pollutants, whether preventive or mitigative measures, must be

implemented at the local levels. Local and national reports have been absent in Albania for over 4 years. International reports rank Albania as one of the most polluted countries in terms of air quality. If regional countries have seasonal pollution due to heating and energy production based on fossil fuel consumption at a large scale, in Albanian cities the concentration of pollutants remains constant throughout the year. Recently, the European Environment Agency cited that health impacts related to air pollution reduce the life expectancy of exposed individuals by approximately 184 days.

Specifically, in our country, pollution is entirely manageable and unfortunately entirely avoidable as long as the lack of green areas, excessive construction, poor quality fuels, and primarily non-compliance and inspection of legal obligations for preventing air emissions persist.

Data on noise pollution also exceed the allowable standard both during the day and at night. Overall, we estimate that over half a million citizens of the Republic of Albania are exposed to and affected by noise and air pollution every day. The importance of monitoring and improving the situation is crucial. The persistent and pervasive corruption and lack of enforcement of legal obligations for managing environmental health are causing degradation in the quality of life and health of residents of major cities in Albania.

Monitoring during the COVID-19 pandemic showed that in Tirana (as the city with the highest air emissions), a 15-day quarantine was necessary for concentrations of all pollutants to fall within World Health Organization standards. The lockdown measures reduced traffic and industrial activities, resulting in lower emissions during the day. However, concentrations of pollution remain unchanged or even higher in some cases compared to before the pandemic.

Air quality and noise monitoring in Albania are shared responsibilities between the National Environment Agency and the Institute of Public Health. However, both of these institutions generate monitoring results that have not been accredited and calibrated since 2016, while the degradation of air quality is a fact easily identified by the majority of citizens. In an ideal situation, these two institutions would strongly encourage local and central levels of government to develop policies and take urgent measures for the benefit of citizens' health. However.

In accordance with the World Health Organization's guidelines, the air quality in Albania is considered moderately unsafe. The most recent data indicates the country's annual mean concentration of PM_{2.5} is 18 µg/m³ which exceeds the recommended maximum of 5 µg/m³. Contributors to poor air quality in Albania include inefficient technologies to heating homes, cement production, construction and infrastructure development and an increase in vehicle emissions.

Available data indicates that Tirana, Elbasan, and Korçë have consistently high levels of air pollution.²⁰

Albania has also been ranked the second country with the highest pollution-related deaths in Europe, according to the yearly European Environment Agency yearly status report on Air Quality outlook of 2020 report. Second only to Bosnia and Herzegovina, roughly 23 percent of deaths in Albania were caused by air and noise pollution. The report said that pollution was resulting in a number of premature deaths. On average, 26,000 years of life have been lost over the last decade due to air pollution. All of these deaths have occurred under the age of 65. Then in January 2020, the (NUMBEO, 2022) placed Tirana as the third most polluted city in Europe. The top spot was taken by Tetovo in North Macedonia followed by Chelyabinsk in Russia. Its levels of pollution had increased as compared to figures from the previous year. But air pollution in Tirana and throughout Albania is not just a consequence of fossil fuel consumption and construction or industry, it's sourcing also from natural disasters and how we cope and manage these occurrences.

In addition, deforestation – forest fires and exploitation of wood as a primary material for various industries, has led to floods in the western lowland, and erosion and landslides everywhere in the country, besides contributing to the world's increasing CO2 levels. Paucity of official data on forests and deforestation hinders the potential calculations on related risks. However, based on Corine maps, the total forest area (broad-leaved, coniferous, and mixed) has shrunk by 9% from 2000 to 2018, while according to INSTAT figures (source of data Ministry of Environment) the total volume of woods has diminished by 32% from 2006 to 2018. These data should be interpreted with caution, but at a first sight they suggest that their major change might be related to forest density reduction and exploitation of mature natural forests (Toto, 2020).

According to DesInventar Albania (completed in 2014), more than 4,000 disaster events are recorded in Albania from 1851 to 2013, where the majority (33%) are meteorological events, followed by climatological (22%), hydrological (21%) and landslides (14%). The remaining 10% of the events were geophysical, biological and technological (Toto, 2014).

This situation is primarily attributed to traffic congestion in urban areas, along with the common issue of relatively old vehicles emitting higher quantities of pollutants, compounded by the quality of fuel traded in the Republic of Albania for years. This issue becomes even more aggressive when

²⁰https://apps.who.int/iris/bitstream/handle/10665/69477/WHO_SDE_PHE_OEH_06.02_eng.pdf;jsessionid=2104E160D80200034BAFB5610A114AA0?sequence=1

considering the pronounced lack of green spaces within residential blocks in our cities, where construction activities and private businesses emit significant amounts of pollutants into the air (largely unregulated as self-monitoring processes are unreliable and oversight by relevant authorities such as the National Environment Agency (NEA) and the Institute of Public Health (IPH) is lacking in most cases).

The adoption of the new environmental cross-cutting strategy and more explicitly legislation implementation from central to local level for the period 2015–2022 has been delayed. As of late 2017, although several issue-specific strategies on environment exist, Albania does not have a visionary umbrella policy framework for environmental protection.

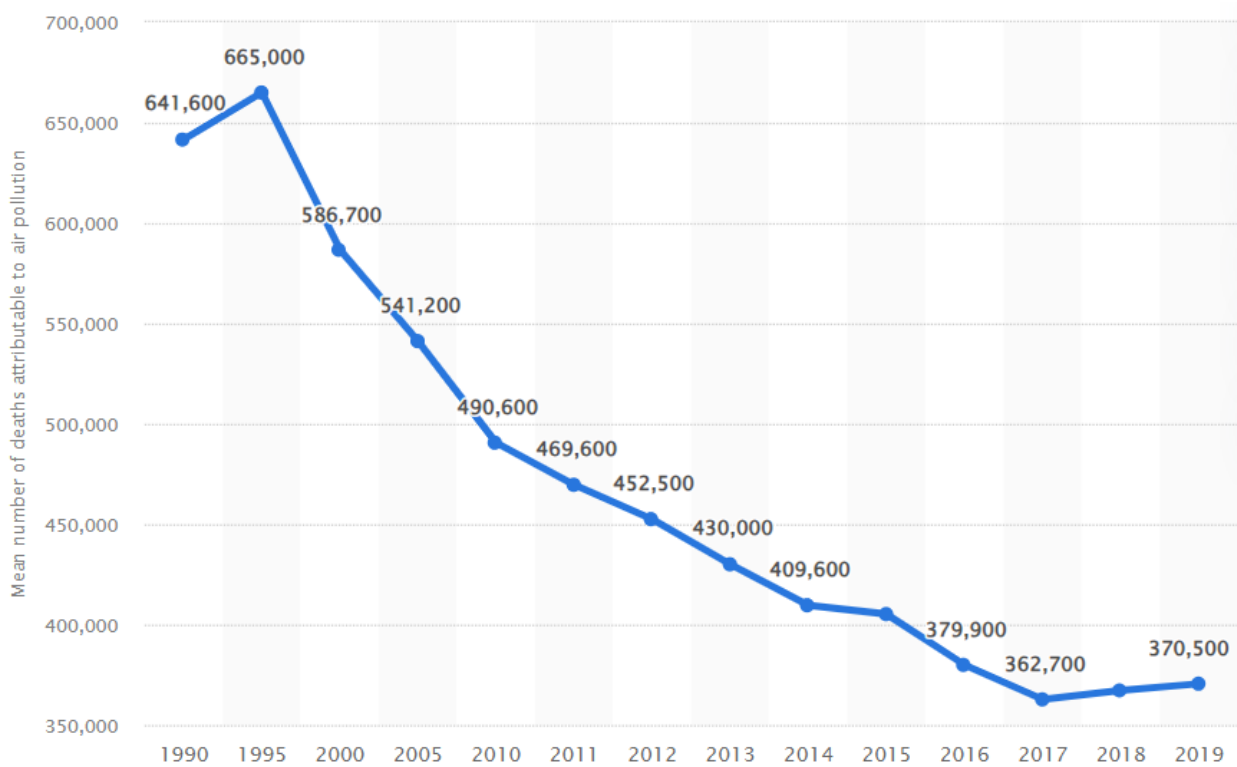
The Government committed to reduce CO₂ emissions in the period 2016–2030 by 11.5 per cent compared with the baseline scenario. Another target is to reduce energy consumption by 9% by 2018 compared with average consumption in the period 2004–2008. In the area of renewable energy, Albania aims to achieve a 38% share of renewable energy sources in gross final energy consumption until the end of 2020, but achieving these goals seemed unlikely at the time and it resulted so. Introducing the Korca Gas Power Plant project, refurbishment of Vlora Thermal Power Plant to use Trans Adriatic Pipeline Gas and the latest introduction of floating Thermal Power Plant harboured in Vlora would at least double Albania's annual GHG emissions as well as the accompanying air pollutants.

Decreasing carbon emissions is linked directly with the reduction of other pollutant released in air such as PM, NO_x and Sox. Hereby, in the situation that GoA perceives to be an Energy State of Emergency, investing in capacities that generate energy from fossil fuel was apparently the most convenient solution.

Efforts have been made by Albania to comply with its international reporting obligations. However, the absence of monitoring data on species and habitats, air quality and greenhouse gas (GHG) emissions has impacted timely reporting in these fields. Hence the credibility of reported data is jeopardized since it's almost based on assumptions and calculations without any practical reference to site-monitoring or inspections. Not only the 4th NDC of Albania appears to reflect contradictory information, but since early 2023 the European Environmental Agency did exclude Albania from its reports given that it is the only country in the European Continent not providing any information with regard to air quality monitoring.

While mitigating air pollution across Europe has been the epitome of policy developments since the early 90s, the effects on public health were considerable when taking into consideration that premature deaths attributed to pollution exposure were reduced by half in a 20-year timespan.

Figure 28: Premature deaths attributed to air pollution in EU countries.



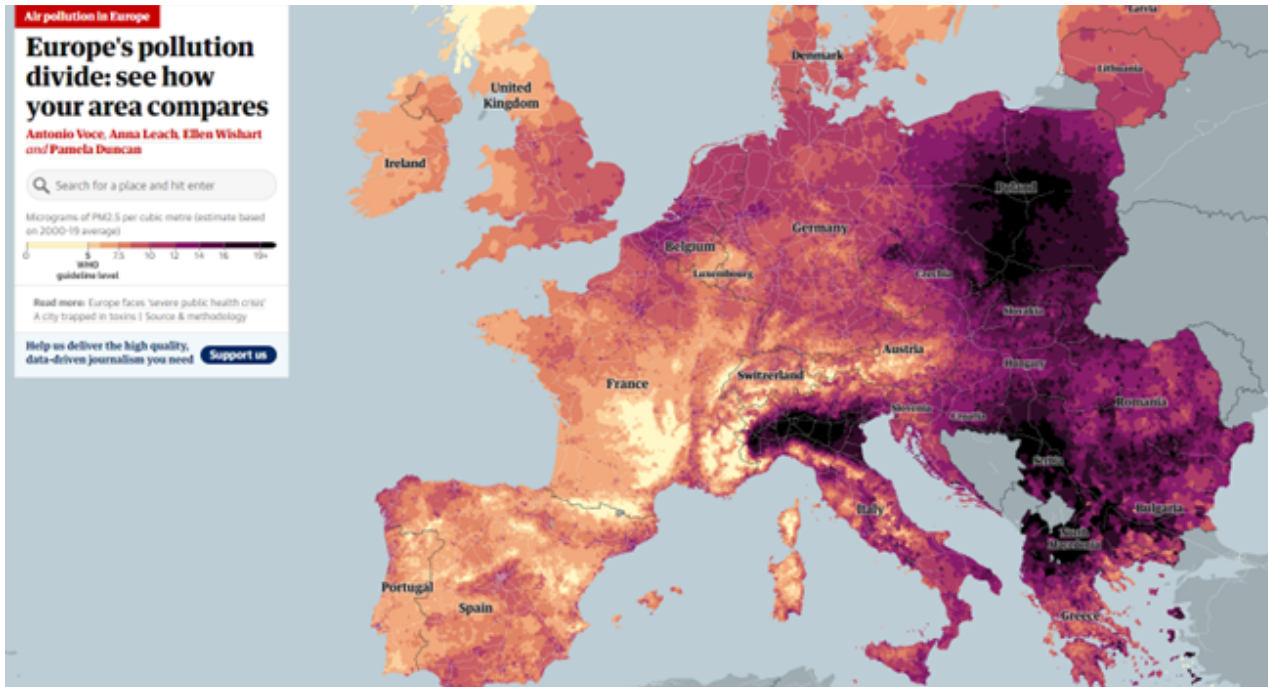
Source: European Environmental Agency, Air Quality Report 2020

Regardless of the strict policies and inspections applied to reduce air pollution, European countries that have not strategically invested into phasing-out energy dependency from fossil fuels appear to have also to have the highest concentration of PM pollutant in their air. For instance, the whole Eastern countries (from north to south) such as Poland, Slovakia, Serbia, North Macedonia, Bulgaria, Greece and apparently the industrial area of North Italy lead the chart of the countries that expose its inhabitants to unhealthy concentration of pollutants in urban air. Nonetheless, Albania is in the same group even though there is no actual heavy industry present in its territory nor any thermal power plant generating electricity.

As most know Albania's inhouse energy demand is already covered at 70% by its Hydro Power capacities and the difference, well that is obviously marketed from coal or nuclear sources in the region. Herby, what cloud the assumptions on why Albania is also facing problems with regard to air pollution to the extended of being comparable with countries that do have heavy industry processes or coal-based TPP?

There could be two arguments on that, first is that all neighbouring countries to Albania do produce their energy through TPP and possibly their emissions under the influence of regional wind patterns can actually have cross-border effects.

Figure 29: Heat-map visualization of PM_{2.5} concentration across Europe



Source: The Guardian²¹

Whilst the second and most credible version to my opinion is that even though there is no heavy industry nor any active TPP the overall irresponsible action from all business and private enterprises across Albania with regard to resources exploitation and management of environment externalities, combined with the total absence of the control and inspection by all relevant environmental authorities could bring far more pollution to the urban areas.

The inefficacy of policies and the mismanagement of taxes dedicated to environmental protection are exemplified by the Carbon Tax. The final price of oil, notwithstanding the fact that 60% of it consists of taxes, includes a Carbon Tax contribution of 3 ALL/Liter to the state budget. An analysis of 2017 data reveals that approximately 832 kilo ton oil equivalent (ktoe) of oil were traded in Albania, generating an estimated revenue of 10-20 million Euros solely from this tax. However, there has been a lack of specific investments in reducing air emissions from transport or construction sectors.

²¹ <https://www.theguardian.com/environment/ng-interactive/2023/sep/20/europes-pollution-divide-see-how-your-area-compares>

Taking into consideration the lack of information from authorities at a national level since 2016 my interest on research and monitoring air quality had a particular attention. By early 2017 i conceptualized and funded the alternative monitoring platform “Mushkeri te Gjelbra” Green-Lungs project, that was funded on the same year by European Delegation in Albania and latter in 2021 by Swedish International Development Agency.

This initiative grew to become the only source of information in Albania with regard to air pollution, noise and ecosystem services from urban greenery. Monitoring on daily basis in 5 different cities across Albania (Tirane, Korces, Durres, Elbasan and Shkoder. It provided substantial information to all interested actors on air, noise and urban ecosystem through its dedicated web-based platform and thematic publications as well as the yearly bulletins since 2018.

More than 117 media appearances and articles referee Green-Lungs as the source of information to the matter, further an average of 31 Master students in Albania elaborated their final thesis by voluntarily joining the initiative and conducting site monitoring activities and research.

More than 3000 different locations were monitored periodically totalling to an approximate of 33,000 monitoring practices across all Municipalities combined. Detailed information on my research activity since 2017 and publication on Green Lungs project could be found at: <https://www.greenlungs.al/#>

The table below offers an overview of average pollutant concentration extracted from the alternative monitoring results leaded by the author since 2017.

Table 2: 2018-2023 average pollution concentration.

	TIRANE	DURRES	SHKODER	ELBASAN	KORCE	EU Standard	WHO	US EPA
PM _{2.5} (µg/m ³)	19	23.6	17.9	31	27.2	20	5	9
PM ₁₀ (µg/m ³)	29	37.1	26.7	39.6	42.1	40	20	150 ²²
NO ₂ (µg/m ³)	117	85.5	126	69.6	59.7	40	10	100
VOC (µg/m ³)	0.35	0.53	0.6	0.52	0.38	0.5	0.1	1.2
CO ₂ (ppm)	462	470	575	531	469.4	350-450	350	450
CO (µg/m ³)	2.4	6	1.1	2.6	7.3	10	1	9
C6H6	21.3	24.7	Na	Na	Na	5	0	5

Source: Author (Green-Lung’s project and doctoral studies)

²² Not to be breached more than 1 day during 3 years

Continuing with physical sources of pollution, the author calculations and estimations based on the public data with regard to the number of private and public cars in Tirana as well as the construction sites (published on a yearly basis by INSTAT²³) these can be classified as follows:

Transport, which is responsible for at least 3,300kton/year of pollution due to:

- The aging private vehicle fleet, which fails to completely burn fuel due to wear and low EURO standards, emitting at least 2,518kton of pollutants into the air annually.
- The old heavy-duty vehicle fleet used in construction, goods transportation, and manufacturing, responsible for at least 489kton of air pollution annually.
- The outdated public service vehicle fleet (waste management trucks, fire engines, ambulances, etc.), accountable for at least 271kton of pollutants released into the air each year.
- The public transport fleet, consisting of 305 buses, which was responsible for releasing at least 22kton of pollutants into the air last year. This is supported by the publication [Decarbonisation of the Public Transport Sector in Tirana](#). Combining these factors with the worsening urban mobility (traffic congestion) and the low quality of traded fuel results in increased and concerning pollution impacting the health of the urban environment and its inhabitants.

Construction is estimated to release around 600kton of pollution annually, mainly in the form of fine particles and dust.

Industrial activity is ranked third, based on the small number of high-capacity industrial units in our country. However, no annual report or source mentions the air emissions from this sector, indicating a lack of monitoring and at least no indicative self-reporting by entities, despite being legally obligated as they are equipped with Environmental Permits.

Residential areas are minimal contributors to focused pollution, especially when using fuels such as gas, wood, coal, or pellets for heating and cooking. The accumulated pollution from all units becomes a significant factor, and in some cases, can be classified as the primary source. This has been particularly evident during the pandemic period in cities like Skopje, Pristina, Belgrade,

²³ <https://www.instat.gov.al/al/temat/mjedisi-dhe-energjia/mjedisi/>

Sarajevo, and to some extent Korçë, where there was a high demand for thermal input as residents were quarantined in their homes.

List of areas in Tirana where pollution may pose a public health risk:

- Technological School Axis – Astir – Customs
- Elbasan Street Intersection
- Economic University Roundabout
- The Block
- Piazza Italia
- 21st December Intersection
- Vasil Shanto Intersection
- Zogu Zi Roundabout
- Kombinat (pollution from organic components like VOCs, Sulfur, etc.)

To my calculations, i estimate that at least 160,000 to 200,000 citizens are at risk given their daily exposure to polluted air.

Figure 30: Collection of photo's showcasing air polltuion in Tirana can be sensed and perceived by all.



Source: Author 2021-2022

Nitrogen Dioxide (NO₂) in Tirana:

Nitrogen dioxide (NO₂) is a significant atmospheric pollutant with substantial impacts on the environment, human health, and physical structures. Understanding NO₂ from chemical, physical, and environmental perspectives provides insight into its effects and the importance of regulating its presence in the atmosphere.

Chemical Properties

Chemical Formula: NO₂

Molecular Weight: 46.01 g/mol

Physical State: At room temperature, NO₂ exists as a reddish-brown gas with a characteristic sharp, acrid odour.

Solubility: It is moderately soluble in water, forming nitric acid (HNO₃) and nitrous acid (HNO₂), contributing to acid rain.

Reactivity: NO₂ is a strong oxidizing agent. It readily reacts with water, other compounds, and materials, leading to various environmental and health effects. It can also act as a precursor to nitrate aerosols, participating in the formation of ground-level ozone.

Physical Properties:

Boiling Point: 21.2°C (70.2°F) at atmospheric pressure.

Melting Point: -11.2°C (11.8°F).

Density: 1.880 g/L at 0°C and 1 atm, indicating it is heavier than air, which can lead to accumulation in lower-lying areas.

Environmental Impact

Atmospheric Formation:

NO₂ is primarily produced from the oxidation of nitric oxide (NO) in the presence of ozone (O₃) and is a significant component of nitrogen oxides (NO_x) emissions. Major sources include combustion processes, such as those occurring in vehicles, power plants, and industrial facilities.

Health Effects:

Exposure to NO₂ can cause respiratory issues, exacerbate asthma, and lead to reduced lung function. Long-term exposure may contribute to the development of cardiovascular diseases and respiratory infections. High concentrations of NO₂ can irritate the eyes, nose, throat, and lungs.

Environmental Effects:

Acid Rain: NO₂ reacts with water vapor in the atmosphere to form nitric acid, contributing to acid rain, which can damage vegetation, aquatic systems, and buildings.

Photochemical Smog: NO₂ plays a crucial role in the formation of ground-level ozone, a key component of photochemical smog, which harms human health, vegetation, and various materials.

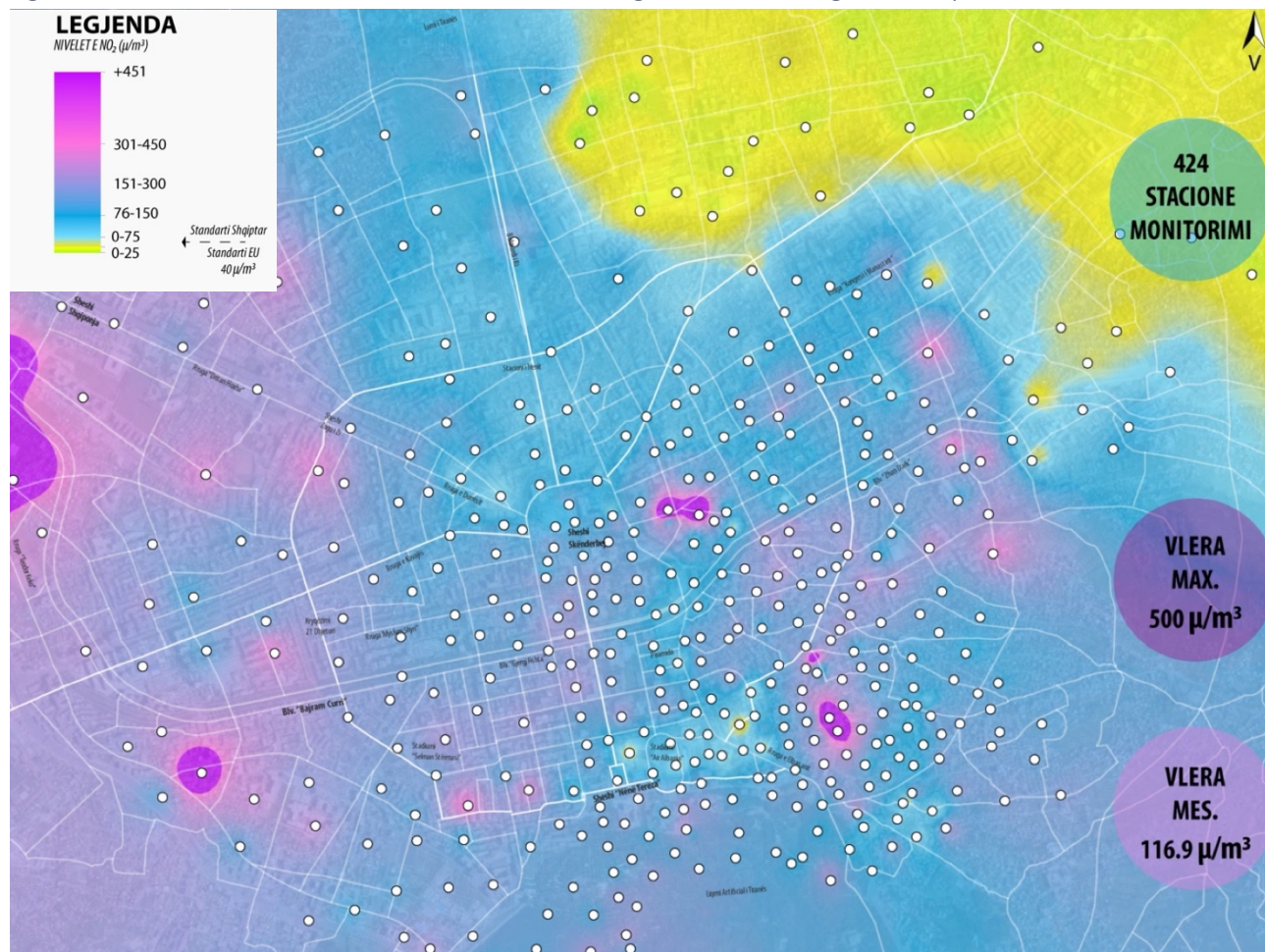
Eutrophication: Nitrogen compounds from NO₂ deposition can lead to nutrient overloading in water bodies, promoting excessive algae growth (eutrophication) that depletes oxygen and harms aquatic life.

Greenhouse Gas: While not a greenhouse gas itself, NO₂ indirectly contributes to global warming by influencing the formation of ozone and other greenhouse gases in the atmosphere.

Impact on Materials:

NO₂ can corrode metals and deteriorate building materials, including stone and paint, due to its oxidative properties and the acidic compounds it forms upon reaction with moisture.

Figure 31: Visualization of NO₂ concentration in Tiran during 2018-2023 through heat-map method.



Source: Author, (Green-Lungs project and doctoral research)

NO₂ concentration was monitored by the author in Tirana from 2018 to 2023 for a total of 424 stations/locations on a bi-monthly sequence, totalling to 10176 monitoring practices.

Thus concluding into the following results:

- a. Average concentration 116,9 µg/m³
- b. EU limit standard exceeded by 3-folds
- c. Maximum values registered 500 µg/m³
- d. 9 permanent hot-spots identified within dense urban areas

Particulate Matter 2.5 (PM_{2.5}) in Tirana:

Particulate Matter 2.5 (PM_{2.5}) refers to atmospheric particulate matter (PM) that has a diameter of less than 2.5 micrometers, which is about 3% the diameter of a human hair. Due to their small size, PM_{2.5} particles can penetrate deep into the human respiratory system and even enter the bloodstream, posing significant health risks.

Chemical Properties

- **Composition:** PM_{2.5} is a complex mixture of tiny particles and liquid droplets made up of a variety of components, including acids (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens (such as fragments of pollen or mold spores).
- **Reactivity:** The chemical composition of PM_{2.5} can vary greatly, depending on location, time of year, and weather conditions, affecting its reactivity and the health impacts it may have. Some components of PM_{2.5}, such as polycyclic aromatic hydrocarbons (PAHs), can be carcinogenic.

Physical Properties

- **Size:** The aerodynamic diameter of PM_{2.5} is less than 2.5 micrometers, allowing it to remain suspended in the air for longer periods and be inhaled more deeply into the lungs.
- **Visibility:** High concentrations of PM_{2.5} can reduce visibility, leading to the phenomenon known as haze, particularly in urban or industrialized areas.

Emission Sources:

- PM_{2.5} is generated from both natural and human-made sources. Natural sources include forest fires and dust storms, while human-made sources encompass emissions from industrial processes, motor vehicles, wood burning, and some agricultural practices.

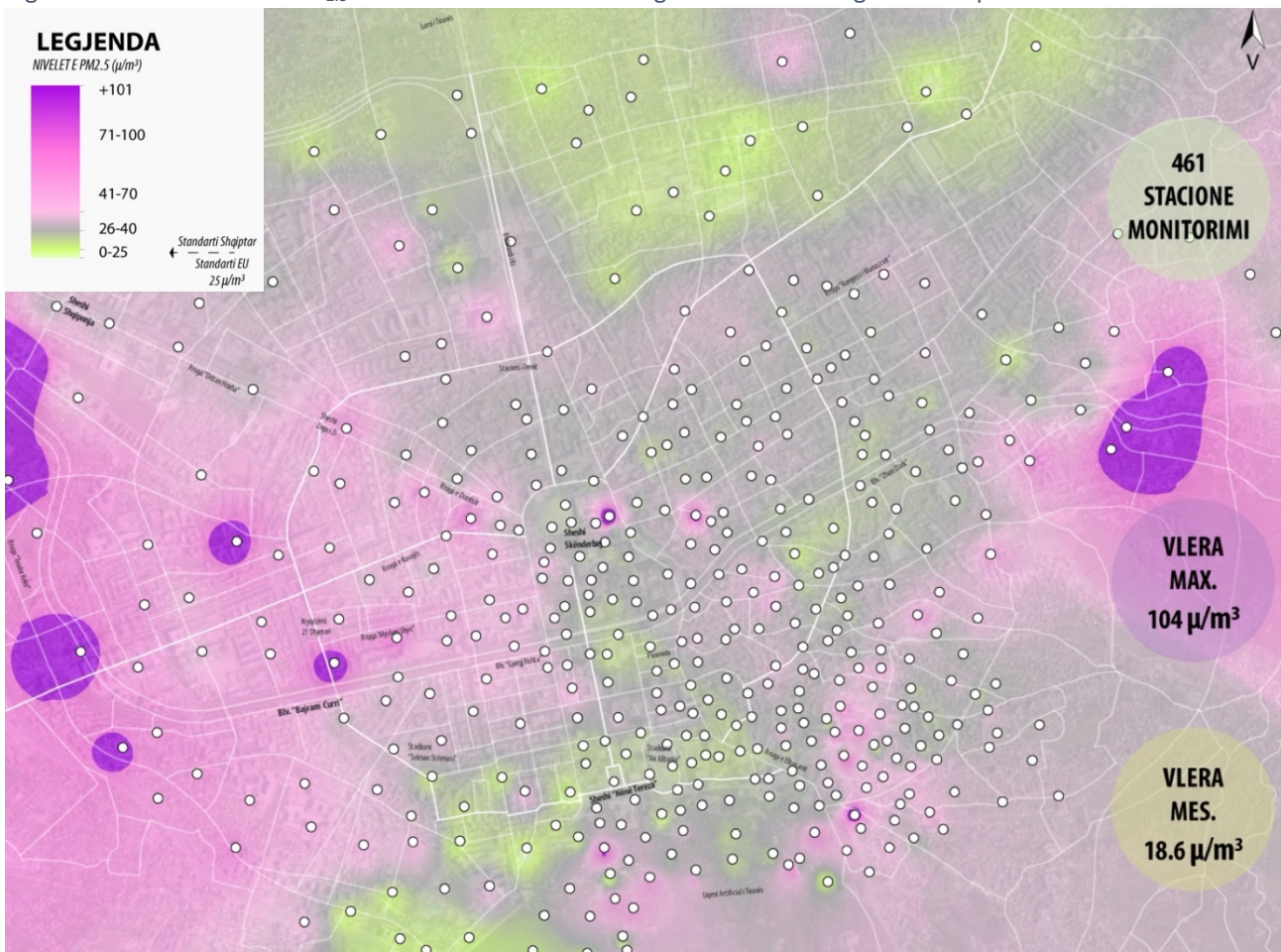
Health Effects:

- Exposure to PM_{2.5} has been linked to numerous health problems, including cardiovascular diseases, respiratory infections, aggravated asthma, and premature death in people with heart or lung diseases. The small size of PM_{2.5} particles allows them to bypass the body's natural defence's, penetrating deep into the lung tissue and even entering the bloodstream.

Environmental Effects:

- **Ecosystem Damage:** PM_{2.5} deposition can affect soil and water quality, altering nutrient balances and harming ecosystems.
- **Impact on Climate:** Certain components of PM_{2.5}, such as black carbon, can absorb sunlight and heat the atmosphere, contributing to climate change. Conversely, other components can reflect sunlight away from the earth, having a cooling effect.

Figure 32: Visualization of PM_{2.5} concentration in Tiran during 2018-2023 through heat-map method



Source: Author, (Green-Lungs project and doctoral research)

PM_{2.5} concentration was monitored by the author in Tirana from 2018 to 2023 for a total of 461 stations/locations on a bi-monthly sequence, totalling to an approximate 11100 monitoring practices.

Thus, concluding into the following results:

- a. Average concentration 18.6 µg/m³
- b. EU limit standard exceeded if the results during COVID-19 are deducted
- c. WHO limit standards exceeded by 4-fold
- d. Maximum values registered 104 µg/m³
- e. 17 permanent hot-spots identified within dense urban areas

Particulate Matter 10 (PM₁₀) Overview

Particulate Matter 10 (PM₁₀) refers to particles with an aerodynamic diameter of 10 micrometres or less. These particles are small enough to be inhaled and can affect the nose, throat, and lungs. PM₁₀ includes a variety of particle types, such as dust, pollen, mold, and metals, which originate from different sources and possess distinct chemical compositions. Understanding PM₁₀ from chemical, physical, and environmental perspectives is essential for assessing its impacts on health and the environment.

Chemical Properties

- **Composition:** PM₁₀ is composed of a diverse mix of substances, including but not limited to organic compounds, metallic elements, soil or dust particles, and biological components such as pollen and spores. The specific chemical makeup of PM₁₀ can vary widely depending on the location, time, and contributing sources.
- **Variability:** The chemical reactivity and potential health effects of PM₁₀ particles can differ significantly based on their chemical composition. Some components of PM₁₀, like heavy metals or carcinogenic organic compounds, can pose severe health risks.

Physical Properties

- **Size:** The defining characteristic of PM₁₀ is its size; these particles have an aerodynamic diameter of 10 micrometres or less, making them inhalable. Their small size allows them to penetrate deeper into the respiratory system but not as deeply as PM_{2.5} particles.

- **Visibility Impact:** High levels of PM₁₀ can reduce visibility, contributing to haze, especially in urban and industrial areas.

Sources:

- PM₁₀ particles arise from both natural and anthropogenic (human-made) sources. Natural sources include wind-blown dust and wildfires, while anthropogenic sources encompass emissions from vehicles, construction sites, agriculture, and industrial processes.

Health Effects:

- Exposure to PM₁₀ can cause adverse health effects, particularly respiratory and cardiovascular problems. These can range from coughing and throat irritation to more severe outcomes like exacerbation of asthma, respiratory infections, and decreased lung function. Long-term exposure may also contribute to heart disease and premature death, especially in individuals with pre-existing health conditions.

Environmental Effects:

- **Ecosystem Damage:** Similar to PM_{2.5}, PM₁₀ can harm ecosystems by affecting soil and water quality, which can disrupt nutrient cycles and harm wildlife.
- **Visibility Reduction:** PM₁₀ particles scatter and absorb sunlight, leading to reduced visibility or haze. This effect is particularly noticeable in urban and industrial regions.

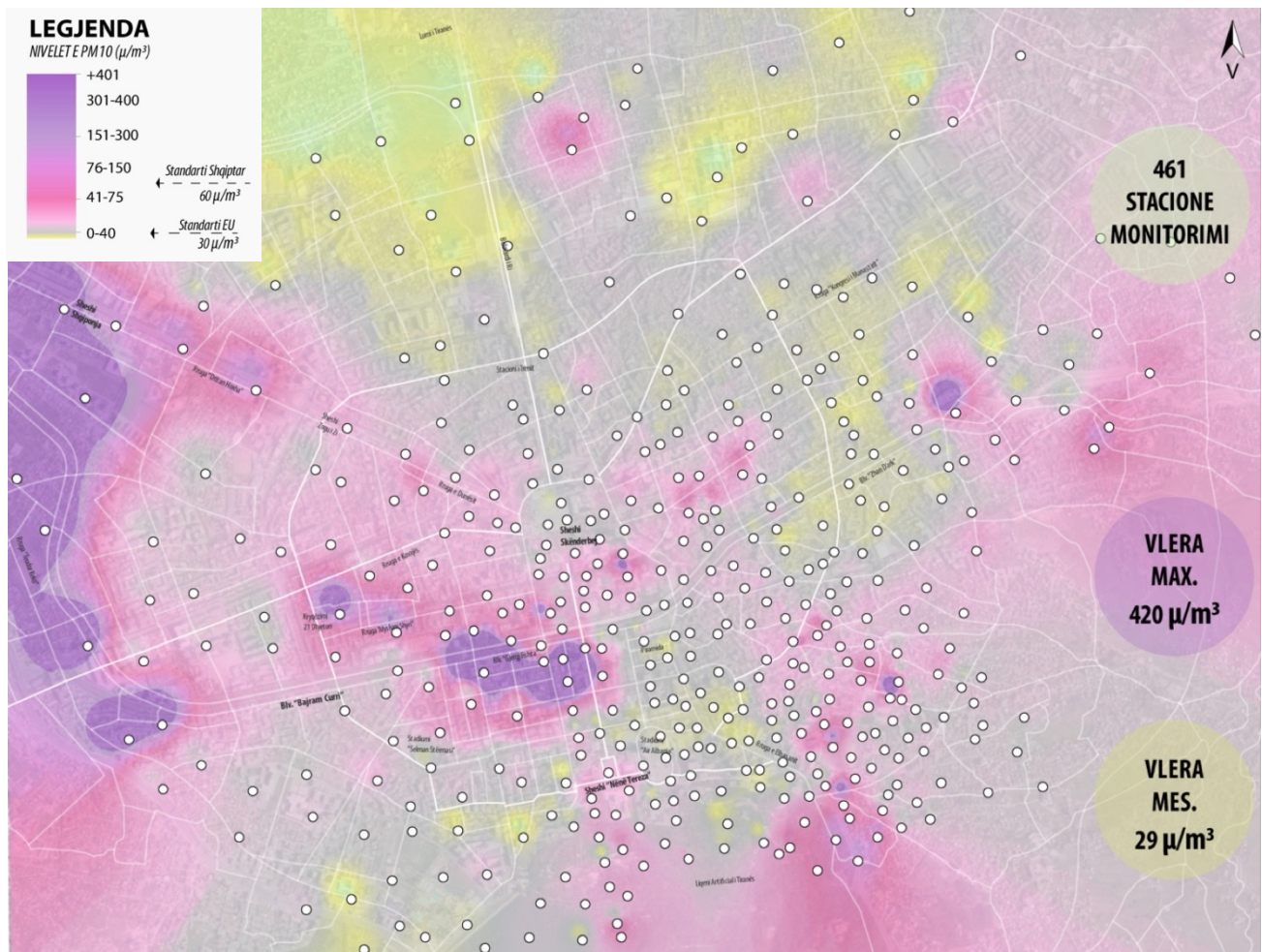
Climate Impact:

- While PM₁₀ does not directly affect climate as much as finer particles like PM_{2.5} or gases like CO₂, its components, such as black carbon, can influence the Earth's energy balance. Moreover, when deposited on snow or ice, darker particles can accelerate melting by increasing solar absorption.

PM_{2.5} concentration was monitored by the author in Tirana from 2018 to 2023 for a total of 461 stations/locations on a bi-monthly sequence, totalling to an approximate 11100 monitoring practices. Thus, concluding into the following results:

- a. Average concentration 18.6 µg/m³
- b. EU limit standard exceeded if the results during COVID-19 are deducted
- c. Maximum values registered 420 µg/m³
- d. 32 permanent hot-spots identified within dense urban areas

Figure 33: Visualization of PM₁₀ concentration in Tiran during 2018-2023 through heat-map method



Source: Author, (Green-Lungs project and doctoral research)

4.4. Methodological Approach of the Empirical Study

Each human breaths an average of 12-24kg of fresh air each day depending on it's age and activity therefore the increasing concentration of air pollutants has become a major environmental issue affecting the whole world, including Albania. This issue is caused by combination of a constant increase in the number of cars, an overall reduction in urban greenery, the combustion of waste, the economic operations of businesses, the use of low-quality gasoline, and other factors. Tirana's particulate matter and nitrogen dioxide particle concentrations surpass both national and World Health Organization guidelines.

There are three key stages on which air pollution cycle is studied:

1. **Emission Phase:** This initial phase pertains to the release process, characterized by several critical parameters, including the nature of the pollutant, the volume released into the

atmosphere, the emission source's height, the temperature of the emitted pollutants, the velocity of the emitted materials, and the emission timeline.

2. **Atmospheric Transportation Phase:** This phase concerns the aerial conveyance of pollutants and represents the most complex stage of the pollution cycle. Here, the potential for physical and chemical transformations, such as photochemical reactions, is significant. The spatial separation between the emission source and the point at which pollutants descend to ground level provides an opportunity to trace their trajectory and assess the absorption rate by the ambient air through which they travel. Meteorological conditions play a crucial role in this stage, as the stratification of air temperature, wind patterns, solar radiation, the presence of additional pollutants, and the configuration of the terrain or built environment dictate the natural dispersion of pollutants.
3. **Final Deposition Phase:** This concluding stage focuses on the ultimate disposition of pollutants, where the local microclimate and prevailing weather conditions, in conjunction with the urban or natural landscape, significantly influence outcomes. Typically, air pollutants remain in proximity to the ground surface, circulating until meteorological phenomena such as rainfall or strong winds facilitate their removal to various receiving environments, which may include terrestrial surfaces, aquatic bodies, vegetation, building exteriors, or indoor spaces.

This research specifically addresses the impact of the built environment on the atmospheric transportation phase of air pollution. The presence of the built environment disrupts the natural dispersion of air pollutants, leading to their accumulation until suitable meteorological conditions allow for their comprehensive removal or final deposition. This analysis highlights the influence of urban form on the dynamics of air pollution, underscoring the interaction between anthropogenic structures and environmental processes in the modulation of pollutant behaviour.

Natural dispersal of air pollutants in urban areas is disrupted by the built environment and eventually until the meteorological conditions are present for a full washout or final disposal of the pollutant either on impervious terrain surfaces, surface waters, greenery or even building facades and indoors, the pollution will circulate in these areas. (Deliu, 2015)

Hereby for the purposes of this research there were selected the three most predominant pollutants in Tirana and also in the eastern Europe (PM_{2.5} particles, PM₁₀ particles and NO₂).

The assessment of wind vortices within the field of fluid dynamics involves a complex interplay of forces and principles. The fundamental equations that govern the behavior of fluids, including wind, are the Navier-Stokes equations, which can be applied to model wind vortex phenomena under specific conditions. However, specific formulas and concepts are particularly relevant for understanding and predicting the formation and characteristics of wind vortices:

Navier-Stokes Equations

The Navier-Stokes equations describe the motion of fluid substances and are central to fluid dynamics. For wind vortices, these equations can be specialized to account for rotating flows and turbulent effects. The equations in their general form are:

$$\rho(\partial\mathbf{v}/\partial t + \mathbf{v} \cdot \nabla\mathbf{v}) = -\nabla p + \mu \nabla^2 \mathbf{v} + \mathbf{f}$$

where:

- ρ is the fluid density,
- \mathbf{v} is the velocity field,
- t is time,
- p is the pressure,
- μ is the dynamic viscosity, and
- \mathbf{f} represents body forces (e.g., gravity).

Circulation and Vorticity

Two key concepts in the study of vortices are circulation (Γ) and vorticity (ω), which describe the rotational properties of a fluid.

- **Circulation** is defined as the line integral of the velocity field around a closed loop, giving a measure of the total "rotation" around the loop:

$$\Gamma = \oint_C \mathbf{v} \cdot d\mathbf{l} = \oint_C \mathbf{v} \cdot d\mathbf{l}$$

- **Vorticity** is a vector field that represents the local spinning motion of the fluid at a point, defined as the curl of the velocity field:

$$\omega = \nabla \times \mathbf{v}$$

For an incompressible fluid, the equation for vorticity dynamics can be derived from the Navier-Stokes equations as:

$$\partial\omega/\partial t + (\mathbf{v} \cdot \nabla)\omega = (\omega \cdot \nabla)\mathbf{v} + \nu \nabla^2 \omega$$

where $\nu = \mu/\rho$ is the kinematic viscosity.

Bernoulli's Equation

In the context of wind vortices, Bernoulli's principle can also be relevant, especially when considering inviscid flow along a streamline:

$$p + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$$

where g is the acceleration due to gravity, and h is the height above a reference point.

For specific cases, like atmospheric vortices (e.g., tornadoes, cyclones), simplified models such as the Rankine vortex model can provide insights. The Rankine vortex combines a solid body rotational flow within a core radius and irrotational flow outside this core.

These equations and concepts form the basis for analyzing and predicting the behaviour of wind vortices. Advanced computational fluid dynamics (CFD) simulations often employ these principles to model the complex dynamics of wind vortices, taking into account the effects of terrain, buildings, and other obstacles on wind flow patterns.

In the context of environmental sciences and meteorology, the cavity region related to the natural dispersal of air and pollutants refers to a localized area where the movement of air and the dispersion of pollutants are significantly influenced by physical barriers, such as buildings, terrain features, or vegetation. These barriers disrupt the prevailing wind flow, creating zones of reduced air movement where pollutants can accumulate, leading to a concentration of contaminants that may exceed levels found in the surrounding environment.

Characteristics and Phenomena in Cavity Regions

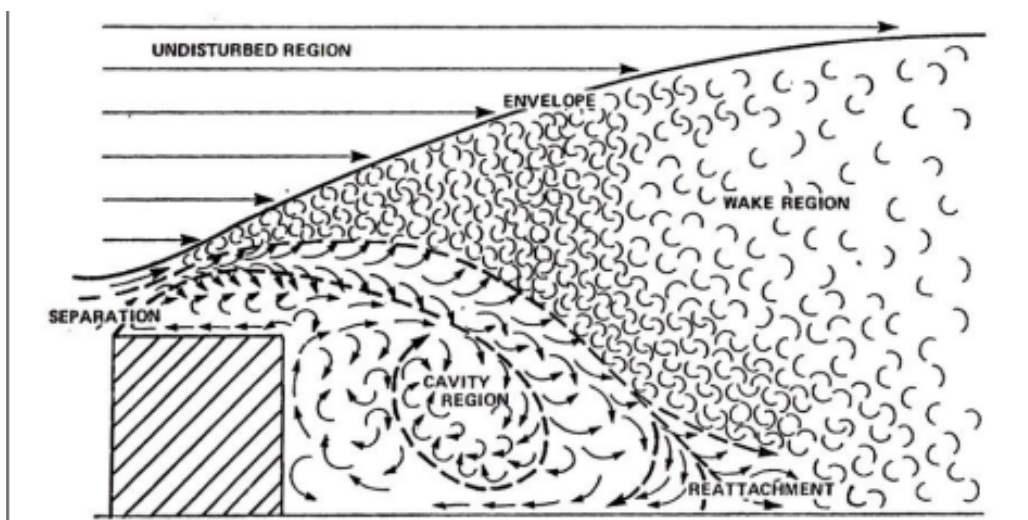
Recirculation Zones: Similar to fluid dynamics principles, recirculation zones occur within these cavity regions, where the air circulates in a vortex-like pattern. This recirculation can trap pollutants, reducing their dispersion and leading to higher concentrations within the cavity region (Blocken, 2013).

Reduced Ventilation: The physical obstructions that create cavity regions also impede the natural ventilation process, limiting the influx of cleaner air and the efflux of polluted air. This reduction in ventilation contributes to the accumulation of pollutants (Tominaga, 2010).

Microclimatic Effects: Cavity regions can exhibit distinct microclimatic conditions, such as variations in temperature, humidity, and wind speed, compared to open areas. These conditions can further affect the chemical reactions of pollutants, potentially leading to the formation of secondary pollutants (Nazarian, 2016).

Health Implications: According to World Health Organization, the publication on *Health effects of particulate matter: Policy implications for countries in eastern Europe, Caucasus and central Asia*. indicates concentration of pollutants in cavity regions poses significant health risks to human populations, especially in urban areas where such regions are common. Increased exposure to pollutants like PM₁₀, PM_{2.5}, NO_x, and O₃ within these zones has been linked to respiratory and cardiovascular diseases.

Figure 34: Visualization of cavity regions created by the disruption of wind flow from a building.



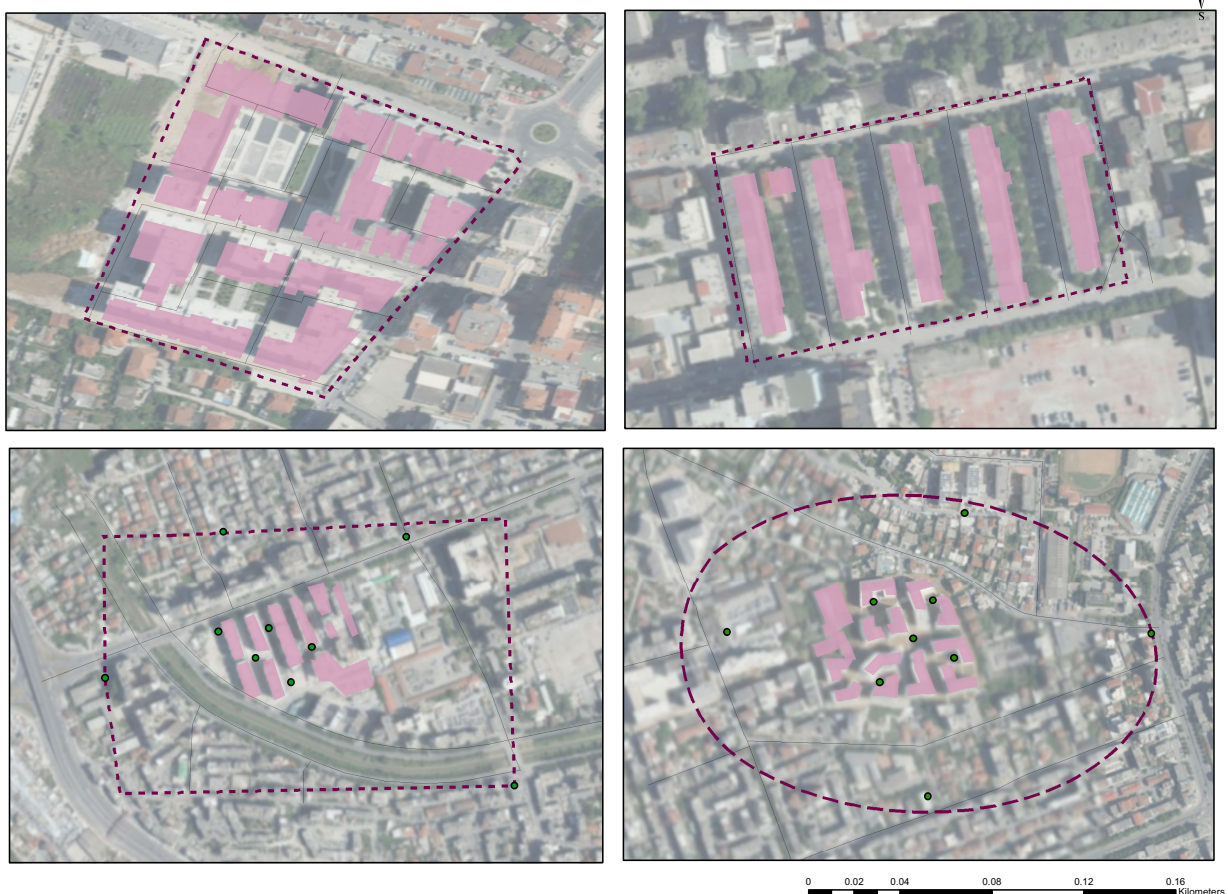
Source: Wikipedia

Nevertheless, this research acknowledges such phenomena by default given the experience and preliminary findings from the authors experience on air monitoring. Hereby the measurements for this study were made in 4 selected areas in Tirana; in the Magnet complex, the Delijorgji complex, the Former Exhibition area and the Kika complex. In the 4 areas under study, 5 focal points were chosen as well as 4 buffer points at a considerable distance from the focal points. In the area, measurements were made for the 3 above-mentioned components.

Given the analysis of urban form and its morphology elaborated at the sub chapter 4.2 of this research, a set of criteria were set prior to selecting the study areas within Tirana.

1. **Urban Forms/Typologies** should be selected based on a **morphological composition**, which reflects similarities of climate and meteorological conditions as well as the property plots
2. **Studying the actual influence of urban form natural dispersal of air pollution**, requires actual monitoring of pollution concentration within the selected areas as well as on a buffer of 250m
3. Zones should have **similar density and performance parameters**: Population density, land use intensity, coverage, height, spaciousness, natural ventilation, green areas. that ensure livability and sustainability
4. **New Residential Blocks** is the applicable typology of urban form for this research discourse given that it is the most prominent typology being applied at a global level.
5. Proximity with pollution sources and orientation to the most prominent wind patterns in the overall scale of the city.

Figure 35: Kika Coplex (upper left) Ish-Ekspozita (upper right) Delijorgji (low left) Kontakt / Ish Partizani (low right)



Source: Author, GIS

Figure 36: Delijorgji Complex 3D perspective

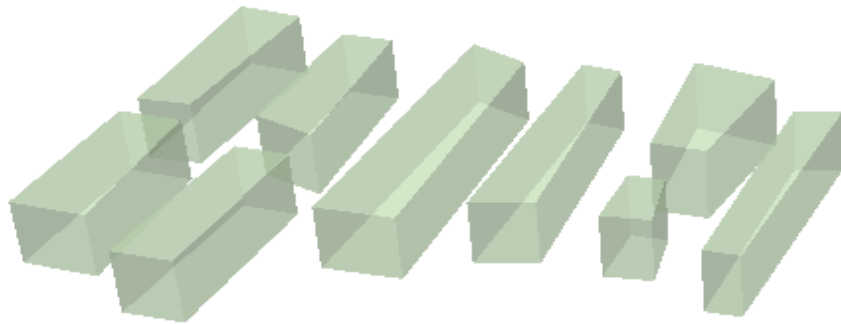
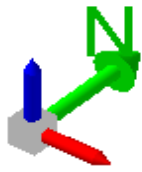


Figure 37: Ish-Ekspozita Complex, 3D Perspective

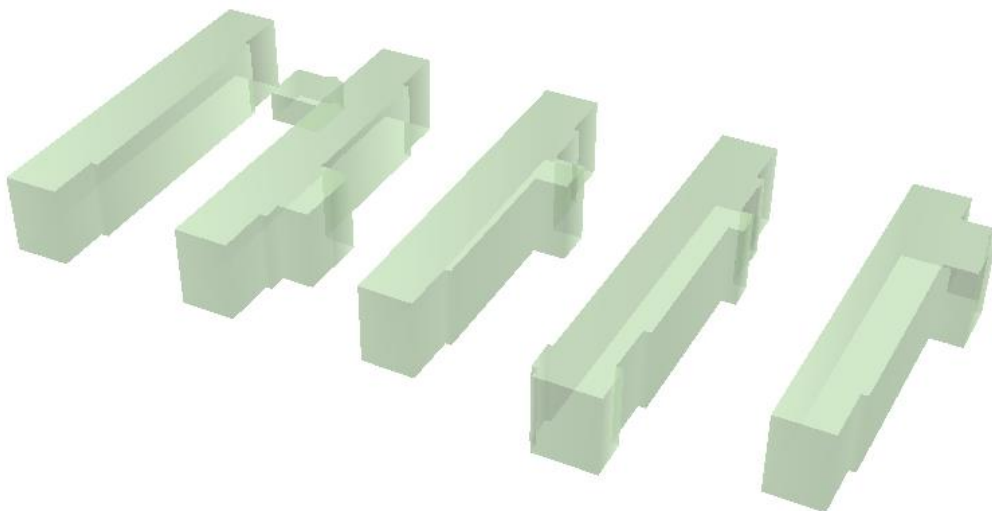
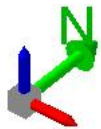


Figure 38: Kontakt / Magnet Complex situated upon ex-Partizani Sport Complex. 3D Perspective

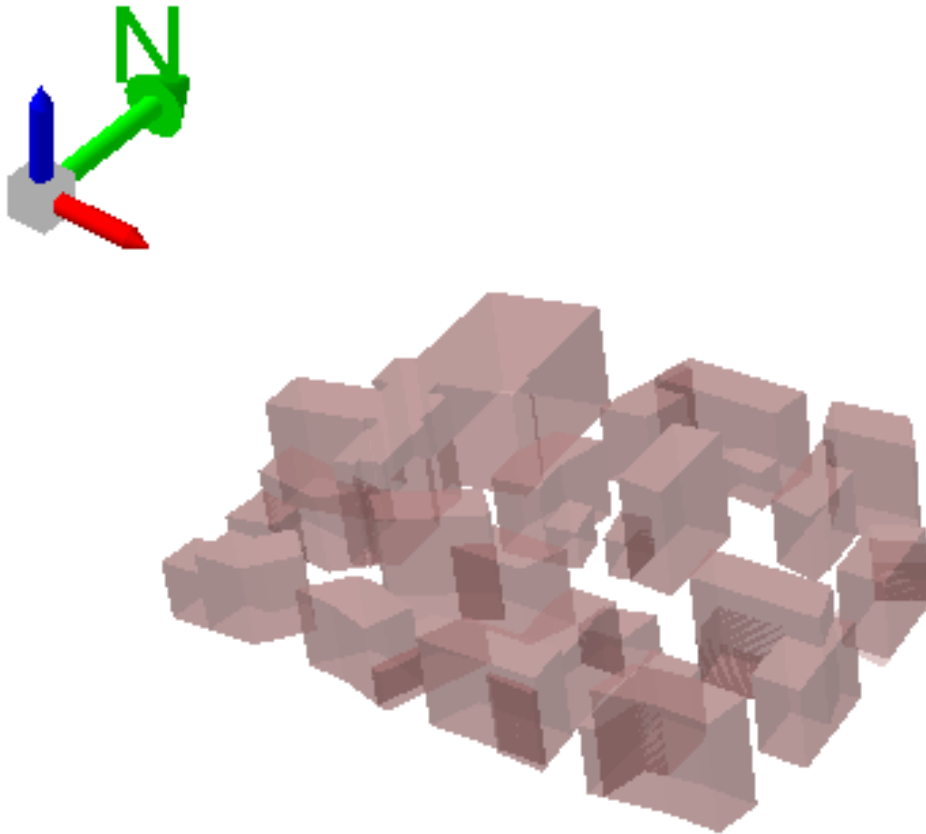
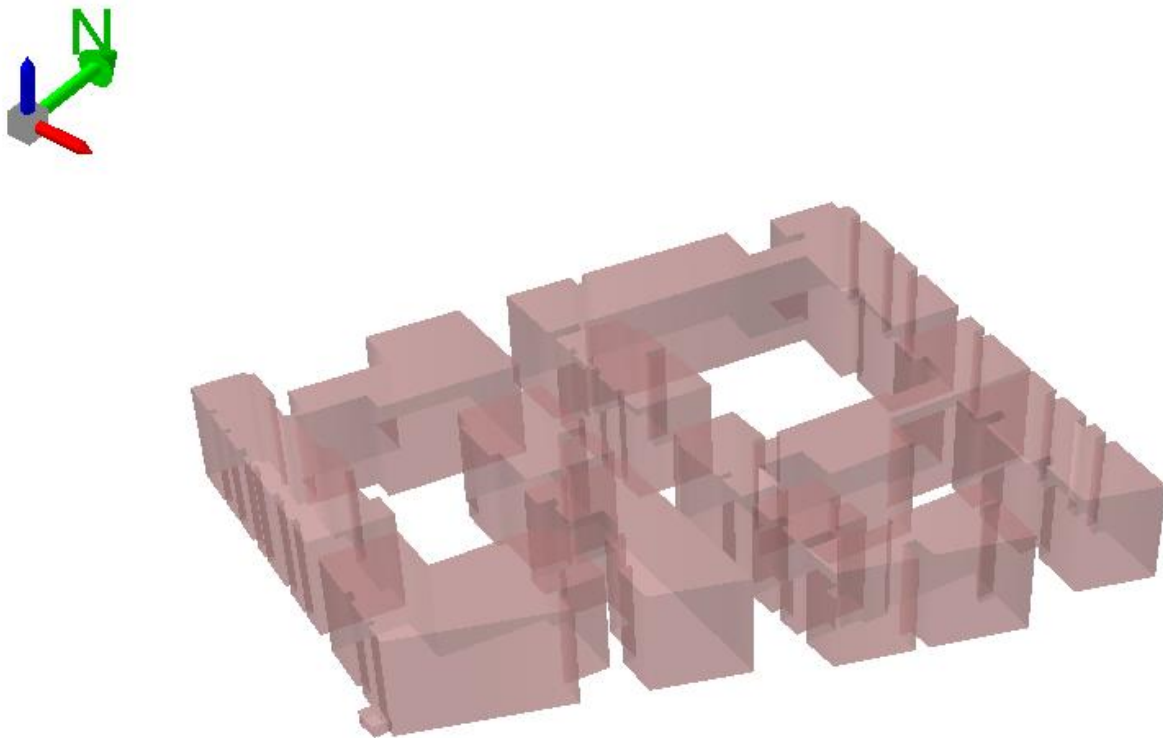


Figure 39: Kika Complex, 3D Perspective.



Source: Author, Autocad

Further a comparative analysis with regard to key urban parameters and indicators, corresponding to the selection criteria number 3 are expressed in the following table.

Table 3: Comparative indicators between the selected areas

Typology	Delijorgji	Magnet	Kika	Ish-Ekspozita
Population Density	High	High	High	Medium
Building Density	High	High	High	Medium
KSHT	45%	45%	45%	45%
Hight (m)	25	26	26	17
Space (ha)	25,07	11,2	3,7	2,6
Transportation Density	High	High	High	High
Function	90% housing	97% Housing	90% housing	94% housing
Approx. Population	15900	12700	5240	2184

Source: Author calculations

In the course of this research, a comprehensive preliminary survey encompassing over 15 distinct location within the cityscape of Tirana was conducted. This meticulous selection process was guided by the set of predefined criteria, with a particular emphasis on the geographical orientation of urban blocks relative to the prevailing wind currents, predominantly from the North-West and East directions. This orientation is pivotal, as it significantly influences the dispersal patterns of airborne pollutants and the formation of microclimatic conditions within urban canyons.

Subsequently, a network of 9 monitoring stations was methodically established within each delineated area of interest. Of these, 5 stations were strategically positioned within the premises of the urban complexes under scrutiny. This placement was deliberately chosen to encompass the perimeter and especially the corners, areas where cavity zones—regions characterized by reduced airflow and potential pollutant accumulation—were visually identified to the preliminary visits.

The remaining 4 stations were allocated to a designated buffer zone surrounding the complexes. These external stations were specifically tasked with monitoring pollution levels emanating from local sources, notably vehicular traffic and ongoing construction activities. The selection and positioning of these monitoring points were informed by their potential to capture a representative sample of pollution levels, thereby facilitating a comprehensive analysis of the spatial distribution of pollutants and their interaction with urban form and atmospheric dynamics.

This systematic approach to site selection and monitoring station placement underscores the critical importance of understanding urban airflow patterns and pollutant dispersion mechanisms.

By incorporating considerations of wind directionality and urban morphology, this study aim to elucidate the complex interplay between built environments and air quality can be more accurate when monitoring results are analysed.

Figure 40: Monitoring stations in each of the study areas.



1 centimeter = 0.06 kilometers

Source: Author elaboration on GIS

The principal objective of this specific monitoring endeavour was to develop a comprehensive database that encapsulates the concentrations of selected pollutants and prevailing meteorological conditions such as **wash-out effect** from rain, storms, wind-speed and direction. This database is instrumental in discerning whether the strategically chosen monitoring stations, situated proximal to the enclosed corners of the buildings, are subjected to pollutant retention attributable to the wind vortex phenomenon, and if so, to ascertain the extent of such impact. Additionally, this repository serves a secondary purpose of enabling the precise determination of the correlation coefficient between wind velocity and the dispersion of pollutants within these locales, thereby laying the groundwork for a subsequent comparative analysis across the various sites under investigation.

Whereas to the commonly referred correlation coefficient, a statistical measure that quantifies the degree to which two variables are related. I will refer to the correlation coefficient of Pearson's

(denoted as r), which assesses the linear relationship between two continuous variables. It provides insights into both the strength and direction of the relationship, with values ranging from -1 to +1. A value of +1 indicates a perfect positive linear relationship, -1 indicates a perfect negative linear relationship, and 0 indicates no linear relationship.

The formula for Pearson's correlation coefficient is:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}$$

where:

- X_i and Y_i are the individual sample points indexed with i ,
- \bar{X} and \bar{Y} are the means of the XX and YY variables, respectively.

In the context of environmental science and particularly in studies assessing air pollution, the correlation factor can be utilized to examine the relationship between meteorological conditions (like wind speed) and pollution dispersal or concentration levels. By analysing the correlation factor, researchers can identify how changes in wind speed may influence the distribution of pollutants in an area, which is crucial for predicting pollution patterns and implementing effective control measures.

The duration of the monitoring initiative spanned three months, during which data collection was systematically executed on a daily basis across all designated areas. This rigorous approach ensures the acquisition of a robust dataset, facilitating a nuanced understanding of the intricate relationship between urban air flow dynamics and pollutant distribution patterns. The insights gleaned from this study are expected to contribute significantly to the body of knowledge on urban pollution dynamics, offering valuable implications for urban design and public health policy.

4.5. Data Collection Methods:

Monitoring sessions were systematically executed across each designated site, with each session spanning approximately two hours and encompassing all nine monitoring stations for the trio of pollutants under scrutiny. Initiating on the morning of January 1st, this strategic commencement enabled the capture of data reflective of the heightened pollution levels attributable to nocturnal New Year's Eve celebrations, characterized by extensive fireworks displays. These sessions were diligently maintained on a daily basis, inclusive of weekends, through to March 31st, 2023.

Throughout the first trimester of 2023, across all 36 monitoring stations (comprising five within each research domain plus four proximal to the nearest source of emissions), a cumulative total exceeding 770 hours of monitoring was recorded. This extensive effort yielded a comprehensive dataset encapsulating 3240 distinct monitoring practices, each yielding specific observations. Initial recordings were meticulously documented on site-specific monitoring logs, subsequently transcribed into a digital format within an Excel database, and ultimately integrated into a Geographic Information System (GIS) for advanced spatial analysis and archiving purposes.

4.5.1. Air Quality Monitoring

In an academic context, the methodology for the selection of sampling locations reflects a strategic approach to optimize the accuracy and representativeness of the selected pollutant measurements. The optimal elevation for sample collection should be situated between 1.5 meters above ground level, approximating the average human respiratory height.

For all pollutants under consideration, sampling devices within traffic-influenced zones are to be positioned at a minimum distance of 10-20 meters from major intersections to mitigate the impact of direct emissions and ensure that measurements reflect ambient air quality rather than localized spikes in pollutant concentrations. Additionally, these devices should not exceed 5 meters from the edge of the pavement to maintain relevance to human exposure scenarios.

Monitoring locations, as prescribed earlier were selected with the clear intention of capturing the influence of micro-climate patterns and the effect of build environment on the natural dispersal of pollutants in the air. The selected urban morphologies designated for this research monitoring are selected in such a manner that pollution levels are influenced by the aggregated contributions of all sources positioned upwind and/or east relative to the monitoring station, ensuring a comprehensive assessment of air quality.

The research's methodology encompasses the measurement of selected pollutants through a three-phased approach, as detailed in the subsequent table.

First stage (Preparation):

- Setting up the monitoring equipment toolbox (comprising the charged headset, pollutant sensors, charged phone for photos, monitoring sheets, pens/pencils, appropriate dressing)
- Defining the monitoring routine from the first five stations within the selected blocks to the 4 buffer monitoring points.

Second Stage (Execution):

- Conducting the monitoring practices throughout a 10-hour shift per day, monitoring at least 10-15 minutes per each station, screenshotting all 3 pollutants and meteorological patterns.
- Extracting the average concentration of pollutants from the device as well as the meteorological information.
- Further compiling the site monitoring sheet and concluding with a double check on the registered figures prior to signing the sheet.

Third Stage (Analysing):

- Digitalizing the recorded data from the monitoring sheet to the excel database
- Controlling the validity of the information between the equipment log and monitoring sheet prior to deleting and calibrating devices for next day monitoring practice
- Digitalizing recorded data into GIS platform
- Analysing all the meteorological and pollution data to provide further conclusion upon the argument of air pollution cavity areas.

For the quantification of atmospheric pollutants, an advanced sensor-based instrument, referred to as "Aeroqual," was employed. This device is distinguished by its capacity to aggregate real-time data regarding the ambient air quality. Its design embodies a versatile solution to air quality monitoring, accommodating up to 27 distinct gas sensors and particulate matter sensors. This modular configuration enables a broad spectrum of applications, ranging from environmental monitoring to specific pollutant detection, thereby facilitating a comprehensive assessment of air quality parameters.

The utilization of "Aeroqual Series 500 and Aeroqual Ranger²⁴" originally manufactured and imported from New Zealand, underscores a methodological advancement in environmental science, particularly in the field of air quality monitoring. The device's ability to be tailored with a diverse array of sensors permits the detailed examination of a wide range of air pollutants, including but not limited to volatile organic compounds (VOCs), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and

²⁴ <https://www.aeroqual.com/products/ranger-portable-air-monitor/ranger-portable-air-quality-monitor>

particulate matter (PM₁₀ and PM_{2.5}). This adaptability not only enhances the precision of pollutant measurement but also provides invaluable insights into the temporal and spatial variability of air quality.

Usage of such technology into air quality monitoring endeavours represents a significant stride towards achieving a nuanced understanding of atmospheric conditions given that the headset is quite portable and handy to be used at different locations and conditions.

Figure 41: Illustrative picture of the devices used by the author for this doctoral empirical research.



Source: aeroqual web page

The undertaking of air pollutant measurement necessitates the implementation of a sensor-based device known as "Aeroqual." This apparatus is engineered to collect ambient air data in real-time, offering a flexible air quality monitoring solution that can be tailored with up to 27 different gas and particulate matter sensors to accommodate a diverse range of environmental monitoring applications.

The execution phase of monitoring activities is set to occur each day starting from 7:00am until the last buffer monitoring point of the last monitoring areas is finished, tentatively each daily practice is set to be concluded between 18:30-19:00pm. Monitoring will represent a screenshot of the momentum urban dynamic and daily weather conditions, with wind speeds ranging from 0-25km/s. In instances of pronounced discharges at the monitoring point, it is reflected that the monitoring

location and the resultant data to be accompanied by a detailed explanation of the encountered situation.

All instruments are properly calibrated and with dated certificates of calibration from the suppliers. For measurements to be deemed valid, calibration levels both before and after air pollution level measurement are essential. For this purpose, a double check is made once per week between both aeroqual equipment's if they indicate the same results as well as among them and the IQ Air sensors that author have installed for other project research purposes in different locations in Tirana.



During the implementation of such alternative monitoring within the selected urban zones, the following monitoring criteria should be applied:

1. When monitoring urban air quality, due to pollution emanating from multiple directions, selecting a position that offers the best possible values and optimal coverage while avoiding physical obstructions in the area is crucial.
2. Air quality measurement devices will be continuously overseen during the monitoring period, with notes taken on the date, time, and prevailing atmospheric conditions, as noise measurements should not be conducted in fog and rain.
3. Immediately before and after each air quality measurement session, the accuracy of the device must be checked and approved by the supervisor (a member of the project team).

4. Measurements are recorded on the device as measured values at the exact point, then referenced on the physical map which the monitor carries during field visits, and finally, data is recorded on the daily monitoring protocol sheet.
5. From the data generated during monitoring, digitization in Excel and GIS is carried out the following day to be submitted within the agreed deadlines to the project group, thereby finalizing the monitoring process for that area.

Data recording will be conducted as follows:

- I. The date, time, location, and duration of the monitoring will be recorded,
- II. All predominant sources of atmospheric pollution, which may include emissions from mobility activity, construction, private business, etc., will be highlighted,
- III. Weather conditions will be recorded, including wind speed and approximate direction, cloud cover, rain, snow and/or ground frost.

4.5.2. Meteorological Data Collection

The methodology for the acquisition of meteorological data is methodically structured and executed with precision. Initially, the deployment of the "Testo 405-V-1," a device renowned for its accuracy in wind speed measurement, was programmed. Concurrently, temperature and humidity parameters were meticulously assessed using a thermos-hygrometer, specifically the "Testo 808-H1" model. Furthermore, to ascertain wind direction, a bespoke wind vane was crafted and affixed atop a 2-meter wooden pole, strategically positioned at the monitoring site for the entirety of the observational period.

This comprehensive monitoring initiative encompassed a total of 36 stations—five within each designated research area plus an additional four stations proximal to the nearest source of emissions. This extensive network facilitated the compilation of over 730 hours of meteorological observations, culminating in a total of 3240 discrete monitoring events. The systematic approach to data collection, spanning a diverse array of meteorological variables, underpins the rigor and depth of the environmental analysis conducted.

Figure 42: Illustrative picture of the devices used by the author for this doctoral empirical research.



Source: Testo web-page

The methodology for monitoring meteorological conditions is designed to systematically capture and analyse data pertaining to various atmospheric parameters. This rigorous approach is essential for understanding weather patterns and its impact on the dispersal of air pollution on the selected monitoring sports.

To be noted is that fact that one of the primary objectives of this methodology is to establish a standardized procedure for the accurate measurement and analysis of meteorological conditions, including temperature, humidity, wind speed and direction.

Data Collection Protocol

- **Frequency:** The execution phase of monitoring activities is set to occur each day starting from 7:00am until the last buffer monitoring point of the last monitoring areas is finished, tentatively each daily practice is set to be concluded between 18:30-19:00pm. Each day from 1st January to 31st March 2023
- **Quality Control:** Weekly checks to identify and correct data anomalies or instrument malfunctions in real-time combined with official publication of weekly weather report from Institute of Geo-Sciences of Albania²⁵ and credible regional Weather Channels.

²⁵ https://www.geo.edu.al/MonitoringForecast/Hydrologic_Meteorological_Forecast/

Data Management and Analysis

- **Data Storage:** All monitored data will be initially recorded in the site monitoring sheet. Further on digitalized in the centralized database together with air quality data.
- Regular backups were conducted to prevent data loss.

4.6. Digitalization and GIS

One of the pivotal outcomes of my academic research within the environmental sciences domain is the usage of a Geographic Information Systems (GIS) platform, to further facilitate an visual representation of collected data in the form of detailed and re-occurring pollution concentration heat-maps. The integration of this technology is acknowledged as one of the most precise methods for accurately depicting the terrain and the various phenomena occurring within it.

The data to be visualized on the GIS platform will be derived from comprehensive field monitoring activities, encompassing noise pollution, air quality, and urban greenery initially across three municipalities, with subsequent expansion to encompass the entire territory. Collected data in the initial phase will be presented in Excel formats, and in the subsequent phase, it will be transformed into GIS-compatible data.

The purpose of displaying data within a GIS framework is to digitalize the information gathered from field observations, facilitating its analysis, processing, and presentation as cartographic products. This is aimed at depicting noise levels, air pollution, and urban greenery within the studied areas, with the objective of highlighting the environmental conditions prevalent in our living spaces.

The utilization of GIS technology commences with the identification and collection of field data, for which a pre-established strategy for data accumulation and preliminary processing is essential prior to integration into a unified database. It is imperative that the data adhere to a consistent coordinate system to ensure spatial accuracy and comparability.

All the digitalized information shall be reflected on the same coordinative system: **WGS 1984 UTM Zone 34N**.

The foundational components of GIS include:

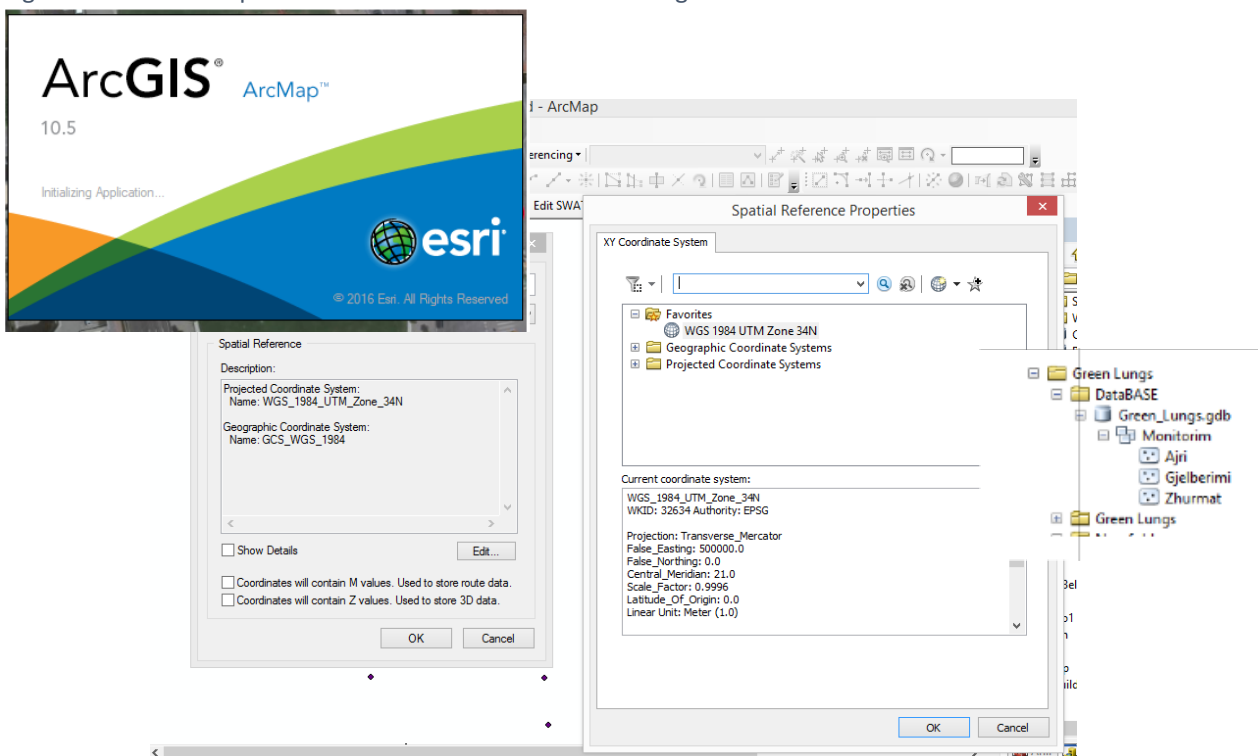
- **Hardware:** This encompasses the computer equipment on which the GIS software package will be installed, providing the necessary computational capacity for data processing and visualization.
- **Software:** This component consists of the specific programs utilized for the collection, analysis, and graphical presentation of defined attributes related to air quality. The most commonly employed GIS software is ESRI's ArcGIS, which includes tools such as ArcMap, ArcCatalog, ArcScene, and ArcGlobe. For this project, ArcGIS version 10.5 will be utilized, offering capabilities for integrating the Albania 2015 or 2019 orthophoto.
- **Data:** This refers to all the information collected from fieldwork, serving as the foundation for the functionality and application of ArcGIS.
- **People:** This component acknowledges all GIS users, ranging from the technical specialists responsible for designing and maintaining the system to those utilizing GIS for daily operational tasks.

GIS is adept at integrating diverse datasets to address or illustrate a problem within a spatial context and to analyze events or situations. The monitoring data undergoes several phases from collection to its final presentation on an online platform:

1. **Pre-Fieldwork Preparation:** The most critical phase following the selection of monitoring locations consists on actual georeferencing these location in all 4 areas. Further the excel database is set with relevant fields for the information of interest and ease of transposition into GIS.
2. **Field Monitoring Planning:** All the monitoring zones are outlined using ArcMap or Google Maps, and these maps are printed as essential materials for the ease of work during scheduled monitoring practices. These along with research branded apparel, folders, pens, Excel tables, measuring devices, cameras/drone (for photographing various problematic situations), maps, etc.
3. **Data Collection and Documentation:** The third phase involves the actual collection of information in the field, the completion of the monitoring sheets and further the Excel tables, and the taking of relevant notes during monitoring.
4. This phase concludes the field monitoring activities and initiates the digitization of collected data into Excel spreadsheets or directly into ArcMap. The choice of digital format for data presentation is contingent upon the proficiency of the working groups with the respective

software tools. It is imperative that all data be consolidated within a unified database, utilizing the WGS 1984 UTM Zone 34N coordinate system. To this end, following the determination of parameters to be collected for the three monitoring aspects, a Geodatabase (.gdb) has been constructed within GIS. This Geodatabase encompasses all the monitored elements, each associated with an Excel-defined attribute table. The representation of air quality within GIS will adopt a point format, with wind speed points representing individual monitoring sections.

Figure 43: Detailed explanation of the data and attributes integration in GIS



Source: Author screenshot on GIS

The penultimate phase, following the completion of attribute data for each monitoring aspect, pertains to the final product: **Heat-Maps Cartographic** representation stands as one of the primary outputs of the entire process, offering the most comprehensive visual depiction of air quality and pollutant concentration, inclusive of all pertinent information.

The maps are thematic, varying according to the monitored parameters and corresponding calculations, thereby providing an insightful visual analysis of the environmental conditions assessed during the monitoring period.

Figure 44: Sample of an Heat-Map indicating noise pollution in Tirana



Source: Author

The culminating phase in the process of data presentation within a Geographic Information System (GIS) entails the transformation of data into a format amenable to comprehensive display across an online platform. Data housed within the Geodatabase will be converted into the *.json format*, a specification designated by the web developers for the monitoring platform's interface.

As previously noted, digital data may be inputted either through Excel or directly within a GIS environment. The procedure for populating tables in ArcMap is somewhat more intricate and is delineated below in several key steps.


1. Initiating the ArcMap 10.5 workspace.
2. Integrating the 2015 or 2019 Orthophoto as a base map within the workspace entails the following sequence: navigating to 'Add Data' – selecting 'GIS Server' – opting for 'Add WMTS Server' – and subsequently entering the URL copied from the ASIG webpage. Detailed guidance on incorporating the orthophoto into ArcMap can be found at the following link: <https://geoportal.asig.gov.al/sq/node/224>.

This procedure delineates the initial steps for configuring the ArcMap environment for spatial analysis, emphasizing the integration of high-resolution aerial imagery to serve as a foundational layer for subsequent geographic data overlays and analyses.

3. Locating the folder containing the Geodatabase through the following navigational pathway: selecting 'Windows' in ArcMap, proceeding to 'ArcCatalog', and then executing 'Connect to Folder...' to establish a link to the desired directory.
4. Displaying the monitored elements within the 'Table of Contents' dialog window in ArcMap, ensuring that all relevant geographic and attribute data are accessible for analysis and visualization
5. Editing data for air quality involves initiating the editing session within ArcMap by selecting 'Editor' followed by 'Start Editing'. Subsequently, one selects the feature to be edited from the 'Create Feature' dialog window. The precise location of the monitoring activity, as documented on the field maps, is marked by placing a point on the map. This is followed by the comprehensive filling of the attribute table with relevant information. This is accomplished by right-clicking on the edited point, selecting 'Attribute', then 'Attribute Table', and concluding with 'Save Edits'. This procedure is systematically repeated for the entry and editing of data pertaining to all monitored elements.


These sequences outline the methodical approach to accessing and organizing the Geodatabase within ArcMap, facilitating the efficient visualization and analysis of environmental monitoring data in a GIS context.

Figure 45: Samples of site-monitoring sheets, filled with results of monitoring practices



Università degli Studi di Ferrara

AIR POLLUTION SITE-MONITORING SHEET




MARS

Research activity on "Air Pollution Cavity Areas APCA"
Urban form impact on ambient air pollution dispersal through the wind vortex effect.


Study Area: Rob-Ekopsite Address: Bule Bulçorum, Cene Tirana - Albania

Date: <u>01/03/2023</u>					Monitoring Duration: <u>17:02-19:00</u>				
Air monitoring sensor: <u>Aero Qual 5500 (PM+PO₂)</u>					Climate Monitoring Equipment: <u>Testo 405</u>				
Weather Conditions: Clear Sky / Clouds / <u>(Rain)</u>					Wind (m/s): <u>2.6 km/h</u>				
Relative Humidity(%): <u>31</u>					Wind (direction): N W S <u>(E)</u> / NW SW SE NE				
Ambient Air Quality Monitoring Results (average concentration) µg/m ³									
Pollutant	Monitoring Point 1	Monitoring Point 2	Monitoring Point 3	Monitoring Point 4	Monitoring Point 5	Buffer Monitoring Point 1	Buffer Monitoring Point 2	Buffer Monitoring Point 3	Buffer Monitoring Point 4
NO ₂	24	26	27	25	26	32	23	27	31
PM ₁₀	4	8	9	7	10	12	11	10	11
PM _{2.5}	4	4	5	4	6	9	5	5	10
Accepted by: <u>Rodion Gjoka</u>					Monitored by: <u>Hajdi Dura</u>				



Università degli Studi di Ferrara

AIR POLLUTION SITE-MONITORING SHEET



Research activity on "Air Pollution Cavity Areas APCA"
Urban form impact on ambient air pollution dispersal through the wind vortex effect.

Study Area: Këta Address: Komuna e Qendër Tirana - Albania

Date: <u>31/01/2023</u>					Monitoring Duration: <u>13:30-16:00</u>				
Air monitoring sensor: <u>Aero Qual 5500 (PM+NO₂)</u>					Climate Monitoring Equipment: <u>Testo 405</u>				
Weather Conditions: <u>(Clear Sky)</u> / Clouds / Rain					Wind (m/s): <u>12.4 km/h</u>				
Relative Humidity(%): <u>56</u>					Wind (direction): <u>(N)</u> W S E / NW SW SE NE				
Ambient Air Quality Monitoring Results (average concentration) µg/m ³									
Pollutant	Monitoring Point 1	Monitoring Point 2	Monitoring Point 3	Monitoring Point 4	Monitoring Point 5	Buffer Monitoring Point 1	Buffer Monitoring Point 2	Buffer Monitoring Point 3	Buffer Monitoring Point 4
NO ₂	78	63	73	69	72	73	71	80	94
PM ₁₀	37	25	31	22	25	23	27	28	51
PM _{2.5}	23	14	20	17	15	23	23	23	33
Accepted by: <u>Rodion Gjoka</u>					Monitored by: <u>Hajdi Dura</u>				

Figure 46: Sample of excel sheet used for the digitalization of the monitoring sheets and further GIS digitalization

Air pollution daily averages during February 2023 / Delijorgji Complex 5 Monitoring Points																
Date	MP1	MP2	MP3	MP4	MP5	w	s	e	n	Avg. NO2 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring length	Daytime
1	155	156	149	156	160	168	172	158	144	155	2.4	E	77%	Sunny	2hrs	7.30-9.30
2	129	130	128	137	143	145	148	154	121	134	4.48	E	57%	Sunny	2hrs	7.30-9.30
3	150	152	156	166	171	189	185	193	147	159	3.04	E	72%	Sunny	2hrs	7.30-9.30
4	166	161	158	166	170	202	224	189	152	164	2.4	E	79%	Cloudy	2hrs	7.30-9.30
5	169	164	159	181	185	217	224	208	150	172	2.72	SE	85%	Sunny	2hrs	7.30-9.30
6	125	124	128	143	142	165	158	155	120	132	3.52	E	93%	Sunny	2hrs	7.30-9.30
7	117	119	126	136	135	151	149	142	114	127	3.2	NE	50%	Sunny	2hrs	7.30-9.30
8	88	93	97	110	117	120	109	105	78	101	4.96	E	43%	Sunny	2hrs	7.30-9.30
9	65	70	67	86	91	99	87	89	63	76	9.76	SE	91%	Sunny	2hrs	7.30-9.30
10	43	48	46	51	50	63	67	66	39	48	9.12	SE	88%	Cloudy	2hrs	7.30-9.30
11	51	56	50	67	73	88	81	77	49	59	4.16	E	77%	Cloudy	2hrs	7.30-9.30
12	70	69	73	85	92	93	95	96	71	78	3.36	NW	77%	Cloudy	2hrs	7.30-9.30
13	88	79	78	77	89	99	86	83	65	82	3.04	W	66%	Sunny	2hrs	7.30-9.30
14	67	64	57	72	77	87	88	87	53	67	4.8	NW	75%	Sunny	2hrs	7.30-9.30
15	64	61	52	58	57	78	74	79	41	58	4.48	W	81%	Sunny	2hrs	7.30-9.30
16	39	37	33	46	51	66	71	73	36	41	14.08	SE	64%	Cloudy	2hrs	7.30-9.30
17	27	22	19	28	28	31	32	31	19	25	17.6	SE	87%	Rainy	2hrs	7.30-9.30
18	21	19	17	19	19	21	25	20	17	21	18.08	SE	86%	Storm	2hrs	7.30-9.30
19	17	16	17	12	18	21	20	19	9	16	15.2	SE	92%	Rainy	2hrs	7.30-9.30
20	18	14	19	20	22	31	28	33	12	19	10.56	SE	90%	Rainy	2hrs	7.30-9.30
21	13	11	9	11	15	17	19	21	7	12	21.12	SE	71%	Rainy	2hrs	7.30-9.30
22	38	33	28	39	44	48	48	47	21	36	7.2	NW	77%	Cloudy	2hrs	7.30-9.30
23	34	31	31	34	35	46	41	47	27	33	7.52	SW	93%	Rainy	2hrs	7.30-9.30
24	54	55	59	71	73	76	75	77	39	62	2.56	E	89%	Sunny	2hrs	7.30-9.30
25	29	24	27	33	43	51	57	52	23	31	9.44	NW	77%	Cloudy	2hrs	7.30-9.30
26	44	49	55	67	68	84	79	88	37	59	9.92	E	66%	Cloudy	2hrs	7.30-9.30
27	66	69	71	81	82	94	99	101	57	74	2.72	NW	83%	Cloudy	2hrs	7.30-9.30
28	78	83	87	105	99	105	117	108	66	90	3.36	NW	73%	Sunny	2hrs	7.30-9.30
29	72	74	77	88	93	107	106	110	57	81	5.28	NW	79%	Sunny	2hrs	7.30-9.31
30	84	88	87	107	114	121	124	134	73	104	2.56	NW	58%	Sunny	2hrs	7.30-9.32
31	89	92	90	111	117	114	105	109	78	100	5.12	N	78%	Sunny	2hrs	7.30-9.33
TOT	73.2	73	72.5	82.6	86.3					77.9						

Source: Author

4.7. Air Quality Regulatory Framework

Albania has established a comprehensive legal and regulatory framework for air quality management, including the Law on the Protection of Ambient Air Quality No. 162/2014, which outlines the responsibilities of competent authorities and measures for reducing air pollution and developing air quality plans. Additionally, Albania has a National Strategy on Ambient Air Quality (DCM No. 594 from 2014) and approved a National Action Plan for Ambient Air Quality Management in June 2019, focusing on measures to reduce transport air pollution.

Nevertheless, none of the policy actions undertaken have been reflected into concrete measures and actions to mitigate or even prevent air pollution from sectors such as transport, businesses and construction.

Not to mention the fact that, the impact of the actions subsequent from the territorial reform being implemented even nowadays have not in a single time since 2016 been monitored with regard to air pollution concentration in the city of Tirana.

Table 4: Limit values per each urban air quality pollutant across EU, US and Albania

POLLUTION CONCENTRATION LIMITS IN URBAN AREAS				
Pollutant	Applied Standard			
	Albania	EU-27	U.S.A EPA	WHO
PM 2.5 (µg/m ³)	<u>20</u>	<u>20</u>	<u>9</u>	<u>5</u>
PM 10 (µg/m ³)	<u>40</u>	<u>40</u>	<u>150²⁶</u>	<u>15</u>
CO ₂	<u>350</u>	<u>350</u>	<u>450</u>	<u>350</u>
SO ₂ (µg/m ³)	<u>125</u>	<u>125</u>	<u>75</u>	<u>40</u>
NO ₂ (µg/m ³)	<u>40</u>	<u>40</u>	<u>53</u>	<u>10</u>
VOC (ppb)	<u>500</u>	<u>500</u>	<u>400-1200</u>	<u>500</u>
O ₃ (µg/m ³)	<u>120</u>	<u>120</u>	<u>70</u>	<u>60</u>
Pb (µg/m ³)	<u>0.5</u>	<u>0.5</u>	<u>0.15</u>	<u>0.5</u>
C ₆ H ₆ (µg/m ³)	<u>5</u>	<u>5</u>	<u>5</u>	<u>1.7</u>
CO (mg/m ³)	<u>10</u>	<u>10</u>	<u>9</u>	<u>1</u>
Cd (ng/m ³)	<u>5</u>	<u>5</u>	<u>2.5</u>	<u>5</u>
Ni (ng/m ³)	<u>20</u>	<u>20</u>	<u>15</u>	<u>25</u>

Source: Author, based on the public data from MTM GoA, EC, EPA US and WHO.

List of the national regulatory framework on Air Quality:

VKM NR. 162, DATË 19.02.2020 PËR RREGULLAT E HOLLËSISHME PËR HARTIMIN, MIRATIMIN, RISHIKIMIN DHE ZBATIMIN E PROGRAMEVE TË PAKËSIMIT TË SHKARKIMEVE NË AJËR. [English: Detailed regulatory for the elaboration, approval and review of the national program to reduce air emissions]

VKM NR. 412, DATË 19.06.2019 PËR MIRATIMIN E PLANIT KOMBËTAR PËR MENAXHIMIN E CILËSISË SË AJRIT. [English: National Plan on Air Quality]

LIGJ 9425, date 06.10.2005, ADERIMI NE KONVENTEN E CLRTAP [English: adherence to the Convention on Long-range Transboundary Air Pollution (CLRTAP)]

LIGJ 162-2014, date 04.12.2014 PËR MBROJTJEN E CILËSISË SË AJRIT NË MJEDIS [English: Protection of Ambient Air Quality]

VKM nr.412, datë 19.6.2019 “Për miratimin e Planit Kombëtar për Menaxhimin e Cilësisë së Ajrit [English: National Plan on the management of air quality]

VKM nr. 154, datë 27.2.2019 “Për disa ndryshime në vendimin nr. 633, datë 26.10.2018, të Këshillit të Ministrave, “Për masat kundër ndotjes së ajrit nga shkarkimet e mjeteve motorike dhe reduktimin e shkarkimeve në ajër të ndotësve të gaztë dhe të lëndës së ngurtë pezull nga motorët me ndezje pozitive dhe ata me ndezje me kompresion që djegin gaz natyror apo të lëngshëm për përdorim në

²⁶ Mandatory not to be exceeded once in three years

automjete” [English: review of decision nr. 633, date 26.10.2018 on specific measures against air pollution from motor vehicle exhausts and the reduction of air emissions of gaseous and particulate pollutants from positive-ignition and compression-ignition engines burning natural or liquid gas for use in vehicles]

VENDIM I KM 594, date 10.09.2014 PËR MIRATIMIN E STRATEGJISË KOMBËTARE PËR CILËSINË E AJRIT TË MJEDISIT. [English: Decision on National Strategy on Air Pollution]

VKM 352, 2015 PËR VLERËSIMIN E CILËSISË SË AJRIT TË MJEDISIT DHE KËRKESAT PËR DISA NDOTËS NË LIDHJE ME TË. [English: Monitoring of Ambient Air Quality and specific requirement on particular pollutants]

VKM 435, 2002 PËR MIRATIMIN E NORMAVE TË SHKARKIMEVE NË AJËR. [English: Approval of Air Emission Standarts]

VKM Nr. 907, datë 21.12.2016, PËR KUFIZIMIN E SHKARKIMEVE TË PËRBËRËSVE ORGANIKË TË AVULLUESHËM NGA PËRDORIMI I TRETËSVE ORGANIKË NË DISA BOJËRA, LLAQE DHE PRODUKTE PËR LUSTRIMIN E MJETEVE. [English: for the reduction and control of volatile organic components discharges from the use of organic solvents in certain paints, varnishes and vehicle polishing products]

EU FRAMEWORK:

The European Union has established a comprehensive framework to combat air pollution, focusing on improving ambient air quality, reducing emissions from various sources, and setting stringent emissions standards to protect both the environment and human health. This framework is structured around key directives and regulations that aim to tackle the issue from multiple fronts (European Commission, 2021)

Ambient Air Quality Directives: These set EU-wide air quality standards for 12 major air pollutants, including sulfur dioxide, nitrogen dioxide/nitrogen oxides, particulate matter (PM₁₀ and PM_{2.5}), ozone, benzene, lead, carbon monoxide, arsenic, cadmium, nickel, and benzo(a)pyrene. The directives aim to reduce air pollution to levels that minimize harmful effects on human health and the environment.

- I. Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe: This directive introduced additional PM_{2.5} objectives targeting the exposure of the population to fine particles and is pivotal

in guiding the assessment of air quality across the EU (EC, 2008).

- II. Directive 2004/107/EC: Relates to arsenic, cadmium, mercury, nickel, and polycyclic aromatic hydrocarbons in ambient air, further emphasizing the control of hazardous air pollutants (EC, 2004).
- III. Commission Directive (EU) 2015/1480: This amends several annexes to Directives 2004/107/EC and 2008/50/EC, adjusting technical specifications and methods for assessing air quality (EC, 2015).
- IV. Commission Implementing Decision 2011/850/EU: Lays down rules for the reciprocal exchange of information and reporting on ambient air quality, ensuring transparency and public access to data (EC, 2011).

Revision of the Ambient AirQuality Directives: As part of the (European Green Deal, 2019), a proposal was made to revise the directives, aiming to align EU air quality standards more closely with the World Health Organization's recommendations. This includes reducing the annual limit value for PM_{2.5} by more than half, among other changes.

EU Air Quality Standards

The EU has established specific air quality standards and objectives, which vary based on the pollutant, concentration levels, averaging periods, and legal nature (limit or target values). For instance, there are different standards for fine particles (PM_{2.5}), sulphur dioxide (SO₂), nitrogen dioxide (NO₂), particulate matter (PM₁₀), lead (Pb), carbon monoxide (CO), benzene, ozone (O₃), arsenic (As), cadmium (Cd), nickel (Ni), and polycyclic aromatic hydrocarbons (expressed as benzo(a)pyrene).

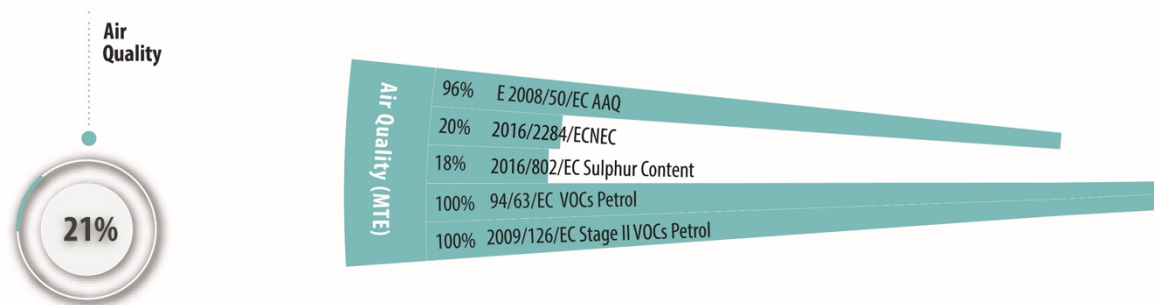
These directives and regulations form the cornerstone of the EU's efforts to address air pollution, focusing on the protection of human health and the environment through a comprehensive legal and regulatory framework.

To conclude, the latest transposition and screening made by Ministry of Tourism and Environment with regard to EU approximation process indicate (referring here to SANE-27) program in Albania that the overall transposition of Air Quality legislation appears satisfactory (at a rate of 72% transposed into national legislation. Meanwhile the implementation is assessed quite poor at 21% of the overall legislation being actually implemented. Moreover, on air quality the official stand of the commission follows; “More efforts are needed to align with the EU **air quality acquis**, including extending and improving the air monitoring system. The implementation of the 2014 national air quality strategy is still pending and the 2019 national plan on air quality management does not provide a functional monitoring system. There are only seven automatic air monitoring stations in

the whole country (located in the main cities) but data is not reported in real time and monitoring is not carried out during the whole year. The plan focuses mostly on transport measures, while air quality monitoring still not in line with EU standards. Implementation of the action plan for air quality and of the Directive on sulphur content in certain liquid fuels is ongoing, while implementation has not yet started for the Directives on controls on volatile organic compound (VOC) emissions and stage II petrol vapour.” (European Commission, 2023)

Figure 47: Implementation and Transposition of Albania’s framework on Air Quality with EU Directives.

Implementation Level



Source: Author graphics

4.8. Description Study Areas and their Description:

MAGNET COMPLEX.

The residential complex in question is situated in the densely populated 21 Dhjetori district of Tirana. Occupying an area of approximately 112,000 square meters, it comprises 17 buildings dedicated to residential and service purposes, featuring structures ranging from six to eleven stories in height, alongside playgrounds and verdant spaces. The construction timeline initiated in 2013, commencing with the Orion building, and concluded in 2020 with the completion of the Ursa and Leo structures.

The candidate selected this specific complex to monitor and further research due to its unique architectural and urban form configuration, which includes enclosed corners that counteract the prevailing north-west wind patterns. This urban form design facilitates the formation of a vortex effect, which, in turn, contributes to the retention of pollution during such events.

Architecturally, the complex boasts hooded facades, each 100mm in thickness, mounted atop 200mm masonry walls. Insulation is achieved through the application of stone wool, renowned for its resilience against atmospheric elements, fire, acoustic, and air pollution. This material's porous composition, fortified by fibers capable of withstanding temperatures up to 1000°C, forms an effective barrier against heat and sound. Such an insulation mechanism not only ensures up to a 60% reduction in energy consumption but also elevates the technical safety standards of the buildings. Internally, the separation between individual apartments and communal areas is facilitated by 20cm thick walls, whereas intra-apartment partitions are constructed from 10cm bricks. In adherence to stringent technical specifications, the masonry work incorporates an anti-seismic belt and columns, both fabricated from reinforced concrete, to bolster the structural integrity against seismic activity.

Figure 48: Aerial view of Magnet Complex



Source: Magnet, Geco.

The Magnet complex is distinguished by its three-story structure, which includes subterranean parking facilities and an additional level dedicated to storage warehouses. The ground floors are occupied by various businesses providing a range of services. Notably, the complex is situated in a pedestrian-only zone, which significantly enhances the quality of life for the area's inhabitants. This pedestrianization contributes to both increased safety and improved air quality, underscoring a commitment to fostering a healthier and more secure environment for residents and visitors alike. Recently, the complex has encountered issues stemming from adverse atmospheric conditions. Intense rainfall led to inundation and subsequent complications within the underground levels of the complex. The vicinity of the complex is characterized by a notably high population and building

density. The land utilization coefficient in this area stands at 45%, with the land use predominantly designated for residential purposes (87%), a combination of residential and service functions (10%), and infrastructure (3%). The area is home to approximately 3,700 residents, attributable to the fact that 97% of the land use is dedicated to residential functions.

Table 5: The number of apartments and residents in the complex

Building 1	81 apartments, 81x3.3=267.3 inhabitants.
Building 2	79 apartments, 64x3.3=211.2 inhabitants.
Building 3	54 apartments, 54x3.3=178.2 inhabitants.
Building 4	63 apartments 63x3.3=207.9 inhabitants.
Building 5	67 apartments, 73x3.3=240.9 inhabitants.
Building 6	67 apartments, 67x3.3=221.1 inhabitants.
Building 7	Kindergarten
Building 8	64 apartments, 64x3.3=211.2 inhabitants.
Building 9	71 apartments, 71x3.3=234.3 inhabitants.
Building 10	66 apartments, 66x3.3=217.8 inhabitants.
Building 11	65 apartments, 65x3.3=214.5 inhabitants.
Building 12	68 apartments, 68x3.3=224.4 inhabitants.
Building 13	81 apartments, 81x3.3=267.3 inhabitants.
Building 14	70 apartments, 70x3.3=231 inhabitants.
Building 15	67 apartments, 67x3.3=221.1 inhabitants.
Building 16	64 apartments, 64x3.3=221.1 inhabitants.
Building 17	73 apartments, 73x3.3=240.9 inhabitants.
1100 apartments and approximately 3700 residents	

Source: Author

The Magnet complex, based on conducted assessments and continuous observation, encompasses a total of 17 structures. The architectural layout includes three initial edifices rising to 11 stories. Central buildings decrease in height, featuring 10, 8, and 6 stories, whereas perimeter buildings exhibit varying elevations of 8, 9, and 11 stories. The complex houses 1,100 apartments.

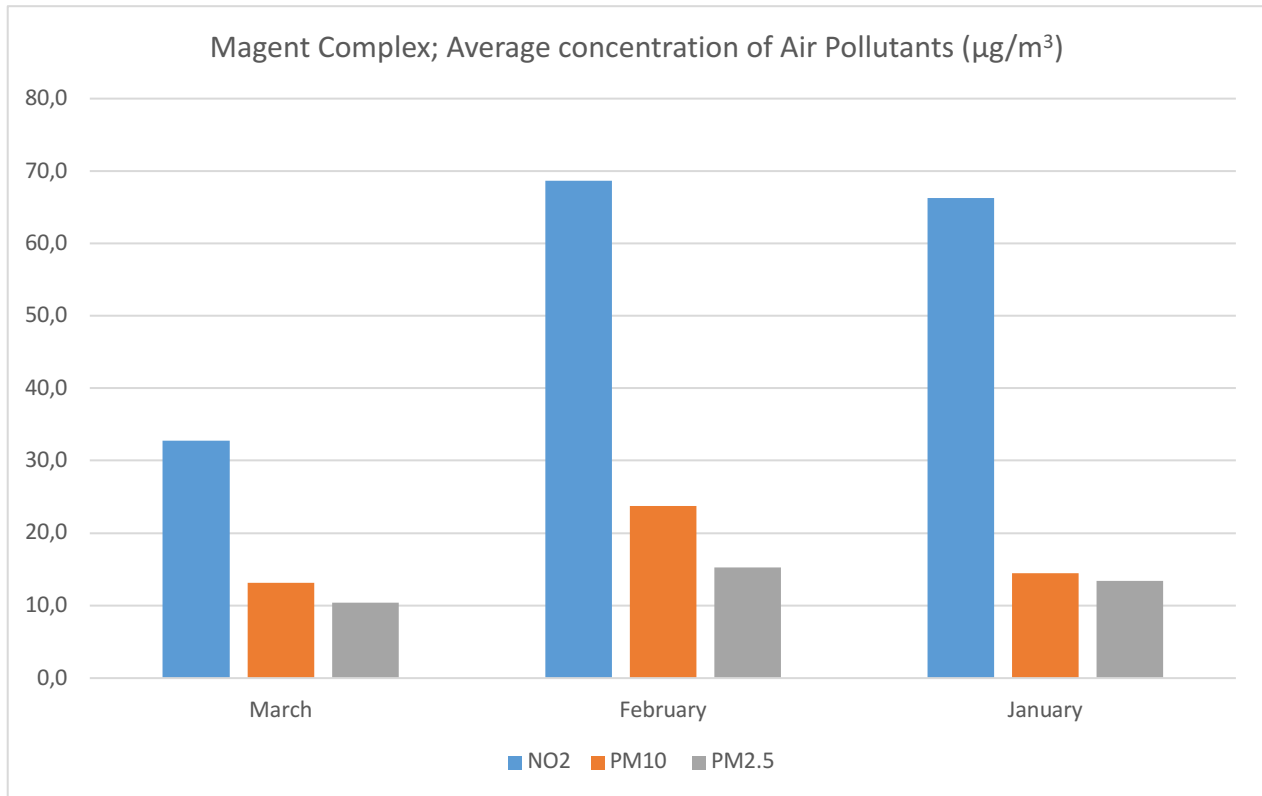
The utilization of ground floor spaces is diverse, hosting amenities such as cafes, supermarkets, electronics stores, hair salons, wine shops, dry cleaners, restaurants, gyms, pizzerias, clinics, child after-school programs, accounting offices, marketing agencies, legal practices, and financial law firms.

Overall Air Quality Analysis from January to March 2023

The air quality within the vicinity of the complex is deemed relatively satisfactory, primarily attributed to the exclusion of vehicular traffic. Air quality assessments were conducted over a three-

month period, focusing on the levels of PM₁₀, PM_{2.5}, and NO₂ pollutants. The findings indicated elevated pollution levels at all buffer measurement points closely linked to a construction site nearby or influenced by traffic emissions. Nevertheless, also the presumed cavity area indicated increased concentration when compared with all the other 4 monitoring points within the complex.

Graphic 1: Air pollution levels during January – March 2023



Source: Author

The predominant sources of pollution in the vicinity are transportation and nearby construction activities. Particularly, construction sites proximal to the monitored buffer zones have been identified as significant contributors to elevated nitrogen dioxide NO₂ and PM₁₀, PM_{2.5} levels. The machinery deployed at these sites, such as bulldozers and excavators, are known to emit considerable quantities of both coarse and fine particulate matter, adversely affecting the air quality. Furthermore, within the complex itself, factors contributing to the escalation of NO₂ and particulate matter include the operation of heating and ventilation systems, the presence of inefficient or contaminated HVAC systems, indoor activities releasing fine particles and chemicals, and the use of chemical products. External environmental factors, such as winds or air movement patterns, have the potential to transport pollutants into the complex, thereby influencing the local air quality.

Nevertheless, when compared to the broader 21 Dhjetori area, the Magnet complex demonstrates a slightly lower pollution level. This discrepancy can be attributed to the complex's strategic incorporation of green spaces within the inter-building corridors. These vegetated areas not only play a critical role in mitigating pollution but also contribute to rainwater absorption, thereby reducing the likelihood of flooding. The presence of these green spaces underscores their significance in enhancing environmental quality and resilience within urban settings.

Figure 49: Base map and landcover overview of Magnet Complex

Source: Author

Green spaces can be seen from the map generated above, where it is noted that the area has a considerable surface with greenery and spaces for recreation.



Author's calculation estimates there are at least 2.3m² of green area per inhabitant in this complex compared with the 0.2m² that the city in overall provides to its urban inhabitants in its urban area.

KIKA COMPLEX.

Situated in the densely populated Komuna e Parisit area of Tirana, this extensive complex encompasses approximately 1,500 residential units, over 200 commercial spaces, a dedicated multi-

office building, and more than 1,000 parking spots. The construction phase of the complex spanned from 2008 to 2022, resulting in structures predominantly featuring nine levels (inclusive of two subterranean and seven residential floors) with the ground level designated for service and commercial use across all buildings. The architectural and engineering design was the result of collaborative efforts among a diverse team of professionals, including architects, civil, mechanical, electrical, and structural engineers, as well as fire protection, planning, architectural, and archaeological consultants.

The candidate selected this specific complex to monitor and further research due to its unique urban form configuration, which includes enclosed corners that counteract the prevailing eastern wind patterns. This urban form design facilitates the formation of a vortex effect, which, in turn, contributes to the retention of pollution during such events.

Figure 50: Aerial view of Kika Complex



Source: Author

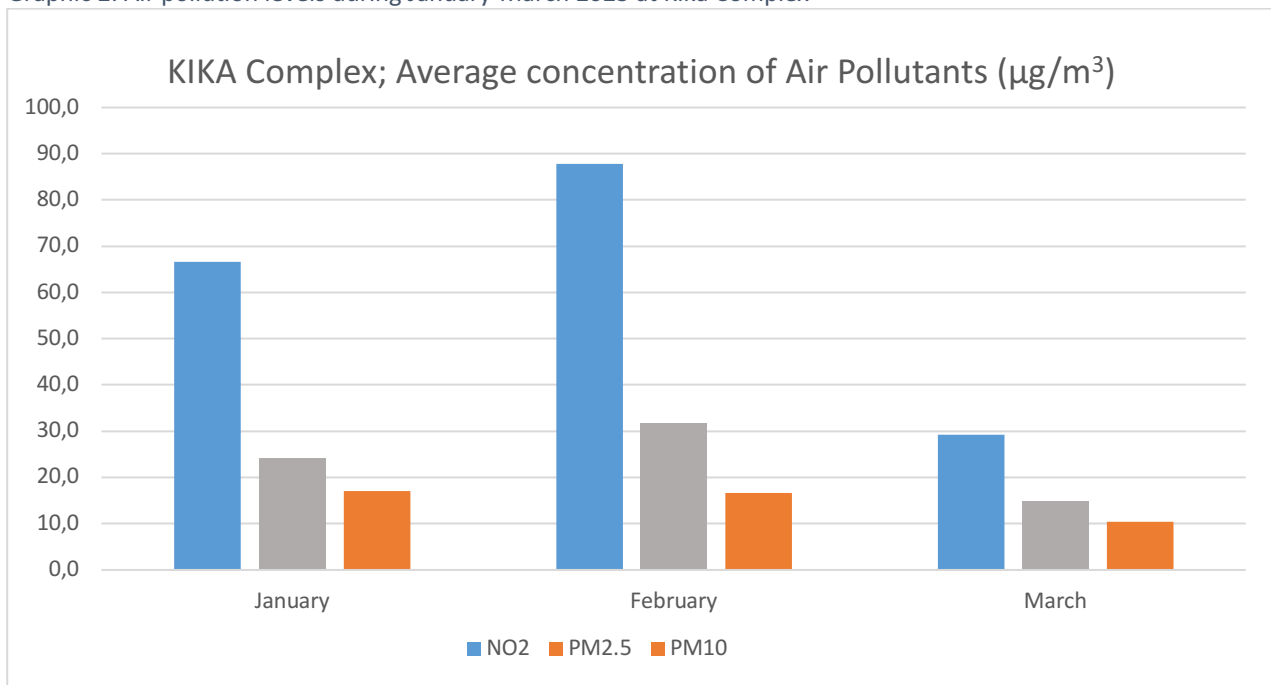
KIKA complex is appropriately interconnected with Tirana's road network as it borders in its north part the Komuna Parisit roundabout and within the complex via three levels of underground parking and boasts amenities such as office spaces, a shopping centre, a cinema, and a children's playground, enhancing its utility and appeal. The external facade employs brick and masonry construction techniques, with stone wool insulation integrated to provide resistance against

acoustic and air pollution. Internal partitions between apartments and communal areas maintain a thickness of 20-22 cm, reinforcing privacy and security.

Overall Air Quality Analysis from January to March 2023

It can be observed that the level of air pollution within the complex most of the time do exceed the limit standards. Even though presumed that the opposite could be expected given the condition attributed to the prohibition of vehicular access within the complex. Over a duration of three months, air quality assessments were conducted, focusing on the concentrations of NO₂ pollutants. This systematic monitoring underscores the effectiveness of vehicular restrictions in maintaining the quality of air in densely populated areas.

Graphic 2: Air pollution levels during January-March 2023 at Kika Complex



Source: Author

The primary contributory factor to the air pollution within this locality is the strategic placement of the complex, which is situated amidst several principal junctions. These junctions facilitate the convergence of Komuna e Parisit road with adjacent areas characterized by substantial vehicular traffic. The findings indicated elevated pollution levels at all buffer measurement points closely linked to a construction site nearby or influenced by traffic emissions. Nevertheless, also the presumed cavity area indicated increased concentration when compared with all the other 4 monitoring points within the complex.

Nonetheless, the other monitoring points within the complex appear to have a normal dispersal of air pollutant, given the corridors and tunnels from the overall architecture of the complex. Thus avoiding capture or retention of pollution a certain extent. This conclusion is backed by the fact that pollution particles, once entered, encounter difficulty in dispersion owing to the urban form of the complex and proximity of the structures within the complex. Additionally, the presence of reduced vegetated/green areas within the complex in comparison to Magnet complex does not have the same effect in absorbing the pollution.

Figure 51: Base map and landcover overview of Kika Complex



Source: Author

Urban greenery as digitalized and visualized in map generated above, is considerably less than Magnet, accounting to 0.55m²/inhabitant complex but yet higher than the overall 0,2m²/inhabitant green space the city in overall provides to its urban inhabitants in its urban area.

ISH-EKSPOZITA.

The vicinity in question, located proximal to Bulevardi Gjergj Fishta—a notably bustling segment of Tirana—is characterized by four buildings, each featuring five entryways, and distributed across five levels with nine residences per entrance. Estimations derived from conducted analyses suggest a total inhabitant count of approximately 1,150 within this area. Encapsulating this residential ensemble is an array of commercial entities including cafes, eateries, supermarkets, hair salons, retail stores, automotive services, and grocery outlets, alongside a construction site positioned directly in front of these edifices, contributing to the locale's vibrant community landscape.

Figure 52: Areal viw of Ish-Ekspozita



Source: Author

The population density in this area is quite high, as is the density of buildings. The coefficient of utilization of the territory in the area is 45% and the area consists of the function 94%, residential + services: 3% and infrastructure 3%. Approximately 1100 residents live in the area.

Table 6: Number of apartments and resident in the monitoring area of Ish Ekspozita

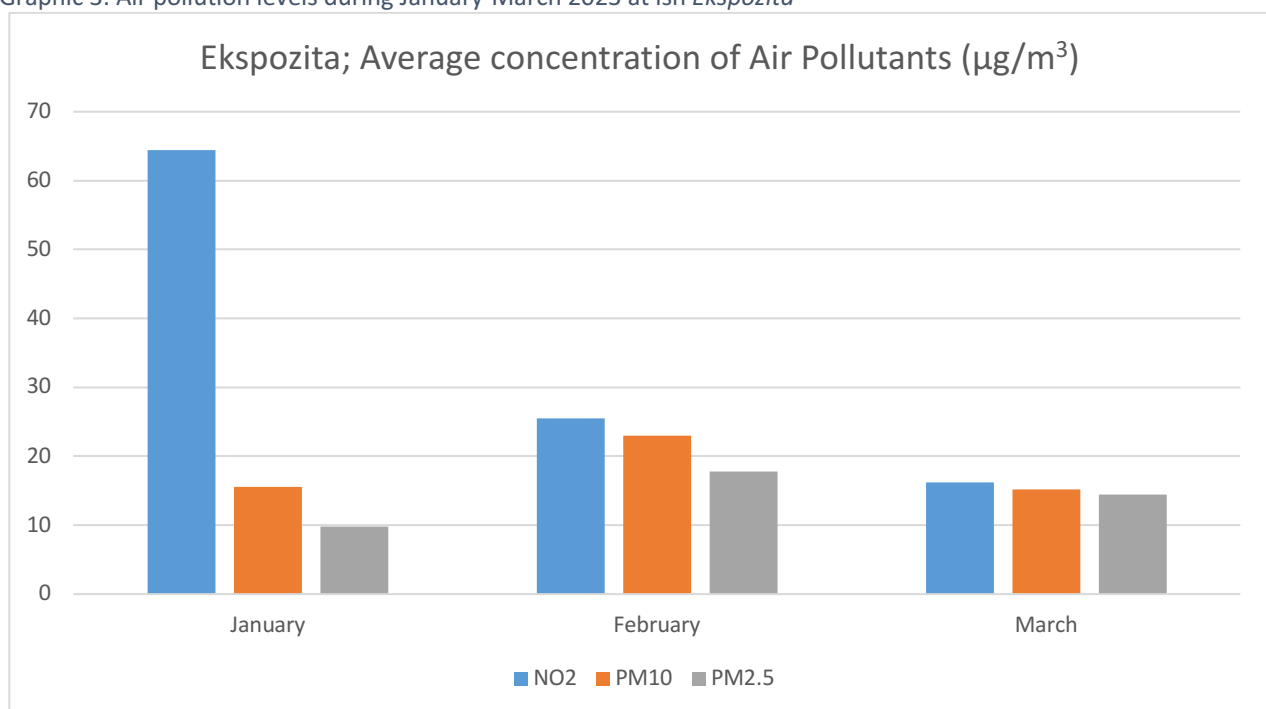
Building 1	75 apartments, 70x3.3=248 inhabitants.
Building 2	78 apartments, 78x3.3=258 inhabitants.
Building 3	81 apartments, 81x3.3=268 inhabitants.
Building 4	83 apartments 83x3.3=274 inhabitants.

Source: Author

Overall Air Quality Analysis from January to March 2023

The area experiences moderate air pollution levels, primarily attributed to a construction site situated directly across from the residential buildings where once was the “Ekspozita”. This concern arises mainly by the transit of heavy and other vehicles but also from the substantial dust emissions within the vicinity. Pollution monitoring within the complex indicated a minor cavity area created by an informal change of the original set-up of the complex. All the other monitoring points were performing accordingly with regard to natural dispersal of air pollution under the effect of wind. Moreover, the elevated pollution metrics can also be traced back to vehicular activity and the suboptimal condition of vehicles operating in the area.

Graphic 3: Air pollution levels during January-March 2023 at ish Ekspozita



Source: Author

The principal contributors to pollution in this locality are identified as transportation and construction activities. Specifically, construction sites near buffer monitoring points significantly elevate NO₂, PM₁₀, and PM_{2.5} levels, impacting both the immediate and surrounding areas, especially during absence of wind or precipitation for more than 2 days in a row. Nevertheless, the urban form created by the air corridors facilitate the transport of particles into and out of the monitoring areas thus not contributing into any major exacerbation the pollution levels.

Conversely, the vegetated areas situated between the buildings serve as a mitigating factor against pollution. These green spaces significantly reduce the concentration of pollutants within the neighbourhood and play a crucial role in absorbing rainwater, thereby decreasing the potential for flooding. This interplay between the built environment and natural elements underscores the complex dynamics influencing urban air quality and the importance of integrated urban planning and green infrastructure in mitigating environmental impacts. Among all the selected monitoring locations, ish-Ekspozita is the only one that does have a mature and dense urban greenery within and in the surrounding area thus the larger the tree canopies the greater are the ecosystem services.

Figure 53: Base map and landcover overview of Ish Ekspozita monitoring area



Source: Author

“DELIJORGJI COMPLEX”.

It is located at one of the busiest areas of Tirana, north the Kavaja street and south-west the Lana river. It has been created in 2015 with a surface of $24000m^2$ where around 4000 inhabitants of the 8-storey buildings are staying. Delijorgji complex is organized in a way that welcomes every age by having different places and activities for each one of them. Inside it are parks for kids, medical and shopping centres, bars and restaurants, banks and any other primary activity that is needed. The complex consists of buildings with 9 construction floors where floor 0 and floor 1 are used for services and offices and the 7 floors above are for housing. All buildings have decorative red brick cladding and uniformly composed facades. The coefficient of space construction is 35%. The buildings are positioned between them in such a way that each apartment is sufficiently exposed to sun. There are supermarkets, banks, pharmacies, public transport, etc.

Figure 54: Areal view of Delijorgji complex.



Source: Author

The candidate selected this specific complex to monitor and further research due to its replication of the urban form generally used during the 1965-1985 in Tirana. An architectural and urban form configuration, which includes wind ventilation tunnels aligned with the prevailing wind patterns of Tirana. This urban form altogether with the Ish-Ekspozita decreases at the maximum the formation of a vortex effect, which, in turn, contributes at avoiding any unnatural retention of pollution.

Another fact to make this area comparable with ish-ekspozita is that at Delijorgji there are less vehicles traveling around the complex given that most of its space is public areas (yet not green). Both areas are equally situated along the most prevailing air corridor created by Lana River, whilst Delijorgji is near on of the main air pollution hotspot in Tirana. Another different characteristic is that at Delijorgji's all ground floor and the first floor of each building are used for businesses such as: Bank (Intesa, Tirana Bank, Union Bank, restaurants, bars, real estate, tourist agency, playground, stores for home products, cars, dry cleaning, phone stores, air conditioning systems, bakeries etc.

Table 7: Number of apartments and resident in the monitoring area of Delijorgji Complex

Building 1:	1 entrance,	14 apartments.	50 inhabitants
Building 2:	2 entrances,	92 apartments.	305 inhabitants.
Building 3:	2 entrances,	97 apartments.	325 inhabitants
Building 4:	2 entrances,	63 apartments.	210 inhabitants.
Building 5:	2 entrances,	84 apartments.	280 inhabitants.
Building 6:	2 entrances,	70 apartments.	235 inhabitants.
Building 7:	1 entrance,	35 apartments.	120 inhabitants
Building 8:	3 entrances,	77 apartments.	265 inhabitants.
Building 9:	3 entrances,	96 apartments.	330 inhabitants.

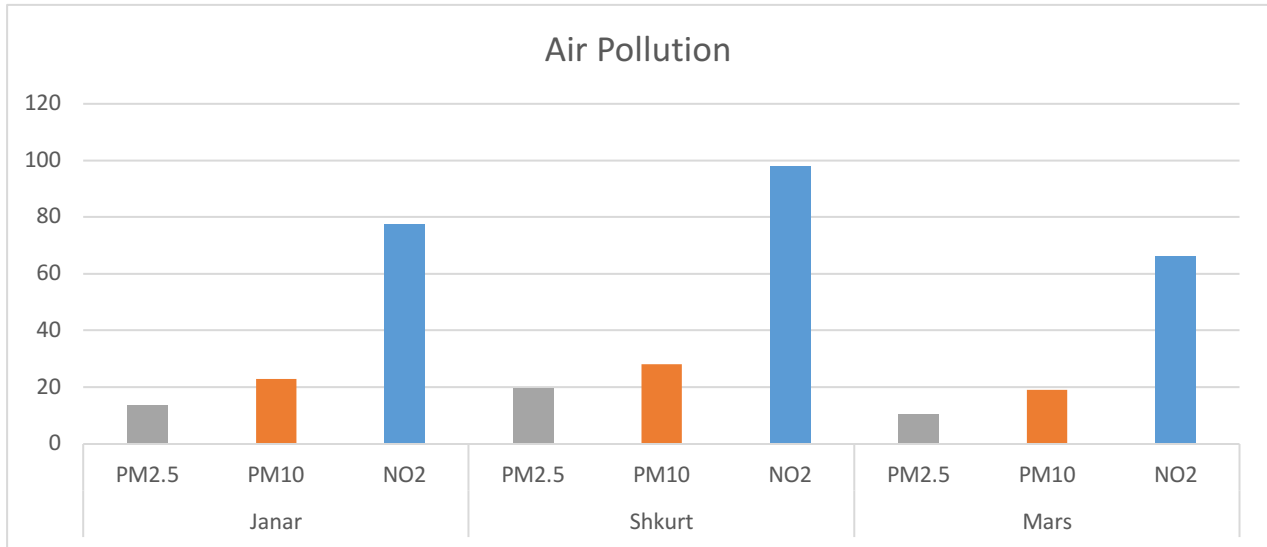
Source: Author

Overall Air Quality Analysis from January to March 2023

The area experiences moderate to severe air pollution levels, we can see the air quality in this area is not the best due to the fact that it is in under the constant influence of the pollution emitted by the Hoteleri-Turizem roundabout and the infrastructure works happening along the outer-ring of Tirana. The inside of the complex is as polluted as it can get given that emission from north-east trespass all the area on a daily basis. On the other hand, the green spaces are quite minimal so that there is no actual absorption of pollutants from ecosystem services.

Pollution monitoring within the complex indicated a minor cavity area created by an informal change of the original set-up of the complex. All the other monitoring points were performing accordingly with regard to natural dispersal of air pollution under the effect of wind.

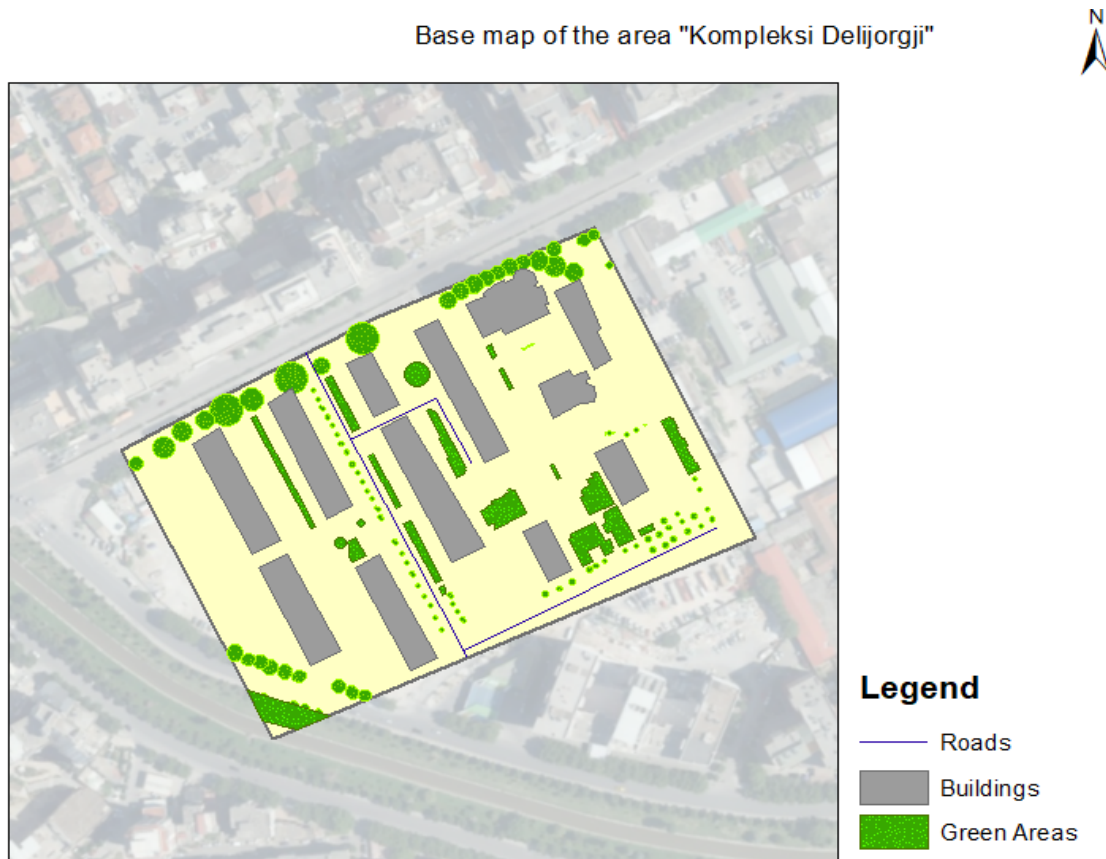
Graphic 4: Air pollution levels during January-March 2023 at Delijorgji



Source: Author

Nevertheless, the wind tunnel created by the air corridors due to the zones urban form facilitate the transport of particles into and out of the monitoring areas thus not contributing into any major exacerbation the pollution levels. As matter of fact the retention occurs only in the northern part of the complex due to the actual positioning of the high rising block on the other part of Kavaja Street.

Figure 55: Base map and landcover overview of Delijorgji monitoring area



Source: Author

Figure 56: Moments during site monitoring practices.



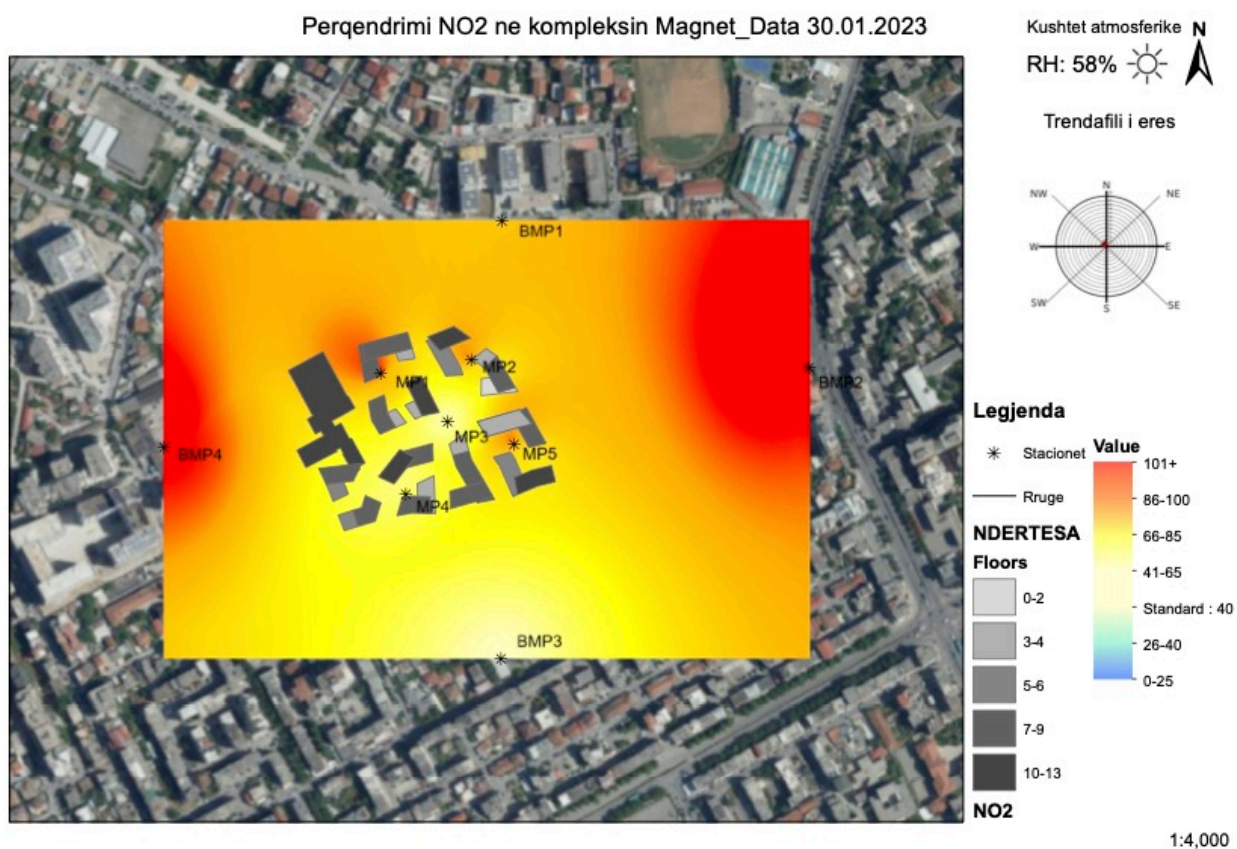
Source: Author

4.9. Detailed monitoring results for each study area

MAGNET COMPLEX.

Within the Magnet complex there were fixed 5 Monitoring Points out of which 2 were presumed to be affected by the vortex effect and that could retain pollution for a more prolonged time compared to other the monitoring location that were strategically position at the intersections whereas the urban morphology of the study area created wind corridors.

Figure 57: Pollution concentration map (1 sample out of 270 maps prepared for Magnet Area)



Source: Author

All the monitored components such as urban form, concentration of pollution, wind direction, wind speed, meteorological condition and relative humidity are expressed within the daily maps. These maps have been replicated under the same conditions also for the PM 2.5 and PM 10 pollutants. Herby there are 270 maps generated for this complex (90 per each pollutant) extracting and visualizing the data from 90 site monitoring sheets. These maps were later joined into a sequence per each pollutant indicating thus the potential cavity areas whereas natural dispersal of air pollutants is impacted by the urban form.

Regarding the monitoring practices at MAGNET Complex were conducted between 10:00am in the morning until 13:00 at maximum. Covering at least 25 minutes of each monitoring point within the block whereas the author was looking for air pollution cavity areas and 7-10 minutes of monitoring for each buffer monitoring point.

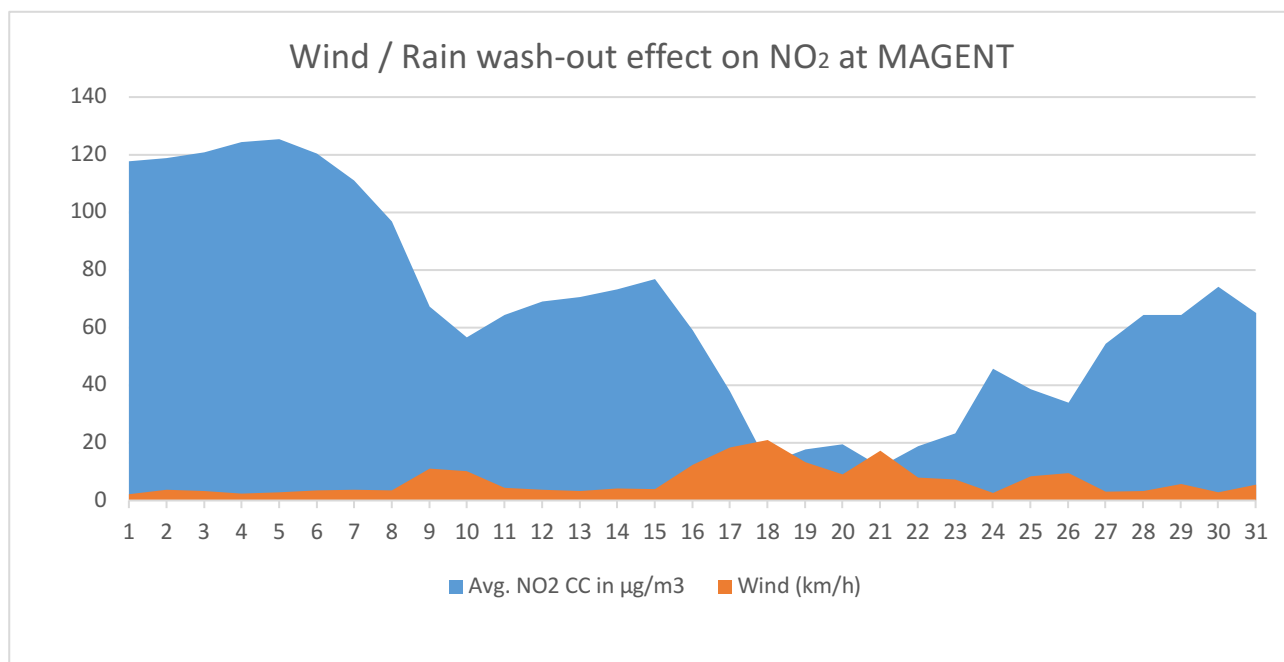
MAGNET _ JANUARY 2023:

Table 8: NO₂ concentrations and meteorological observations during January 2023 / Kontakt Magnet Complex.

Date	Within the MAGNET COMPLEX					N / konviktet / E / UPT		S / Naimi		W / Njja		Avg. NO ₂ CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitorin g length
	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4								
1	111	116	109	121	132	113	151	107	133	118	2,2	E	65%	Sunny	2hrs	10:00 -12:20	
2	104	128	107	118	137	106	133	103	134	119	3,8	E	53%	Sunny	2hrs	10:00 -12:20	
3	98	131	109	122	144	121	161	112	168	121	3,4	E	77%	Sunny	2hrs	10:00 -12:20	
4	102	135	110	124	151	125	193	109	163	124	2,5	E	81%	Cloudy	2hrs	10:00 -12:20	
5	99	139	107	127	155	112	199	111	183	125	2,8	SE	79%	Sunny	2hrs	10:00 -12:20	
6	87	144	88	126	157	98	141	89	140	120	3,6	E	88%	Sunny	2hrs	10:00 -12:20	
7	79	121	87	120	148	97	127	86	124	111	3,7	NE	56%	Sunny	2hrs	10:00 -12:20	
8	78	89	63	117	137	79	99	62	109	97	3,5	E	42%	Sunny	2hrs	10:00 -12:20	
9	48	71	52	76	89	66	81	51	77	67	11	SE	87%	Sunny	2hrs	10:00 -12:20	
10	29	66	37	70	81	48	74	33	59	57	10,1	SE	82%	Cloudy	2hrs	10:00 -12:20	
11	57	69	45	67	84	60	88	44	68	64	4,3	E	77%	Cloudy	2hrs	10:00 -12:20	
12	68	74	54	63	86	64	92	53	67	69	3,7	NW	76%	Cloudy	2hrs	10:00 -12:20	
13	71	81	49	63	89	71	89	46	71	71	3,4	W	68%	Sunny	2hrs	10:00 -12:20	
14	79	79	51	65	92	64	96	47	69	73	4,2	NW	73%	Sunny	2hrs	10:00 -12:20	
15	92	88	38	67	99	58	121	35	66	77	3,9	W	84%	Sunny	2hrs	10:00 -12:20	
16	47	72	31	62	83	46	78	29	43	59	12,5	SE	65%	Cloudy	2hrs	10:00 -12:20	
17	28	45	28	40	49	34	44	15	36	38	18,5	SE	87%	Rainy	2hrs	10:00 -12:20	
18	8	15	13	11	17	14	38	10	28	13	21	SE	86%	Storm	2hrs	10:00 -12:20	
19	21	18	14	17	19	15	31	8	24	18	13,4	SE	92%	Rainy	2hrs	10:00 -12:20	
20	39	16	12	14	17	21	28	11	29	20	9,1	SE	90%	Rainy	2hrs	10:00 -12:20	
21	16	11	11	10	11	11	19	6	24	12	17,2	SE	71%	Rainy	2hrs	10:00 -12:20	
22	27	21	16	12	18	33	44	18	37	19	7,9	NW	77%	Cloudy	2hrs	10:00 -12:20	
23	34	24	21	17	21	31	28	19	44	23	7,4	SW	93%	Rainy	2hrs	10:00 -12:20	
24	56	48	33	39	53	51	73	29	66	46	2,7	E	89%	Sunny	2hrs	10:00 -12:20	
25	43	45	22	41	42	34	62	17	47	39	8,3	NW	77%	Cloudy	2hrs	10:00 -12:20	
26	35	37	26	34	38	56	58	31	63	34	9,5	E	66%	Cloudy	2hrs	10:00 -12:20	
27	68	62	34	44	64	63	81	38	93	54	3,1	NW	83%	Cloudy	2hrs	10:00 -12:20	
28	88	73	39	45	77	69	98	44	101	64	3,3	NW	73%	Sunny	2hrs	10:00 -12:20	
29	78	69	47	52	76	70	89	48	94	64	5,65	NW	79%	Sunny	2hrs	10:00 -12:20	
30	92	83	53	59	84	79	128	50	121	74	2,77	NW	58%	Sunny	2hrs	10:00 -12:20	
31	83	78	40	49	75	74	112	46	98	65	5,48	N	78%	Sunny	2hrs	10:00 -12:20	
TOT	63,4	72,5	49,9	64,3	81,5	64,0	92,1	48,6	83,2	66,3							

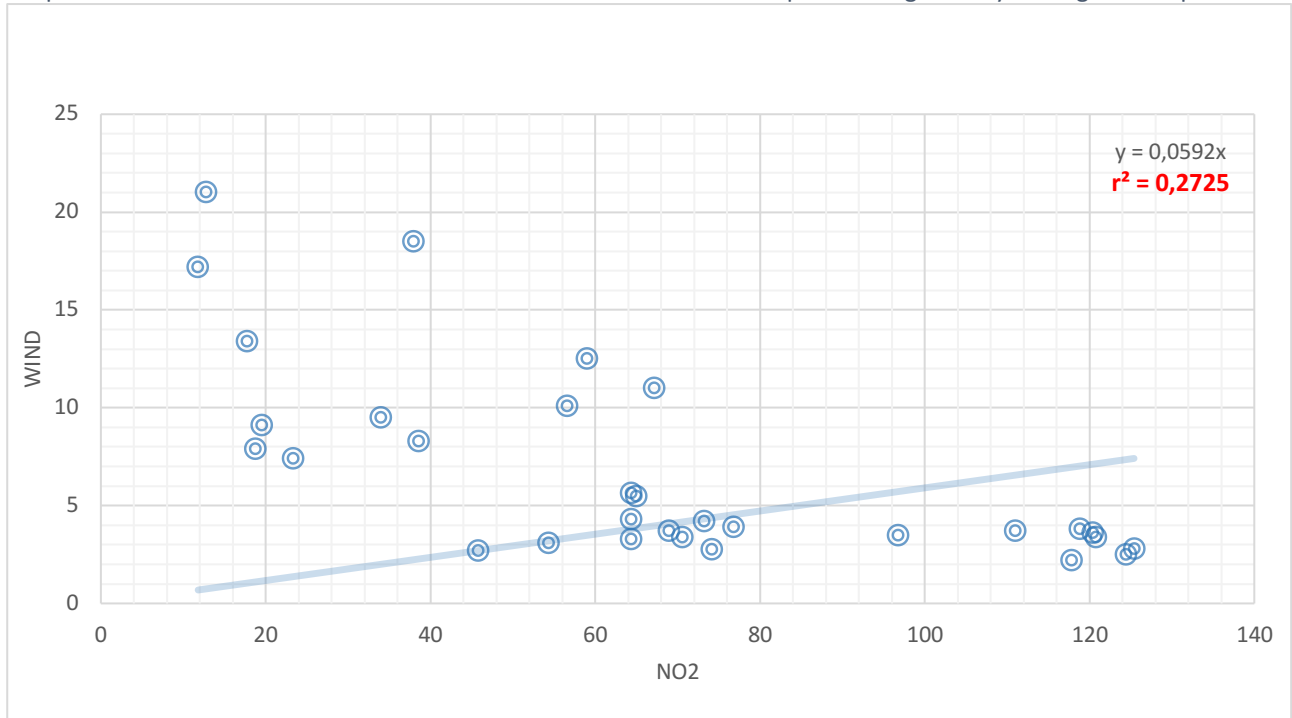
Source: Author

Graphic 5: Effect of wind and rain on the wash-out of NO₂ concentration at Magnet complex.



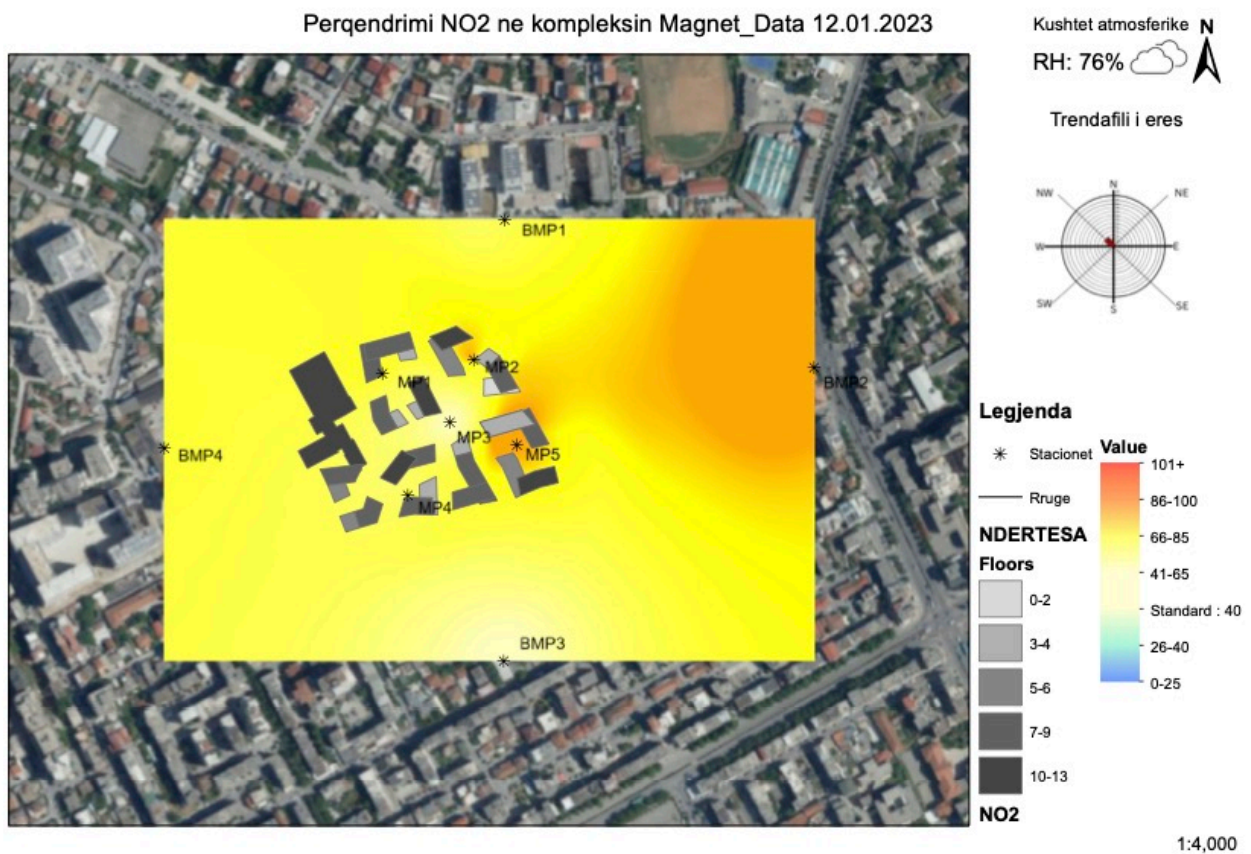
Source: Author

Graphic 6: Correlation factor between concentration of NO₂ and Wind speed during January at Magnet Complex.



Source: Author

Figure 58: Sample from the dispersal of NO₂ sequence (12.1.2023)



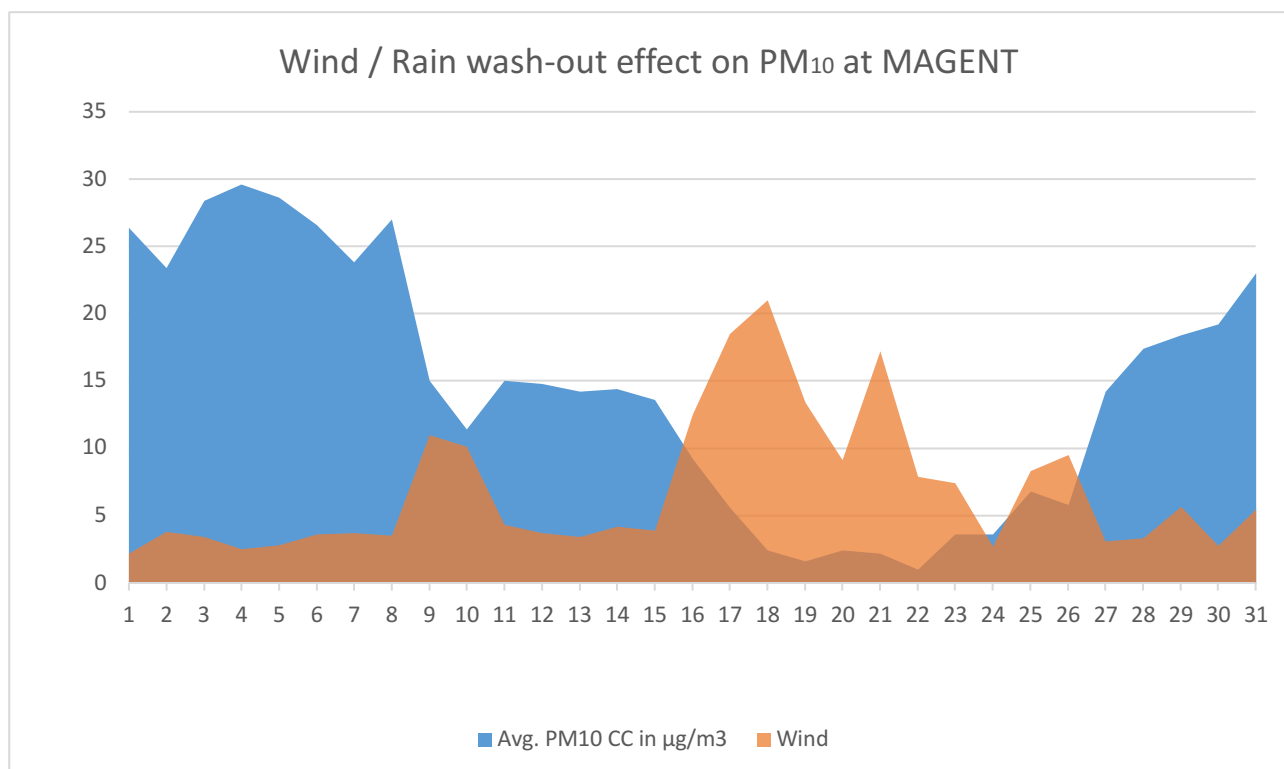
Source: Author

Table 9: PM₁₀ concentrations and meteorological observations during January 2023 / Kontakt Magnet Complex

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m ³	Wind	Direction	Humidity	Weather	Monitoring	Daytime
1	27	26	25	26	28	32	39	29	37	26	2,2	E	77%	Sunny	2hrs	10:00-12:20
2	26	19	17	25	30	30	37	22	38	23	3,8	E	57%	Sunny	2hrs	10:00-12:20
3	28	27	29	27	31	39	43	33	44	28	3,4	E	72%	Sunny	2hrs	10:00-12:20
4	28	29	29	28	34	40	52	32	45	30	2,5	E	79%	Cloudy	2hrs	10:00-12:20
5	28	27	29	26	33	43	54	34	52	29	2,8	SE	85%	Sunny	2hrs	10:00-12:20
6	27	23	21	27	35	35	42	27	41	27	3,6	E	93%	Sunny	2hrs	10:00-12:20
7	23	22	20	22	32	28	34	24	33	24	3,7	NE	50%	Sunny	2hrs	10:00-12:20
8	29	20	18	31	37	23	29	20	27	27	3,5	E	43%	Sunny	2hrs	10:00-12:20
9	17	14	12	15	17	20	24	17	24	15	11	SE	91%	Sunny	2hrs	10:00-12:20
10	14	11	7	13	12	19	25	13	23	11	10,1	SE	88%	Cloudy	2hrs	10:00-12:20
11	17	17	10	16	15	18	24	14	20	15	4,3	E	77%	Cloudy	2hrs	10:00-12:20
12	18	15	10	15	16	17	24	12	21	15	3,7	NW	77%	Cloudy	2hrs	10:00-12:20
13	17	13	8	17	16	17	27	13	17	14	3,4	W	66%	Sunny	2hrs	10:00-12:20
14	16	14	9	15	18	16	32	12	18	14	4,2	NW	75%	Sunny	2hrs	10:00-12:20
15	18	9	7	17	17	17	33	11	19	14	3,9	W	81%	Sunny	2hrs	10:00-12:20
16	12	7	8	11	8	13	24	9	21	9	12,5	SE	64%	Cloudy	2hrs	10:00-12:20
17	9	3	4	8	4	8	16	6	10	6	18,5	SE	87%	Rainy	2hrs	10:00-12:20
18	5	1	1	4	1	5	7	4	6	2	21	SE	86%	Storm	2hrs	10:00-12:20
19	4	0	1	3	0	8	8	3	9	2	13,4	SE	92%	Rainy	2hrs	10:00-12:20
20	5	0	3	4	0	10	11	5	13	2	9,1	SE	90%	Rainy	2hrs	10:00-12:20
21	2	2	5	2	0	16	14	8	24	2	17,2	SE	71%	Rainy	2hrs	10:00-12:20
22	1	1	1	0	2	11	20	6	14	1	7,9	NW	77%	Cloudy	2hrs	10:00-12:20
23	3	5	8	2	0	16	18	12	22	4	7,4	SW	93%	Rainy	2hrs	10:00-12:20
24	6	3	1	5	3	11	24	8	15	4	2,7	E	89%	Sunny	2hrs	10:00-12:20
25	9	5	5	8	7	13	23	8	18	7	8,3	NW	77%	Cloudy	2hrs	10:00-12:20
26	7	6	5	6	5	17	18	9	25	6	9,5	E	66%	Cloudy	2hrs	10:00-12:20
27	16	14	12	17	12	22	29	18	32	14	3,1	NW	83%	Cloudy	2hrs	10:00-12:20
28	21	17	14	19	16	18	31	16	26	17	3,3	NW	73%	Sunny	2hrs	10:00-12:20
29	20	19	14	21	18	25	33	19	37	18	5,65	NW	79%	Sunny	2hrs	10:00-12:20
30	22	11	10	27	26	25	34	17	38	19	2,77	NW	58%	Sunny	2hrs	10:00-12:20
31	27	22	18	25	23	21	30	21	29	23	5,48	N	78%	Sunny	2hrs	10:00-12:20
TOT	16,2	13,0	11,6	15,5	16,0	20,4	27,7	15,5	25,7	14,5	6,9					

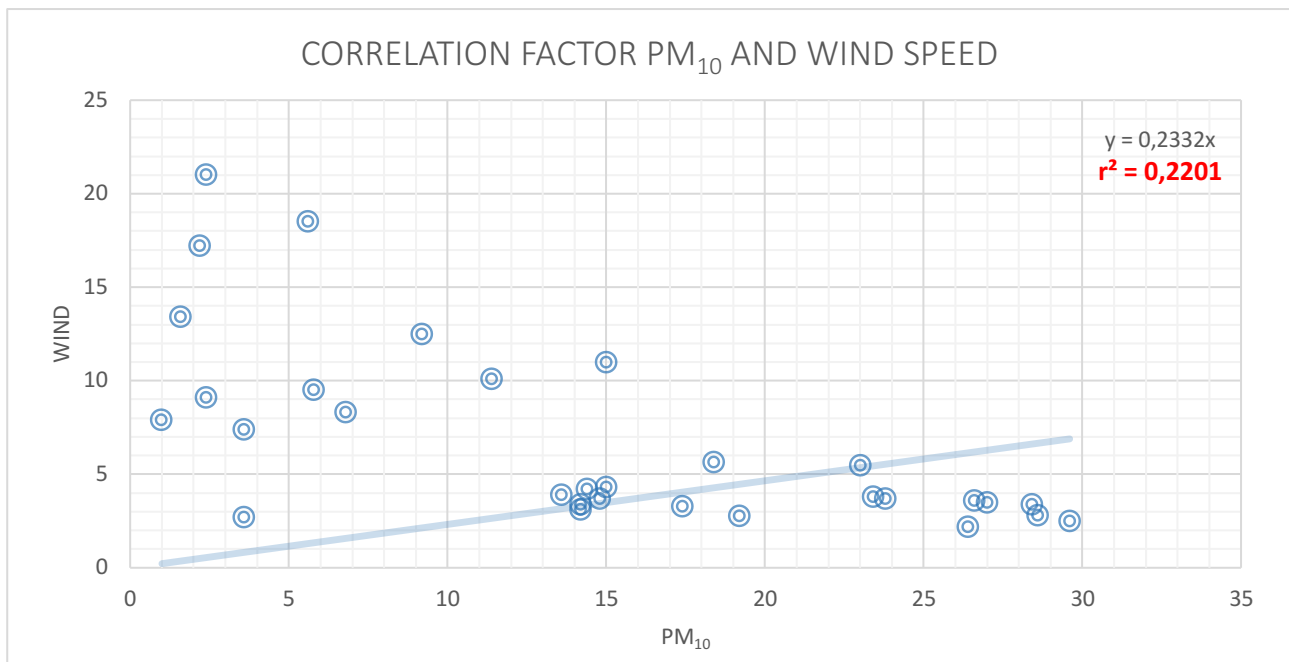
Source: Author

Graphic 7: Effect of wind and rain on the wash-out of PM₁₀ concentration at Magnet complex during January.



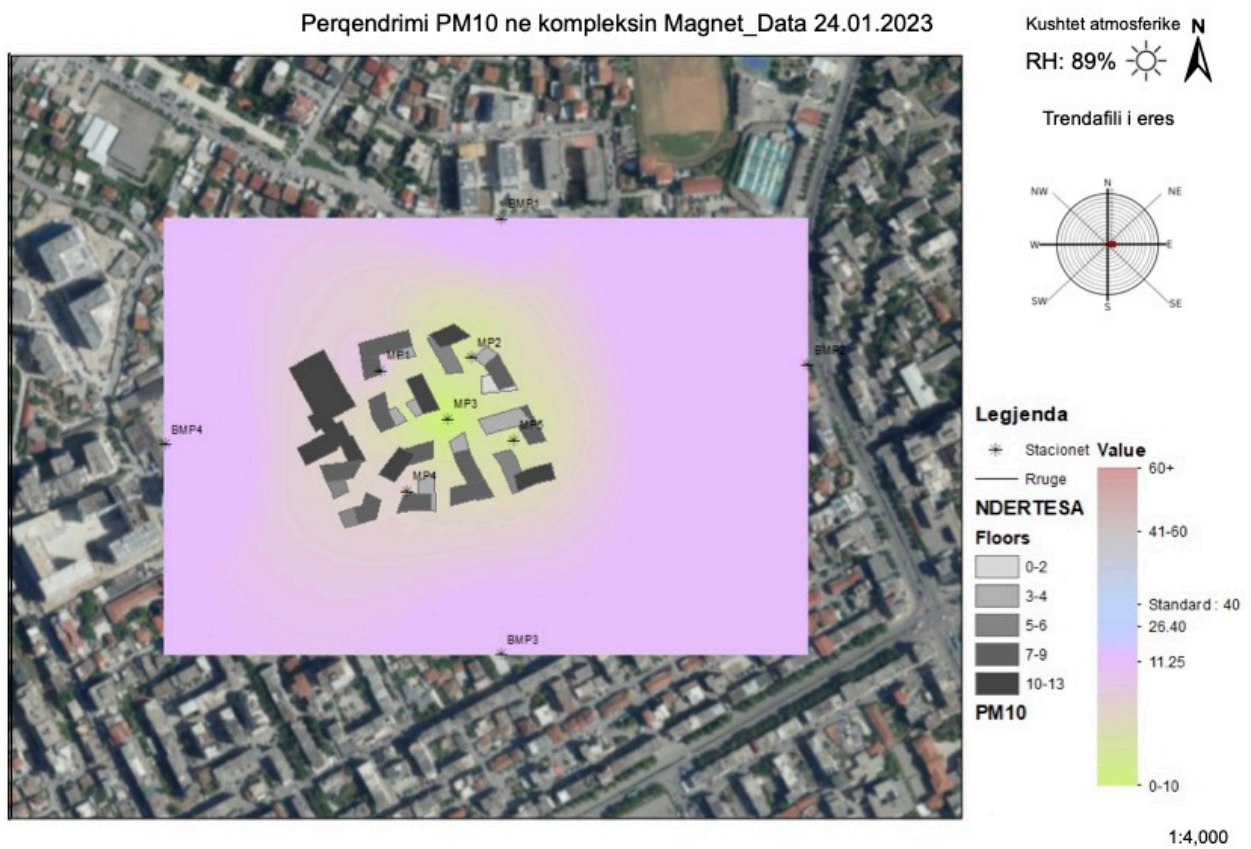
Source: Author

Graphic 8: Correlation factor between concentration of PM₁₀ and Wind speed during February at Magenet Complex



Source: Author

Figure 59: Sample from the dispersal of PM₁₀ sequence (24.1.2023)



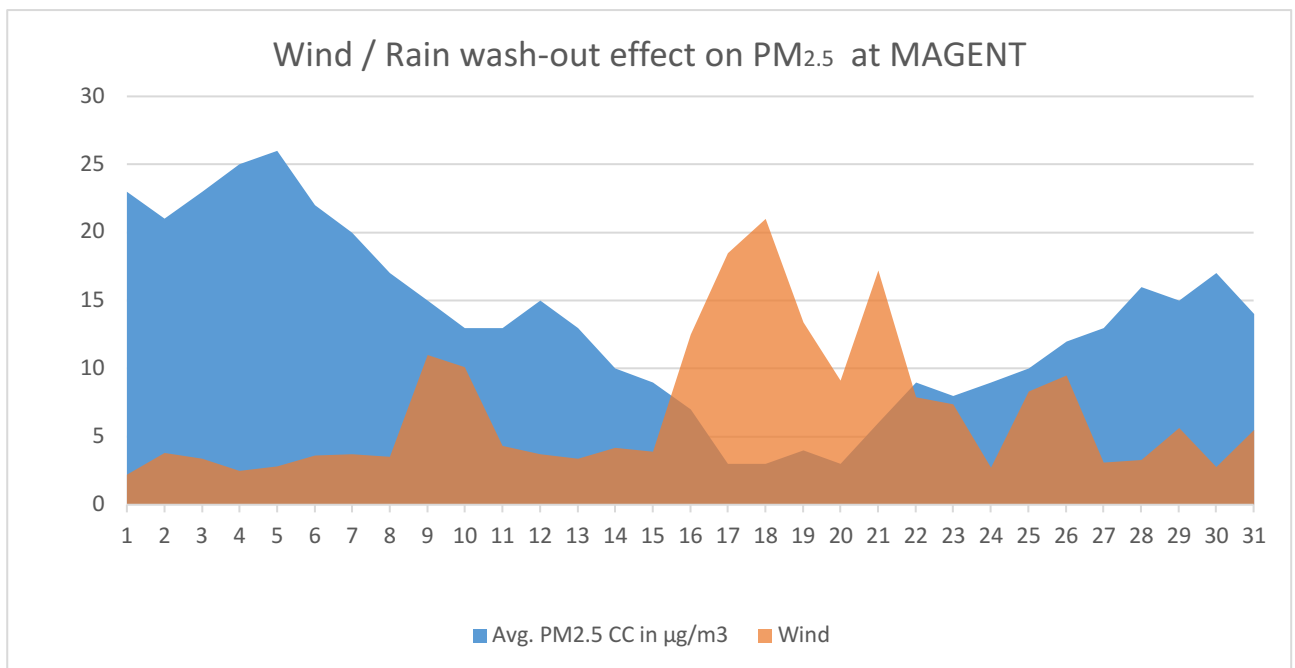
Source: Author

Table 10: PM_{2.5} concentrations and meteorological observations during January 2023 / Kontakt Magnet Complex

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM2.5 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring	Daytime
1	17	16	15	16	18	17	23	14	20	16	2,2	E	77%	Sunny	2hrs	10:00 - 12:20
2	12	12	15	11	16	16	21	13	20	13	3,8	E	57%	Sunny	2hrs	10:00 - 12:20
3	18	17	18	17	21	20	23	17	24	18	3,4	E	72%	Sunny	2hrs	10:00 - 12:20
4	16	17	23	16	22	22	29	19	24	19	2,5	E	79%	Cloudy	2hrs	10:00 - 12:20
5	19	18	23	17	24	24	30	21	27	20	2,8	SE	85%	Sunny	2hrs	10:00 - 12:20
6	16	12	17	16	24	19	22	16	23	17	3,6	E	93%	Sunny	2hrs	10:00 - 12:20
7	16	15	16	15	25	17	21	13	20	17	3,7	NE	50%	Sunny	2hrs	10:00 - 12:20
8	16	9	11	18	24	14	16	10	16	16	3,5	E	43%	Sunny	2hrs	10:00 - 12:20
9	17	14	11	15	17	15	14	9	16	15	11	SE	91%	Sunny	2hrs	10:00 - 12:20
10	18	15	8	17	16	12	16	7	17	15	10,1	SE	88%	Cloudy	2hrs	10:00 - 12:20
11	21	21	11	20	19	13	17	9	15	18	4,3	E	77%	Cloudy	2hrs	10:00 - 12:20
12	23	20	10	20	21	12	17	8	18	19	3,7	NW	77%	Cloudy	2hrs	10:00 - 12:20
13	23	19	9	23	22	11	13	8	12	19	3,4	W	66%	Sunny	2hrs	10:00 - 12:20
14	20	18	8	19	22	9	12	6	11	17	4,2	NW	75%	Sunny	2hrs	10:00 - 12:20
15	24	15	8	23	23	8	10	7	12	19	3,9	W	81%	Sunny	2hrs	10:00 - 12:20
16	18	13	9	17	14	7	11	5	13	14	12,5	SE	64%	Cloudy	2hrs	10:00 - 12:20
17	9	3	2	8	4	3	4	0	6	5	18,5	SE	87%	Rainy	2hrs	10:00 - 12:20
18	6	2	4	5	2	2	5	1	3	4	21	SE	86%	Storm	2hrs	10:00 - 12:20
19	4	0	1	3	0	3	4	0	4	2	13,4	SE	92%	Rainy	2hrs	10:00 - 12:20
20	5	0	3	4	0	3	5	0	5	2	9,1	SE	90%	Rainy	2hrs	10:00 - 12:20
21	4	4	2	4	2	7	8	1	9	3	17,2	SE	71%	Rainy	2hrs	10:00 - 12:20
22	5	5	7	4	6	11	10	4	10	5	7,9	NW	77%	Cloudy	2hrs	10:00 - 12:20
23	5	7	9	4	2	10	9	6	11	5	7,4	SW	93%	Rainy	2hrs	10:00 - 12:20
24	10	7	12	9	7	9	11	5	12	9	2,7	E	89%	Sunny	2hrs	10:00 - 12:20
25	10	6	8	9	8	14	16	6	15	8	8,3	NW	77%	Cloudy	2hrs	10:00 - 12:20
26	10	9	7	9	8	15	15	7	16	9	9,5	E	66%	Cloudy	2hrs	10:00 - 12:20
27	17	15	10	18	13	13	17	8	15	15	3,1	NW	83%	Cloudy	2hrs	10:00 - 12:20
28	23	19	14	21	18	16	19	11	17	19	3,3	NW	73%	Sunny	2hrs	10:00 - 12:20
29	19	18	14	20	17	17	18	10	18	18	5,65	NW	79%	Sunny	2hrs	10:00 - 12:20
30	17	17	15	22	21	18	21	10	20	18	2,77	NW	58%	Sunny	2hrs	10:00 - 12:20
31	24	19	18	22	20	15	17	12	15	21	5,48	N	78%	Sunny	2hrs	10:00 - 12:20
TOT	14,9	12,3	10,9	14,3	14,7	12,6	15,3	8,5	15,0	13,4	6,9					

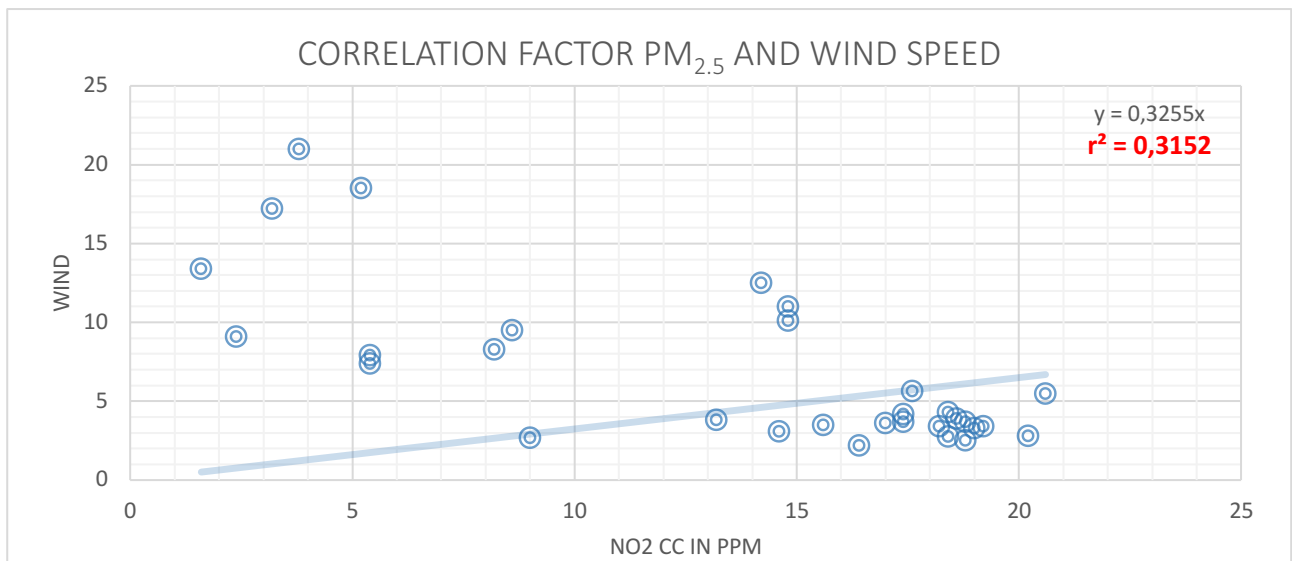
Source: Author

Graphic 9: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Magnet complex



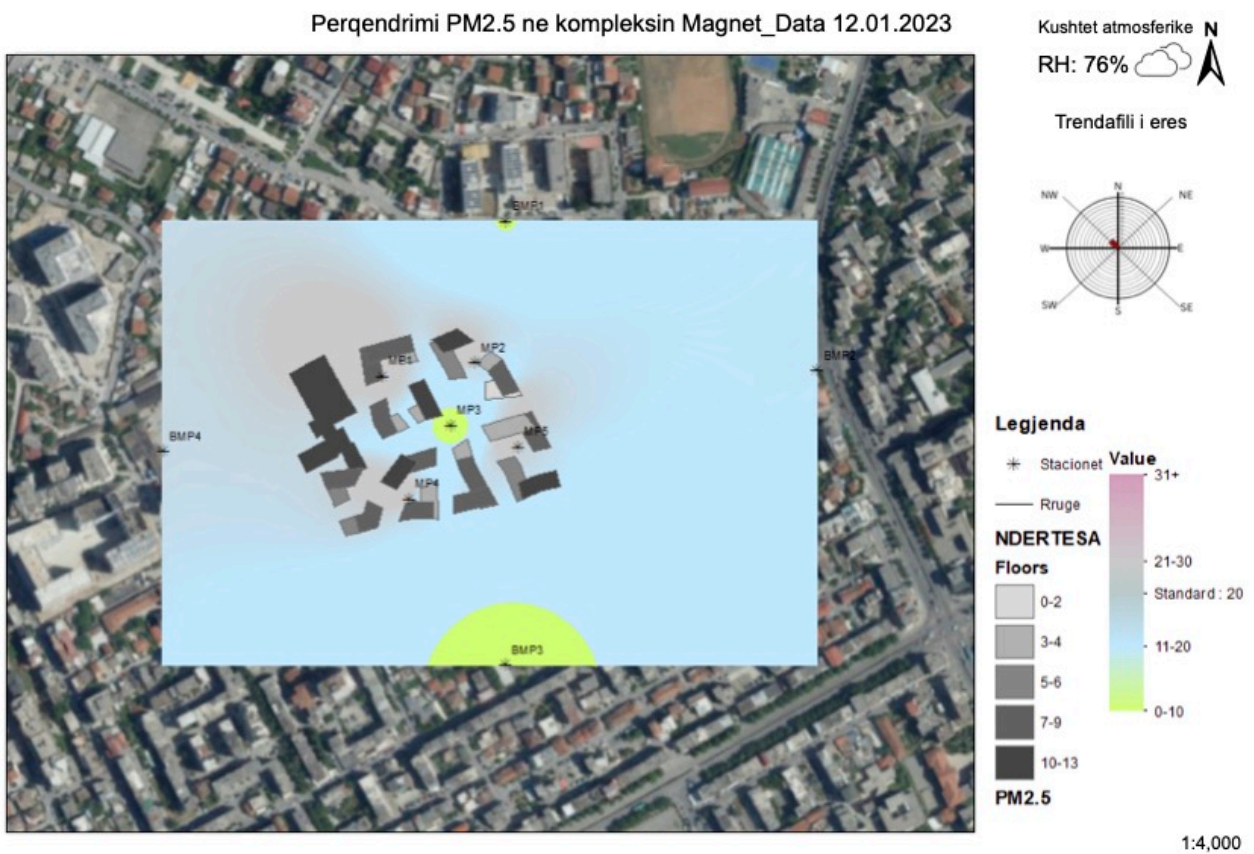
Source: Author

Graphic 10: Correlation factor between concentration of NO2 and Wind speed during February at Magenet Complex



Source: Author

Figure 60: Sample from the dispersal of PM_{2.5} sequence (12.1.2023)



Source: Author

Given that during January 19% of the time was characterized by rain's the correlation factor results indicating the effect of wind speed on the natural dispersal of air pollution within Magnet Complex have an overall result of $r=0.3$, nevertheless showing a moderate correlation between the to variables. If we exclude from the analysis the results of air monitoring from those 6 rainy days the correlation factor increases its result to $r=0.65$ indicating a strong correlation between these variables.

Table 11: Number of days with sun, cloud and rain during January at Magnet Complex:

Sun	Cloud	Rain
16	9	6
52%	29%	19%

Source: Author

Nevertheless, taking into consideration that the predominating wind directions are from North-West and East / South-East it appears that the assumptions on the creation of the vortex effect due to urban form near Monitoring Point 1 and 5 are correct.

Table 12: Number of days indicating the orientation of the wind during January at Magnet Complex

N	S	W	E	NW	NE	SE	SW
1	0	2	9	8	1	9	1
3%	0%	6%	29%	26%	3%	29%	3%

Source: Author

Coming to the conclusion that MP5 could be considered Air Pollution Cavity Area given that the average concentration is at least 21% higher during January than all other nearby monitoring points exposed.

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During February the author had the closest to ideal condition for the interpretation of his findings given that throughout that month a light rain occurred only during 26th February. Herby 96% of the monitoring results indicate the direct correlation of wind on the dispersal of air pollutants within the Magnet Complex.

Table 13: Number of days with sun, cloud and rain during February at Magnet complex.

Sun	Cloud	Rain
14	13	1
50%	46%	4%

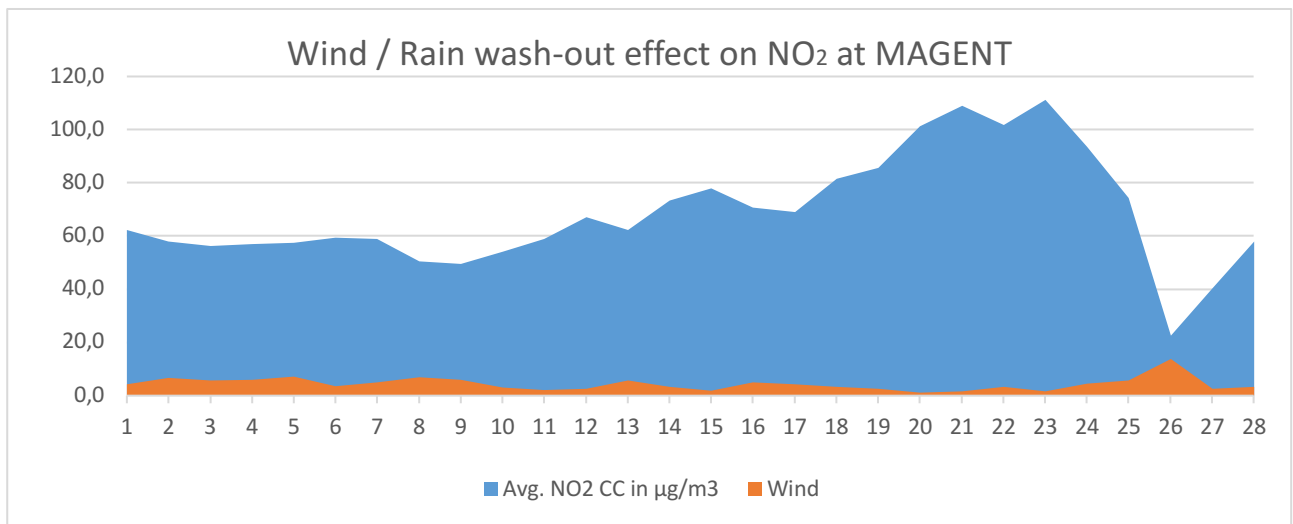
Source: Author

Table 14: NO₂ concentrations and meteorological observations during February 2023 / Magnet Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. NO2 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring length	
1	67	57	51	62	74	75	150	79	93	62,2	4,3	E	71%	Sunny	2hrs	10.30-12.00
2	62	51	45	56	76	78	117	79	101	58,0	6,7	E	85%	Cloudy	2hrs	10.30-12.00
3	63	48	39	59	72	77	110	71	80	56,2	5,8	NW	93%	Cloudy	2hrs	10.30-12.00
4	67	46	40	55	77	84	103	77	88	57,0	5,9	NW	84%	Cloudy	2hrs	10.30-12.00
5	69	43	41	56	78	87	92	79	89	57,4	7,1	N	67%	Sunny	2hrs	10.30-12.00
6	71	41	44	57	84	96	112	83	98	59,4	3,5	N	59%	Sunny	2hrs	10.30-12.00
7	64	39	44	59	88	103	105	76	90	58,8	5,1	E	61%	Sunny	2hrs	10.30-12.00
8	50	41	32	52	77	92	98	60	72	50,4	6,9	E	52%	Sunny	2hrs	10.30-12.00
9	47	38	34	55	74	90	108	57	70	49,6	1,6	N	51%	Cloudy	2hrs	10.30-12.00
10	51	42	36	59	83	103	113	64	79	54,2	3	E	66%	Cloudy	2hrs	10.30-12.00
11	55	48	41	61	89	113	154	62	69	58,8	2	N	63%	Sunny	2hrs	10.30-12.00
12	72	46	42	76	99	128	164	85	100	67,0	2,5	E	51%	Cloudy	2hrs	10.30-12.00
13	70	44	38	77	83	109	145	88	111	62,4	5,8	E	73%	Sunny	2hrs	10.30-12.00
14	77	53	50	91	96	129	151	108	130	73,4	3,3	SW	75%	Sunny	2hrs	10.30-12.00
15	83	61	59	93	94	128	158	111	135	78,0	1,9	N	75%	Sunny	2hrs	10.30-12.00
16	72	57	49	89	86	120	126	104	127	70,6	5	N	83%	Sunny	2hrs	10.30-12.00
17	76	53	42	84	90	127	113	96	117	69,0	4,3	N	93%	Sunny	2hrs	10.30-12.00
18	83	65	58	99	103	148	144	113	138	81,6	3,2	E	89%	Cloudy	2hrs	10.30-12.00
19	89	70	62	102	105	154	163	133	163	85,6	2,6	E	92%	Cloudy	2hrs	10.30-12.00
20	107	88	85	111	115	171	179	156	191	101,2	1,2	N	95%	Cloudy	2hrs	10.30-12.00
21	112	94	98	118	123	186	174	172	211	109,0	1,7	E	72%	Sunny	2hrs	10.30-12.00
22	103	86	87	116	117	180	168	153	188	101,8	3,2	E	84%	Sunny	2hrs	10.30-12.00
23	109	97	98	124	128	200	184	163	201	111,2	1,7	N	91%	Cloudy	2hrs	10.30-12.00
24	91	78	74	118	107	170	156	135	167	93,6	4,5	SE	92%	Sunny	2hrs	10.30-12.00
25	77	61	53	108	72	116	139	95	118	74,2	5,6	SE	76%	Sunny	2hrs	10.30-12.00
26	23	19	8	41	22	36	69	29	35	22,6	13,8	SE	89%	Light Rain	2hrs	10.30-12.00
27	49	44	32	38	39	65	80	61	76	40,4	2,5	E	91%	Cloudy	2hrs	10.30-12.00
28	66	42	38	71	73	123	97	82	103	58,0	3,2	E	76%	Cloudy	2hrs	10.30-12.00
TOT	72,3	55,4	50,7	78,1	86,6	117,5	131,2	95,4	115,7	68,6	4,4					

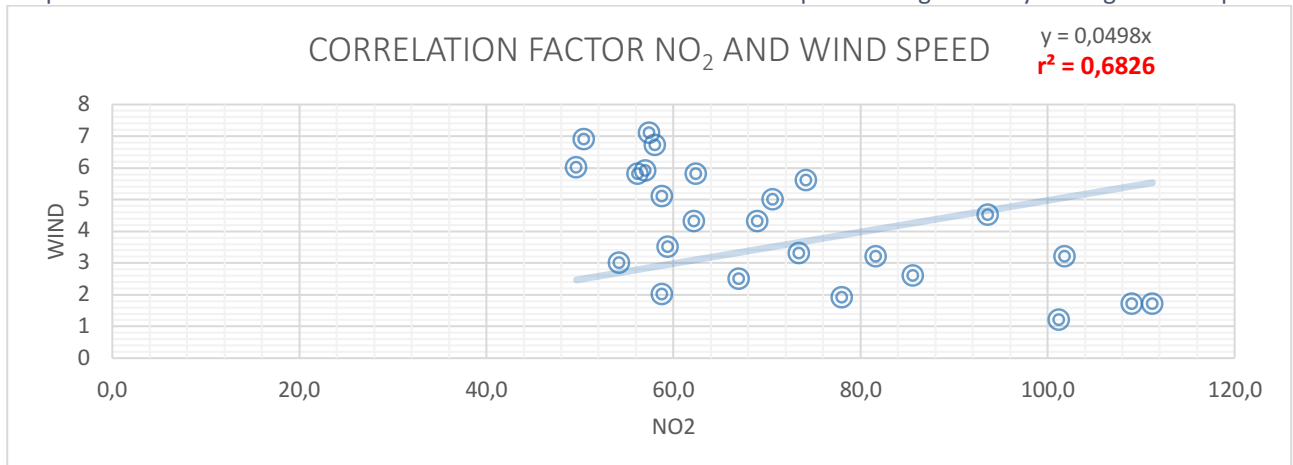
Source: Author

Graphic 11: Effect of wind and rain on the wash-out of NO₂ concentration at Magnet complex during February.



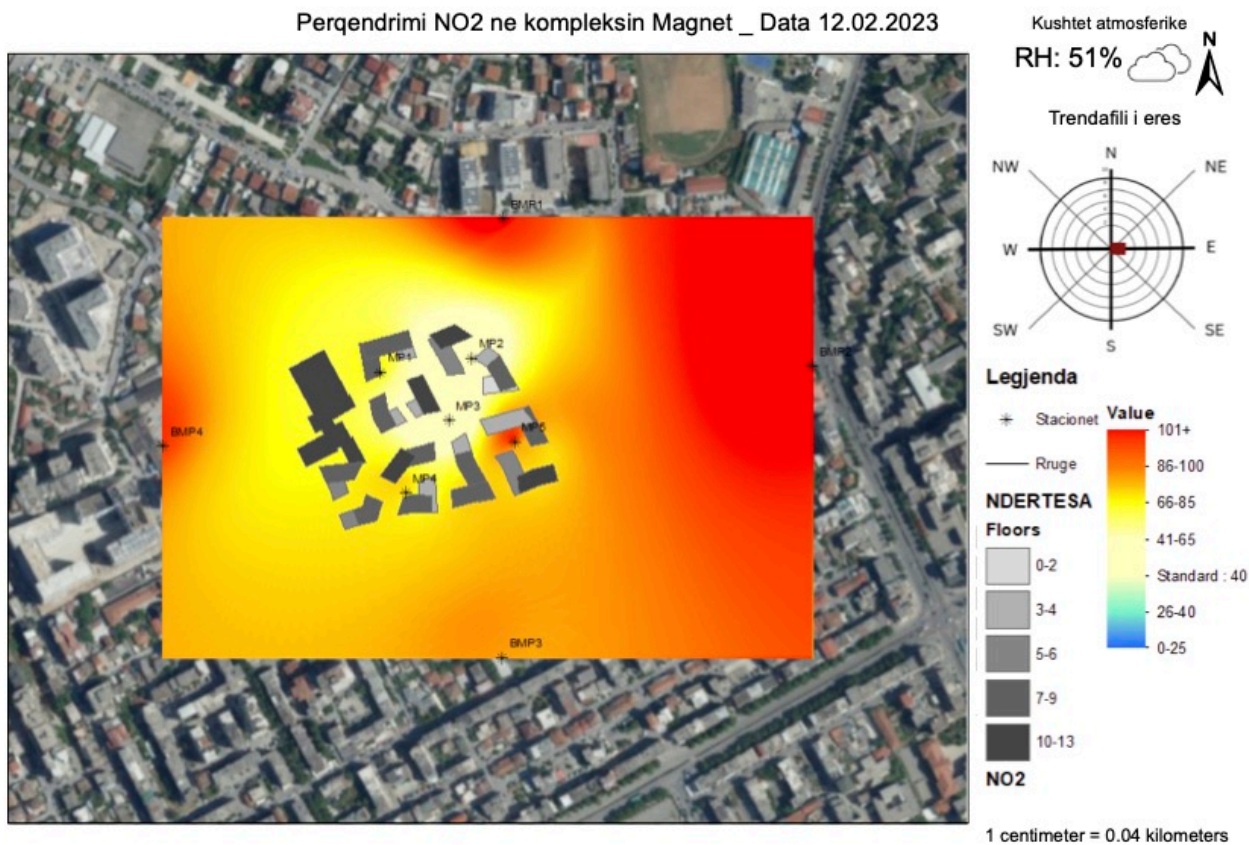
Source: Author

Graphic 12: Correlation factor between concentration of NO₂ and Wind speed during February at Magenet Complex



Source: Author

Figure 61: Sample from the dispersal of NO₂ sequence (12.2.2023)



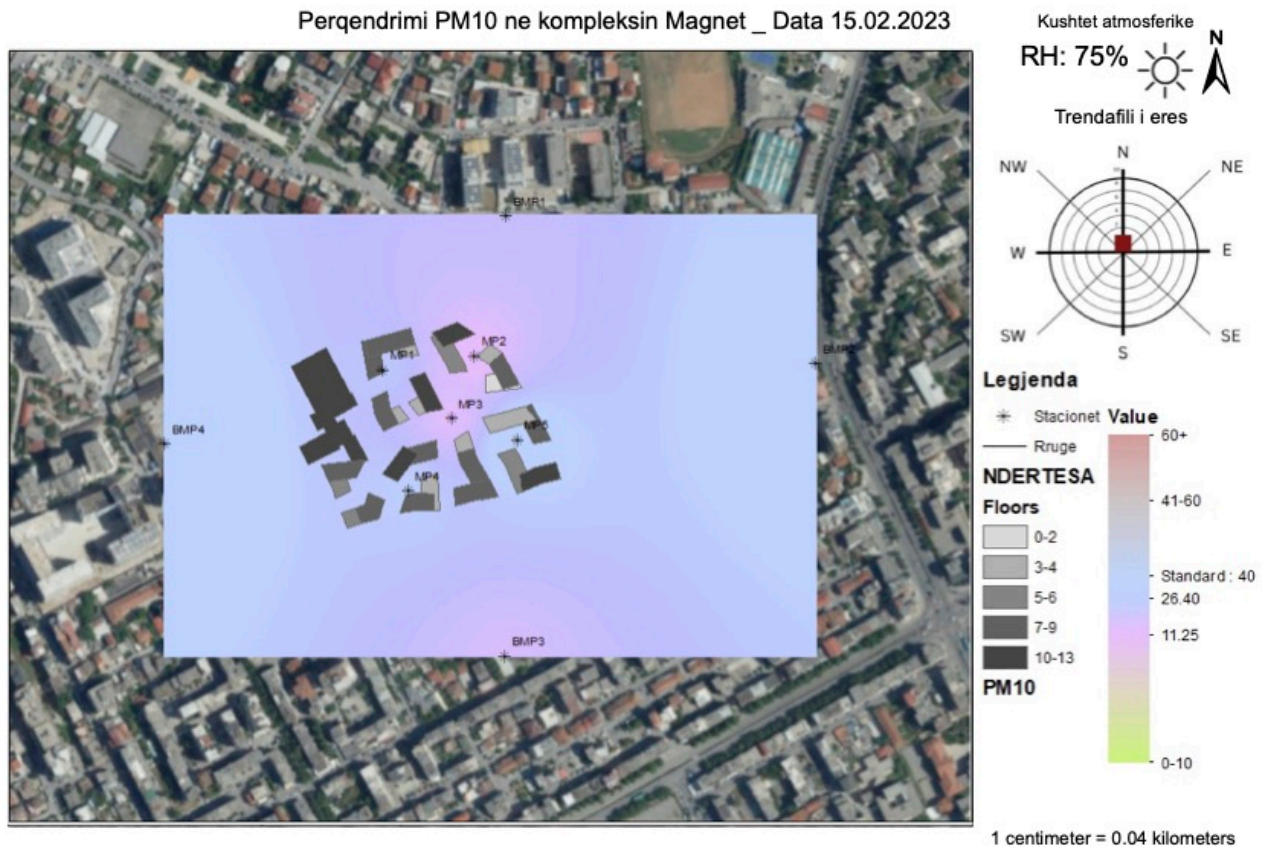
Source: Author

Table 15: PM₁₀ concentrations and meteorological observations during February 2023 / Magnet Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m ³	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	25,2	23,3	24,2	25,3	25,6	26,3	27,5	25,3	27,2	24,7	4,3	E	71%	Sunny	2hrs	10.30-12.00
2	24,8	16,8	17,7	24,0	26,2	19,9	24,6	18,9	25,1	21,9	6,7	E	85%	Cloudy	2hrs	10.30-12.00
3	25,2	14,3	14,8	24,7	27,0	18,2	25,3	15,9	24,9	21,2	3,8	NW	93%	Cloudy	2hrs	10.30-12.00
4	26,3	15,6	15,2	25,2	26,3	17,5	25,8	16,6	23,5	21,7	3,9	NW	84%	Cloudy	2hrs	10.30-12.00
5	21,6	13,2	14,5	22,2	23,4	16,9	24,2	15,2	22,1	19,0	7,1	N	67%	Sunny	2hrs	10.30-12.00
6	22,5	15,7	16,9	24,8	25,7	19,1	28,0	18,1	26,7	21,0	3,5	N	59%	Sunny	2hrs	10.30-12.00
7	18,7	14,7	13,8	19,7	23,2	16,6	22,6	15,1	24,5	18,0	5,1	E	61%	Sunny	2hrs	10.30-12.00
8	16,2	13,4	14,2	17,4	22,4	17,0	21,8	15,6	23,2	16,7	6,9	E	52%	Sunny	2hrs	10.30-12.00
9	15,5	12,7	13,3	16,4	23,4	15,8	21,5	14,8	19,7	16,3	6	N	51%	Cloudy	2hrs	10.30-12.00
10	16,0	14,2	15,6	18,2	24,8	17,9	22,9	16,6	22,2	17,8	3	E	66%	Cloudy	2hrs	10.30-12.00
11	19,2	16,8	19,5	21,4	26,7	21,6	27,0	20,5	24,8	20,7	2	N	63%	Sunny	2hrs	10.30-12.00
12	21,6	18,2	20,5	23,5	28,2	22,9	29,4	21,7	27,0	22,4	2,5	E	51%	Cloudy	2hrs	10.30-12.00
13	19,5	16,1	19,2	22,7	27,7	21,4	26,3	20,3	26,1	21,0	3,8	E	73%	Sunny	2hrs	10.30-12.00
14	22,7	15,6	18,4	21,5	28,5	20,8	29,0	19,4	28,2	21,3	3,3	SW	75%	Sunny	2hrs	10.30-12.00
15	26,5	21,3	22,3	27,2	29,8	24,8	32,0	23,3	33,4	25,4	1,9	N	75%	Sunny	2hrs	10.30-12.00
16	24,4	20,1	20,7	28,5	29,3	23,4	31,0	22,2	29,5	24,6	5	N	83%	Sunny	2hrs	10.30-12.00
17	25,6	23,3	22,5	28,2	30,1	25,2	33,0	23,9	27,6	25,9	4,3	N	93%	Cloudy	2hrs	10.30-12.00
18	25,2	22,5	23,7	26,2	31,2	26,1	36,0	24,7	31,7	25,8	3,2	E	89%	Cloudy	2hrs	10.30-12.00
19	26,6	24,3	25,5	27,8	30,5	28,3	37,0	26,8	33,5	26,9	2,6	E	92%	Cloudy	2hrs	10.30-12.00
20	27,5	25,8	26,0	30,5	31,2	28,7	44,0	27,2	38,7	28,2	1,2	N	95%	Cloudy	2hrs	10.30-12.00
21	29,4	28,5	27,8	32,2	33,8	30,5	47,8	29,3	43,6	30,3	1,7	E	72%	Sunny	2hrs	10.30-12.00
22	31,2	27,1	30,2	34,2	35,2	33,0	52,0	31,7	46,5	31,6	3,2	E	84%	Sunny	2hrs	10.30-12.00
23	34,2	32,7	33,5	37,5	39,5	36,1	56,5	34,7	50,1	35,5	1,7	N	91%	Cloudy	2hrs	10.30-12.00
24	35,1	33,5	34,2	35,6	32,2	37,0	47,0	35,5	46,6	34,1	4,5	SE	92%	Sunny	2hrs	10.30-12.00
25	33,2	32,4	31,2	34,4	31,5	33,6	33,0	32,6	34,5	32,5	5,6	SE	76%	Sunny	2hrs	10.30-12.00
26	13,2	12,6	12,7	12,5	13,6	14,8	14,0	13,8	12,8	12,9	13,8	SE	89%	Light Rain	2hrs	10.30-12.00
27	23,5	22,6	24,2	23,5	22,7	26,6	32,7	25,4	28,7	23,3	2,5	E	91%	Cloudy	2hrs	10.30-12.00
28	25,8	24,1	25,5	23,8	25,1	27,6	39,5	26,5	33,5	24,9	3,2	E	76%	Cloudy	2hrs	10.30-12.00
TOT	24,2	20,4	21,4	25,3	27,7	23,8	31,8	22,6	29,9	23,8	4,4					

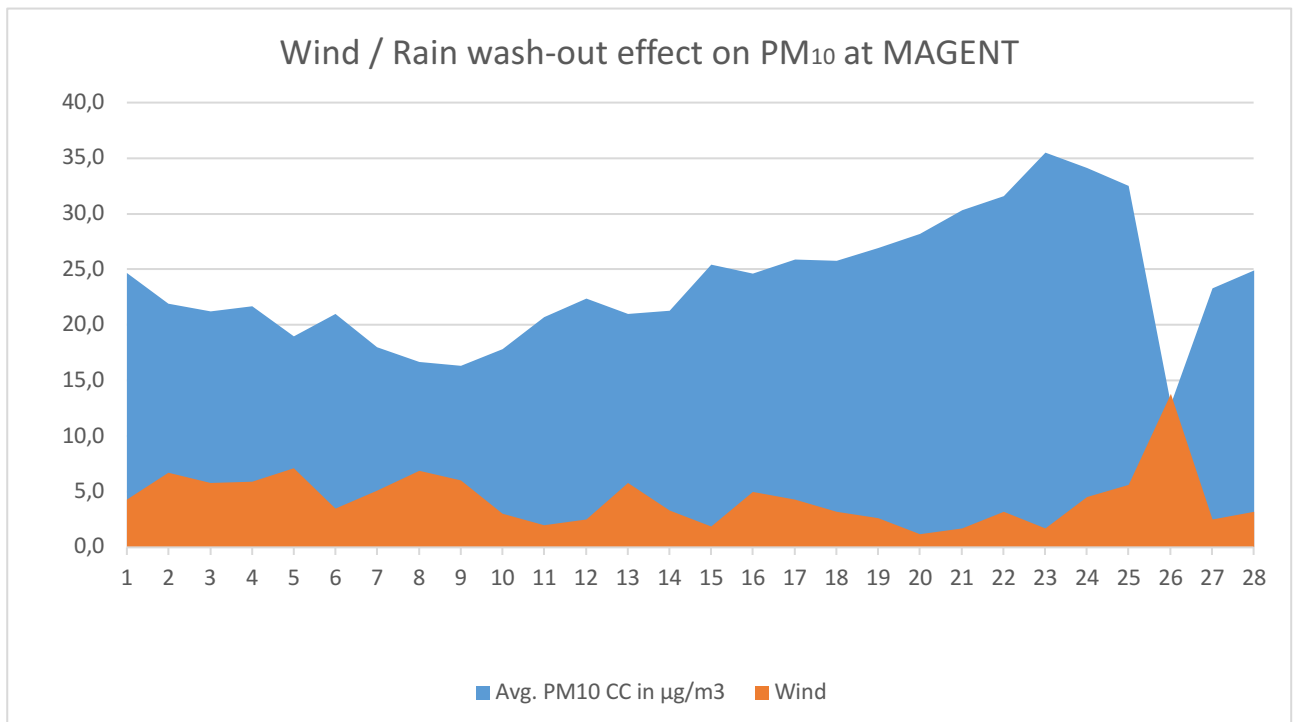
Source: Author

Figure 62: Sample from the dispersal of PM₁₀ sequence (15.2.2023)



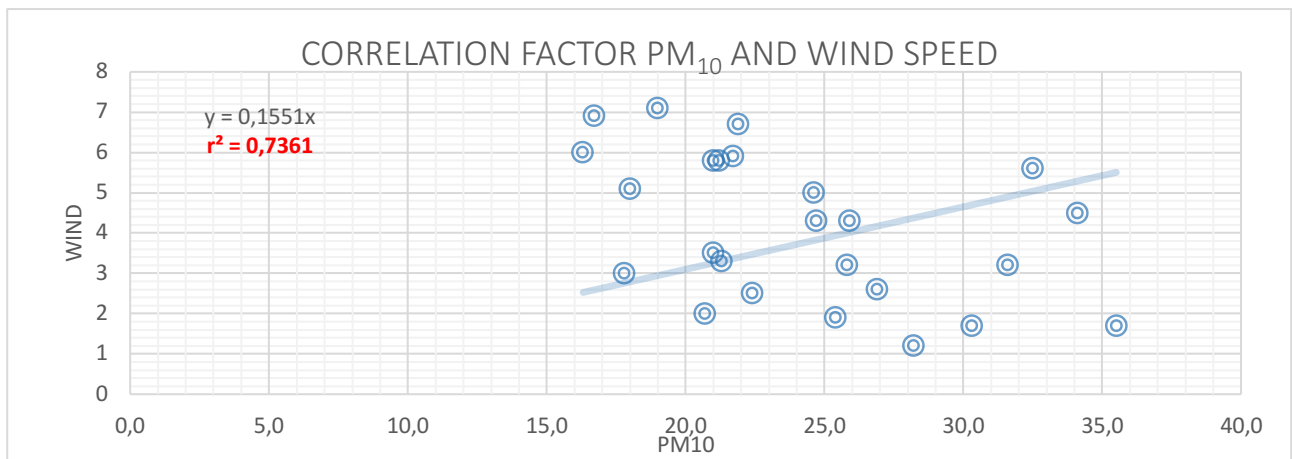
Source: Author

Graphic 13: Effect of wind and rain on the wash-out of PM₁₀ concentration at Magnet complex during January.



Source: Author

Graphic 14: Correlation factor between concentration of PM₁₀ and Wind speed during February at Magnet Complex.



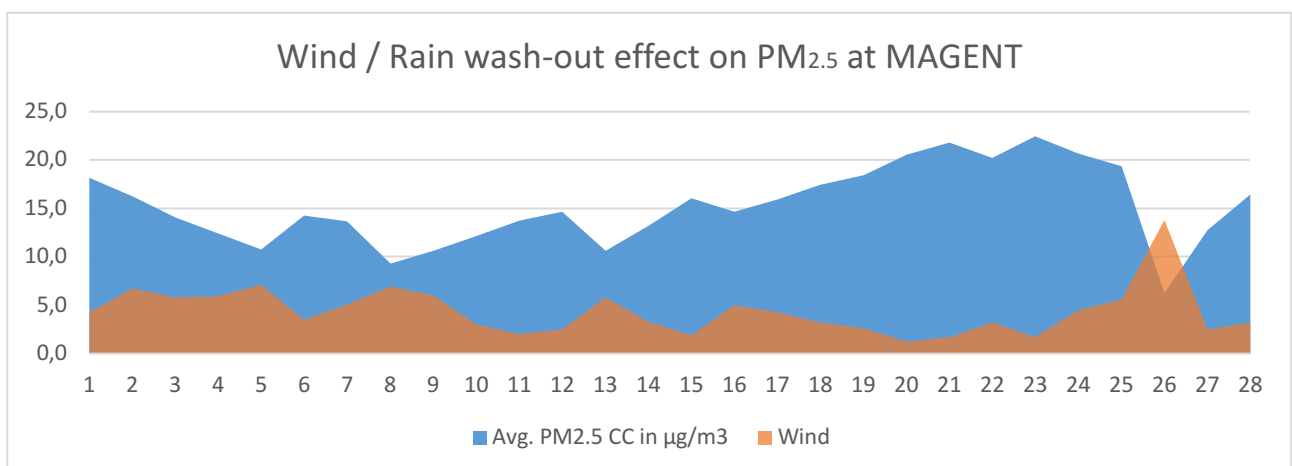
Source: Author

Table 16: PM_{2.5} concentrations and meteorological observations during February 2023 / Kontakt Magnet Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM2.5 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	18,50	17,20	17,80	18,50	18,90	19,5	22,7	17,4	19,5	18,2	4,3	E	71%	Sunny	2hrs	10.30 -12.00
2	17,70	12,00	15,60	17,20	18,80	17,8	22,5	16,1	17,8	16,3	6,7	E	85%	Cloudy	2hrs	10.30 -12.00
3	16,20	9,10	11,80	15,80	17,30	16,2	21,3	13,2	16,2	14,0	5,8	NW	93%	Cloudy	2hrs	10.30 -12.00
4	15,00	8,90	8,70	14,40	15,10	17,7	18,8	10,3	17,7	12,4	5,9	NW	84%	Cloudy	2hrs	10.30 -12.00
5	12,80	6,80	7,70	12,70	13,70	14,1	17,2	9,4	14,1	10,7	7,1	N	67%	Sunny	2hrs	10.30 -12.00
6	15,20	10,60	11,40	16,70	17,40	17,2	20,4	12,5	17,2	14,3	3,5	N	59%	Sunny	2hrs	10.30 -12.00
7	14,10	11,20	10,60	14,80	17,50	15,4	21,0	12,1	15,4	13,6	5,1	E	61%	Sunny	2hrs	10.30 -12.00
8	9,10	7,50	7,90	9,50	12,40	13,4	16,3	9,3	13,4	9,3	6,9	E	52%	Sunny	2hrs	10.30 -12.00
9	10,20	8,30	8,70	10,80	15,30	11,2	19,3	10,1	11,2	10,7	6	N	51%	Cloudy	2hrs	10.30 -12.00
10	11,00	9,70	10,70	12,50	17,00	14,2	21,2	12,0	14,2	12,2	3	E	66%	Cloudy	2hrs	10.30 -12.00
11	12,70	11,10	12,90	14,20	17,70	17,0	21,8	14,2	17,0	13,7	2	N	63%	Sunny	2hrs	10.30 -12.00
12	14,10	11,80	13,60	15,30	18,40	18,5	21,9	14,8	18,5	14,6	2,5	E	51%	Cloudy	2hrs	10.30 -12.00
13	9,80	8,10	9,70	11,50	13,90	16,2	17,5	10,9	16,2	10,6	5,8	E	73%	Sunny	2hrs	10.30 -12.00
14	14,10	9,40	11,50	13,40	17,80	18,7	21,6	12,9	18,7	13,2	3,3	SW	75%	Sunny	2hrs	10.30 -12.00
15	16,70	13,40	14,00	17,30	18,80	21,2	22,8	15,5	21,2	16,0	1,9	N	75%	Sunny	2hrs	10.30 -12.00
16	14,50	12,00	12,30	17,00	17,50	20,7	21,6	13,9	20,7	14,7	5	N	83%	Sunny	2hrs	10.30 -12.00
17	15,70	14,30	13,80	17,30	18,60	21,1	21,8	15,8	21,1	15,9	4,3	N	93%	Cloudy	2hrs	10.30 -12.00
18	17,40	15,60	14,40	18,10	21,60	23,2	25,1	15,9	23,2	17,4	3,2	E	89%	Cloudy	2hrs	10.30 -12.00
19	18,20	16,60	17,50	19,00	20,90	24,1	24,0	18,7	24,1	18,4	2,6	E	92%	Cloudy	2hrs	10.30 -12.00
20	20,00	18,70	19,00	22,30	22,80	27,6	26,3	20,4	27,6	20,6	1,2	N	95%	Cloudy	2hrs	10.30 -12.00
21	21,20	20,50	20,00	23,10	24,30	29,1	27,4	21,6	29,1	21,8	1,7	E	72%	Sunny	2hrs	10.30 -12.00
22	20,10	17,00	19,40	21,90	22,60	23,7	25,8	20,6	23,7	20,2	3,2	E	84%	Sunny	2hrs	10.30 -12.00
23	21,70	20,70	21,20	23,70	25,00	26,9	28,1	23,2	26,9	22,5	1,7	N	91%	Cloudy	2hrs	10.30 -12.00
24	21,30	20,30	20,50	21,60	19,60	22,6	23,4	21,5	22,6	20,7	4,5	SE	92%	Sunny	2hrs	10.30 -12.00
25	19,70	19,20	18,70	20,50	18,80	21,7	22,0	19,7	21,7	19,4	5,6	SE	76%	Sunny	2hrs	10.30 -12.00
26	6,50	6,10	6,20	5,90	6,70	11,0	9,8	7,4	11,0	6,3	13,8	SE	89%	Light Rain	2hrs	10.30 -12.00
27	12,90	12,40	13,30	12,70	12,50	15,2	15,5	14,4	15,2	12,8	2,5	E	91%	Cloudy	2hrs	10.30 -12.00
28	17,00	15,90	16,80	15,50	16,90	17,9	19,9	18,0	17,9	16,4	3,2	E	76%	Cloudy	2hrs	10.30 -12.00
TOT	15,5	13,0	13,8	16,2	17,8	19,0	21,3	15,1	19,0	15,2	4,4					

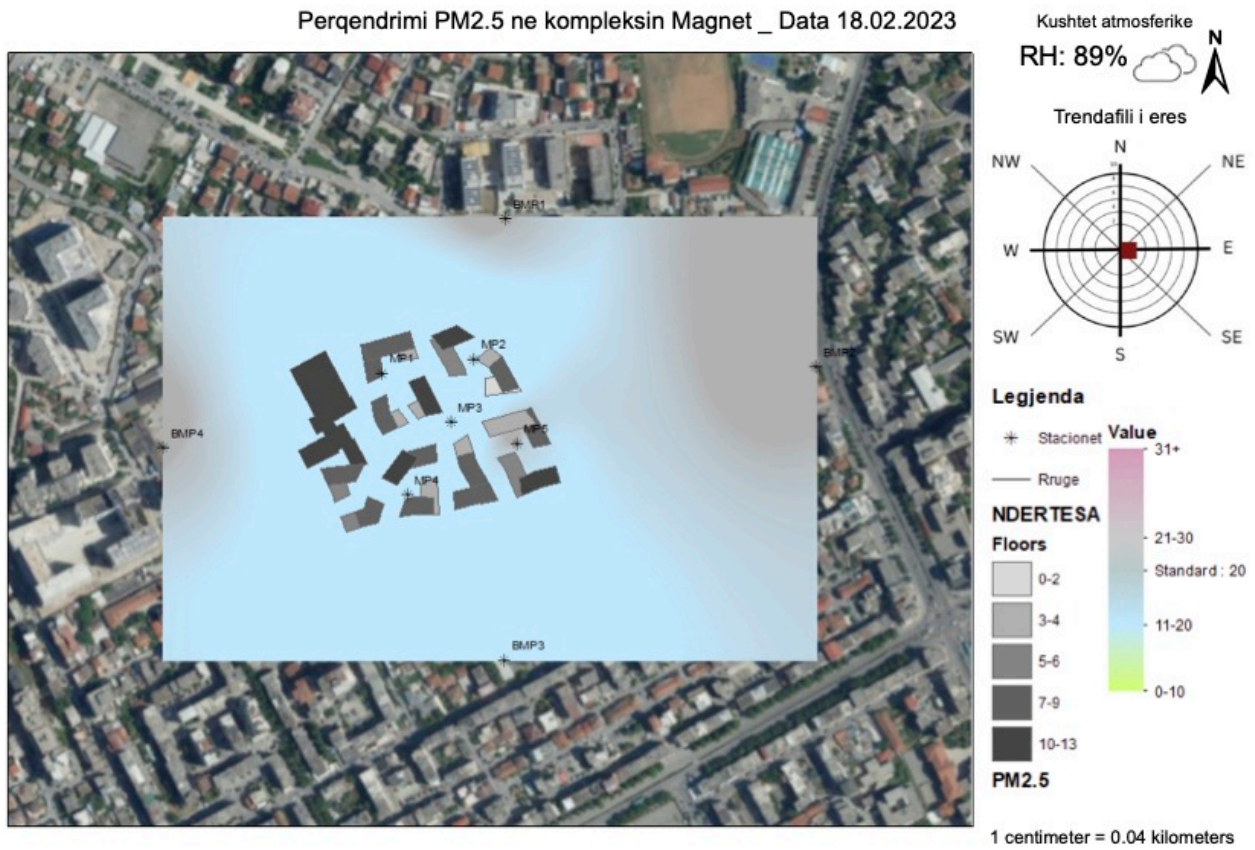
Source: Author

Graphic 15: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Magnet complex during February 2023.



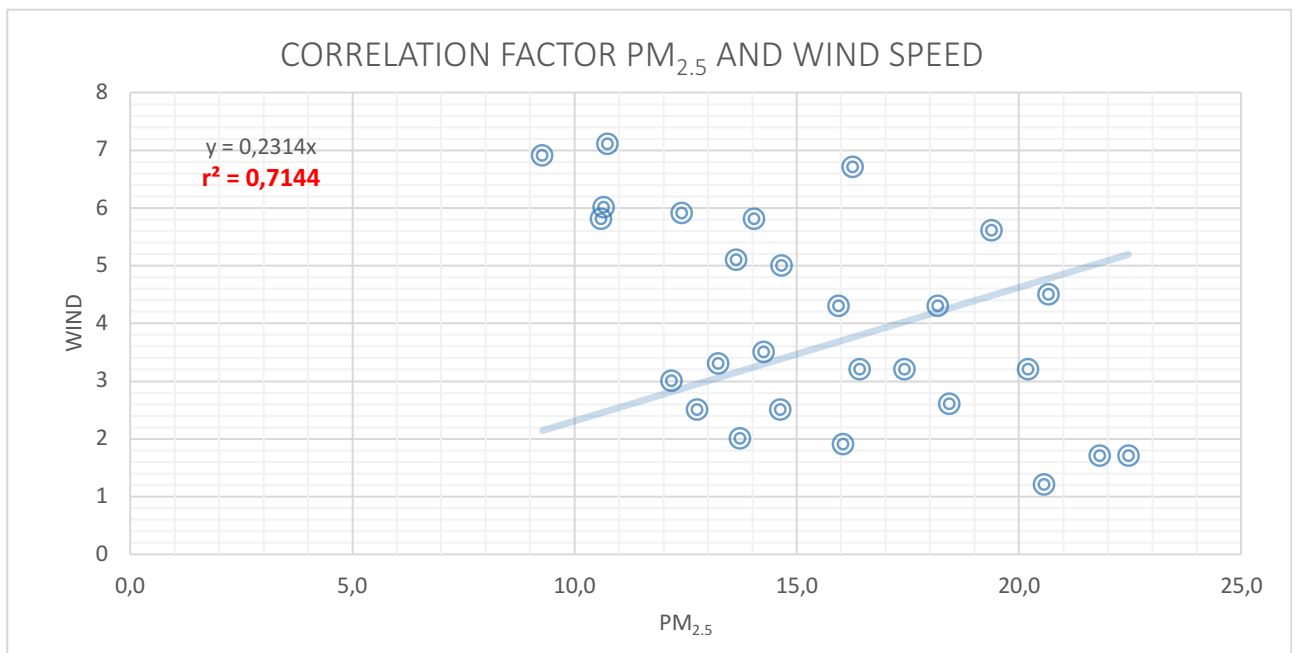
Source: Author

Figure 63: Sample from the dispersal of PM_{2.5} sequence (18.2.2023)



Source: Author

Graphic 16: Correlation factor between concentration of PM_{2.5} and Wind speed during February at Magnet Complex.



Source: Author

Given that during February 96% of the time was characterized by dry weather the correlation factor results indicating the effect of wind speed on the natural dispersal of air pollution within Magnet Complex have an overall result of $r=0.72$, indicating a strong correlation between these variables.

Nevertheless, taking into consideration that the predominating wind directions are from North or those from East it appears that the assumptions on the creation of the vortex effect slightly change from the results of January.

Table 17: Number of days indicating the orientation of the wind during February at Magnet Complex

N	S	W	E	NW	NE	SE	SW
9	0	0	13	2	0	3	1
32%	0%	0%	46%	7%	0%	11%	4%

Source: Author

Concluding that the change on wind patterns during February, and the drought weather along all the month indicates MP.1, MP.4 and MP5 to be considerably under the influence of Air Pollution Cavity Area given that the average concentration of all these three locations 17.8% higher during February than all other nearby monitoring points exposed.

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March on the other hand reserved another interesting meteorological pattern. Predominating wind patterns from East combined with the fact that during the first half of the month, the weather was either cloudy or rainy whilst the second part of the month. Such occurrence contributed to an overall reduction of all pollutant concentration at the area. Offering thus the possibility for the research to obtain an occurrence where both scenarios when pollution accumulated from February was totally washed out and latter build up during the second part of the month. Providing thus a temporal perspective upon the creation of the pollution retention phenomena in such particular meteorological circumstances.

Table 18: Number of days with sun, cloud and rain during March at Magnet complex.

Sun	Cloud	Rain
14	10	7
45%	32%	23%

Source: Author

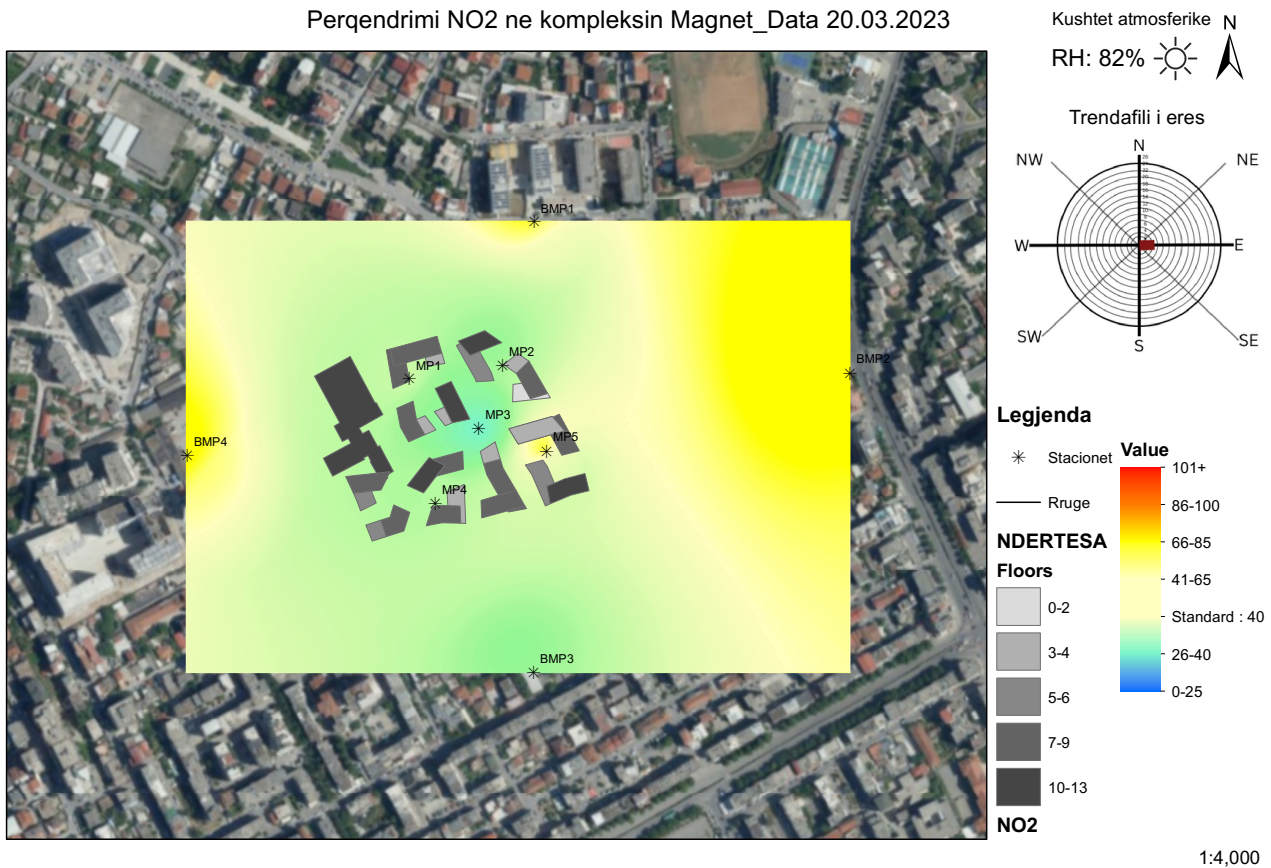
Table 19: NO₂ concentrations and meteorological observations during March 2023 / Magnet Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	NO2 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	54	43	37	52	58	66,0	83,4	44,4	63,9	49	10,0	E	63%	Cloudy / Rainy	2hrs	10.20 - 12.45
2	58	53	51	57	63	67,3	88,4	58,3	73,9	56	4,7	E	84%	Cloudy	2hrs	10.20 - 12.45
3	68	61	58	61	67	75,2	92,9	65,1	82,4	63	1,8	E	89%	Cloudy	2hrs	10.20 - 12.45
4	31	30	36	34	32	48,7	58,2	43,3	51,7	33	2,5	E	85%	Rainy	2hrs	10.20 - 12.45
5	51	49	45	48	55	62,1	80,4	52,5	69,9	50	2,1	E	90%	Cloudy	2hrs	10.20 - 12.45
6	44	47	41	42	37	55,7	62,0	48,5	67,5	42	10,8	SE	91%	Cloudy	2hrs	10.20 - 12.45
7	36	40	39	38	33	51,4	58,0	46,2	60,5	37	6,4	E	77%	Cloudy	2hrs	10.20 - 12.45
8	28	22	24	22	26	36,4	52,2	31,0	43,7	24	9,4	SE	93%	Rainy	2hrs	10.20 - 12.45
9	26	25	25	29	27	43,4	52,8	32,4	46,3	26	7,6	SE	71%	Cloudy	2hrs	10.20 - 12.45
10	17	14	18	20	18	34,6	44,3	25,1	35,8	17	8,6	SE	77%	Rainy	2hrs	10.20 - 12.45
11	12	12	11	14	12	28,4	38,0	18,2	33,5	12	10,4	SE	93%	Rainy	2hrs	10.20 - 12.45
12	25	26	22	26	24	40,2	49,7	29,3	47,2	25	5,7	E	92%	Cloudy	2hrs	10.20 - 12.45
13	30	32	27	31	29	45,2	54,5	34,5	53,0	30	3,9	E	67%	Sunny	2hrs	10.20 - 12.45
14	32	36	30	32	33	46,5	58,8	37,5	57,3	33	4,3	SE	55%	Cloudy	2hrs	10.20 - 12.45
15	16	13	17	19	18	33,7	44,4	24,1	34,9	17	12,4	SE	74%	Rainy	2hrs	10.20 - 12.45
16	33	31	26	30	28	44,6	53,8	33,6	52,3	30	3,2	N	70%	Cloudy	2hrs	10.20 - 12.45
17	31	28	25	29	32	43,4	57,5	32,7	49,0	29	5,0	E	68%	Sunny	2hrs	10.20 - 12.45
18	36	31	28	33	40	47,5	80,8	20,5	67,3	34	2,1	E	72%	Sunny	2hrs	10.20 - 12.45
19	40	42	31	38	47	52,1	72,4	38,5	62,9	40	2,5	E	63%	Sunny	2hrs	10.20 - 12.45
20	46	43	35	44	56	57,7	81,5	42,0	64,0	45	2,9	E	82%	Sunny	2hrs	10.20 - 12.45
21	29	28	24	31	29	45,1	54,3	31,6	48,8	28	1,0	NE	91%	Rainy	2hrs	10.20 - 12.45
22	35	32	30	34	32	48,5	57,3	38,0	52,8	33	2,9	E	92%	Sunny	2hrs	10.20 - 12.45
23	45	44	38	42	46	56,7	71,2	46,3	64,7	43	1,7	E	67%	Sunny	2hrs	10.20 - 12.45
24	52	51	47	49	50	63,3	75,8	54,3	72,3	50	6,7	E	66%	Sunny	2hrs	10.20 - 12.45
25	49	47	40	45	43	59,6	69,4	47,0	68,9	45	4,5	NW	66%	Sunny	2hrs	10.20 - 12.45
26	54	53	44	51	39	65,5	65,2	51,1	74,7	48	18,0	NW	86%	Sunny	2hrs	10.20 - 12.45
27	31	30	30	32	31	46,4	56,9	37,3	51,4	31	8,3	NW	63%	Rainy	2hrs	10.20 - 12.45
28	36	32	35	41	38	55,2	63,8	42,2	53,3	36	2,2	N	83%	Sunny	2hrs	10.20 - 12.45
29	33	27	30	32	31	46,2	56,4	37,6	47,9	31	11,2	NE	55%	Sunny	2hrs	10.20 - 12.45
30	28	24	28	27	28	41,6	53,4	36,0	44,9	27	7,5	E	62%	Sunny	2hrs	10.20 - 12.45
31	25	23	22	25	22	37,2	45,4	29,6	41,9	23	6,2	E	76%	Sunny	2hrs	10.20 - 12.45
TOT	34,0	32,6	30,3	33,5	33,4	47,7	59,6	37,2	54,2	32,8	6,1					

Source: Author

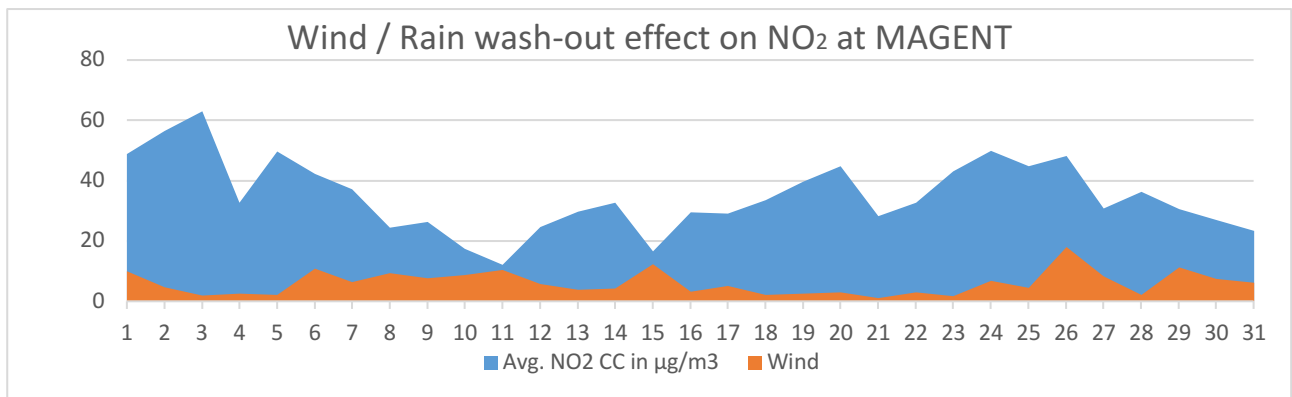
Figure 64: Sample from the dispersal of NO₂ sequence (20.3.2023)

Perqendrimi NO₂ ne kompleksin Magnet_Data 20.03.2023



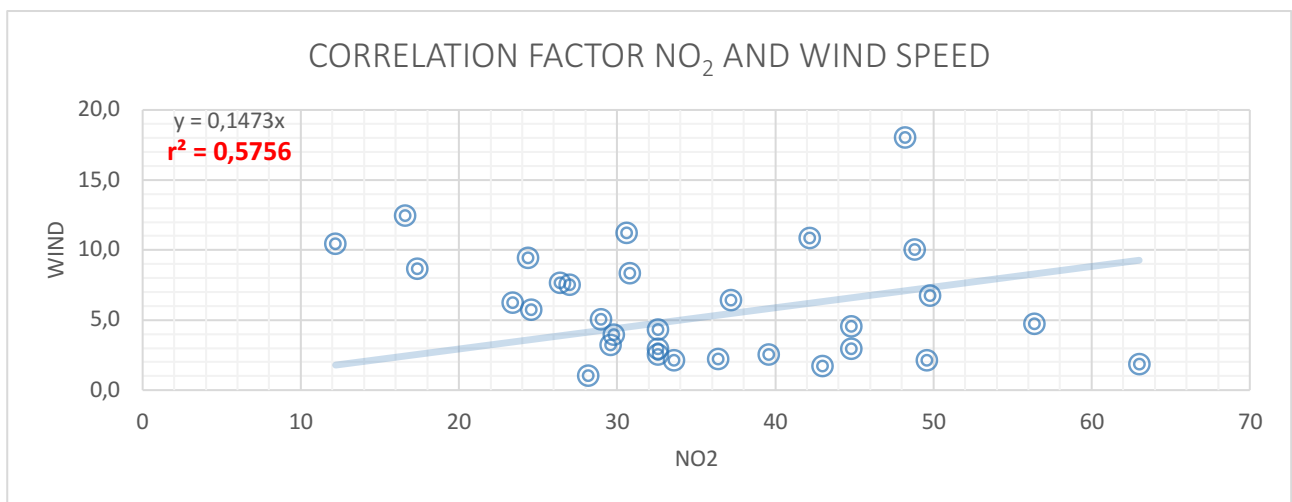
Source: Author

Graphic 17: Effect of wind and rain on the wash-out of NO₂ concentration at Magnet complex during March 2023.



Source: Author

Graphic 18: Correlation factor between concentration of NO₂ and Wind speed during March at Magnet Complex.



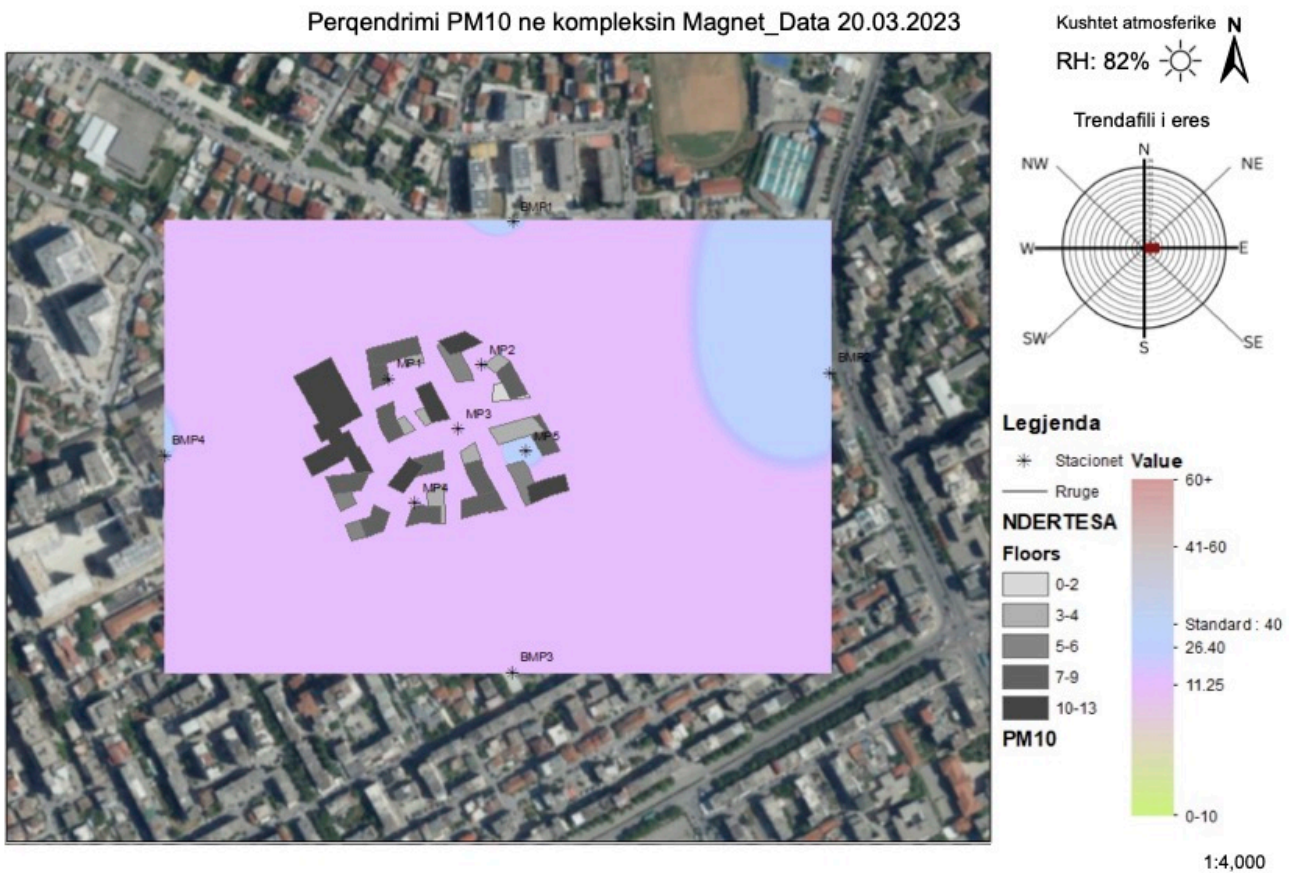
Source: Author

Table 20: PM₁₀ concentrations and meteorological observations during March 2023 / Magnet Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	22,8	20,0	21,2	23,0	23,1	26,1	28,4	19,7	26,3	22	10,0	E	63%	Cloudy / Rainy	2hrs	10.20 - 12.45
2	25,2	23,1	22,3	24,7	27,2	28,4	30,1	22,9	27,9	25	4,7	E	84%	Cloudy	2hrs	10.20 - 12.45
3	28,5	25,7	24,5	25,6	28,1	32,0	31,5	25,2	29,1	26	1,8	E	89%	Cloudy	2hrs	10.20 - 12.45
4	12,9	12,5	14,7	14,0	13,3	16,9	20,2	11,5	18,0	13	2,5	E	85%	Rainy	2hrs	10.20 - 12.45
5	20,0	19,3	17,8	18,9	21,5	23,4	24,3	18,9	22,3	20	2,1	E	90%	Cloudy	2hrs	10.20 - 12.45
6	17,1	18,2	16,7	16,4	14,4	20,1	21,4	18,2	19,4	17	10,8	SE	91%	Cloudy	2hrs	10.20 - 12.45
7	15,2	16,8	16,4	16,0	14,2	17,9	21,0	17,1	18,7	16	5,4	E	77%	Cloudy	2hrs	10.20 - 12.45
8	14,1	11,4	12,3	11,4	13,2	17,8	17,6	10,7	15,1	12	9,4	SE	93%	Rainy	2hrs	10.20 - 12.45
9	11,3	11,0	10,9	12,5	11,7	15,0	18,3	10,3	16,2	11	7,6	SE	71%	Cloudy	2hrs	10.20 - 12.45
10	9,3	7,9	9,8	10,7	9,8	13,2	17,0	7,0	14,6	10	8,6	SE	77%	Rainy	2hrs	10.20 - 12.45
11	6,0	6,4	6,2	7,2	6,4	9,7	13,2	5,7	10,9	6	10,4	SE	93%	Rainy	2hrs	10.20 - 12.45
12	5,6	5,7	5,1	5,7	5,5	9,1	11,4	5,2	9,2	6	5,7	E	92%	Cloudy	2hrs	10.20 - 12.45
13	10,0	11,2	9,7	10,9	10,3	13,5	16,4	10,7	14,4	10	3,9	E	67%	Sunny	2hrs	10.20 - 12.45
14	14,3	15,9	13,5	14,3	14,7	18,1	20,1	15,1	18,1	15	4,3	SE	55%	Cloudy	2hrs	10.20 - 12.45
15	7,3	6,2	7,6	8,4	8,0	11,3	14,8	5,2	12,4	8	12,4	SE	74%	Rainy	2hrs	10.20 - 12.45
16	14,9	14,1	12,1	13,7	12,9	18,8	19,5	13,2	17,6	14	3,2	N	70%	Cloudy	2hrs	10.20 - 12.45
17	15,4	14,0	12,7	14,5	15,8	19,1	20,0	13,3	18,2	14	5,0	E	68%	Sunny	2hrs	10.20 - 12.45
18	18,7	16,3	14,8	17,2	20,5	22,5	22,2	15,5	5,2	18	2,1	E	72%	Sunny	2hrs	10.20 - 12.45
19	18,7	19,5	14,8	17,8	21,7	22,1	23,2	19,1	21,2	19	2,5	E	63%	Sunny	2hrs	10.20 - 12.45
20	21,0	19,7	16,3	20,2	E	24,0	25,7	19,7	23,2	19	2,9	E	82%	Sunny	2hrs	10.20 - 12.45
21	11,8	11,4	10,0	12,5	11,8	15,2	17,8	11,0	15,9	12	1,0	NE	91%	Rainy	2hrs	10.20 - 12.45
22	15,9	15,2	14,4	16,1	15,2	19,7	21,4	14,4	19,9	15	2,9	E	92%	Sunny	2hrs	10.20 - 12.45
23	17,2	16,8	14,7	16,2	17,5	21,2	21,4	15,8	20,2	16	1,7	E	67%	Sunny	2hrs	10.20 - 12.45
24	21,3	21,2	19,4	20,2	20,6	24,9	26,0	20,6	23,8	21	5,7	E	66%	Sunny	2hrs	10.20 - 12.45
25	21,2	20,0	17,5	19,6	18,8	25,1	26,0	19,1	23,5	19	4,5	NW	66%	Sunny	2hrs	10.20 - 12.45
26	19,4	19,1	16,1	18,4	14,4	23,2	24,6	18,3	22,2	17	18,0	NW	86%	Sunny	2hrs	10.20 - 12.45
27	11,2	10,2	10,2	10,9	10,6	14,9	16,8	9,5	14,6	11	8,3	NW	63%	Rainy	2hrs	10.20 - 12.45
28	13,3	12,5	13,0	15,0	14,5	16,8	20,8	12,0	18,5	14	2,2	N	83%	Sunny	2hrs	10.20 - 12.45
29	12,3	10,3	11,3	12,0	11,5	15,8	17,4	9,8	15,5	11	11,2	NE	55%	Sunny	2hrs	10.20 - 12.45
30	9,8	8,6	9,8	9,5	9,8	13,7	14,9	7,7	13,4	10	7,5	E	62%	Sunny	2hrs	10.20 - 12.45
31	17,5	11,3	17,8	12,4	12,5	14,8	15,5	22,0	21,1	14	5,2	E	76%	Sunny	2hrs	10.20 - 12.45
TOT	15,5	14,6	14,0	15,0	15,0	18,8	20,6	14,3	18,3	14,8	6,0					

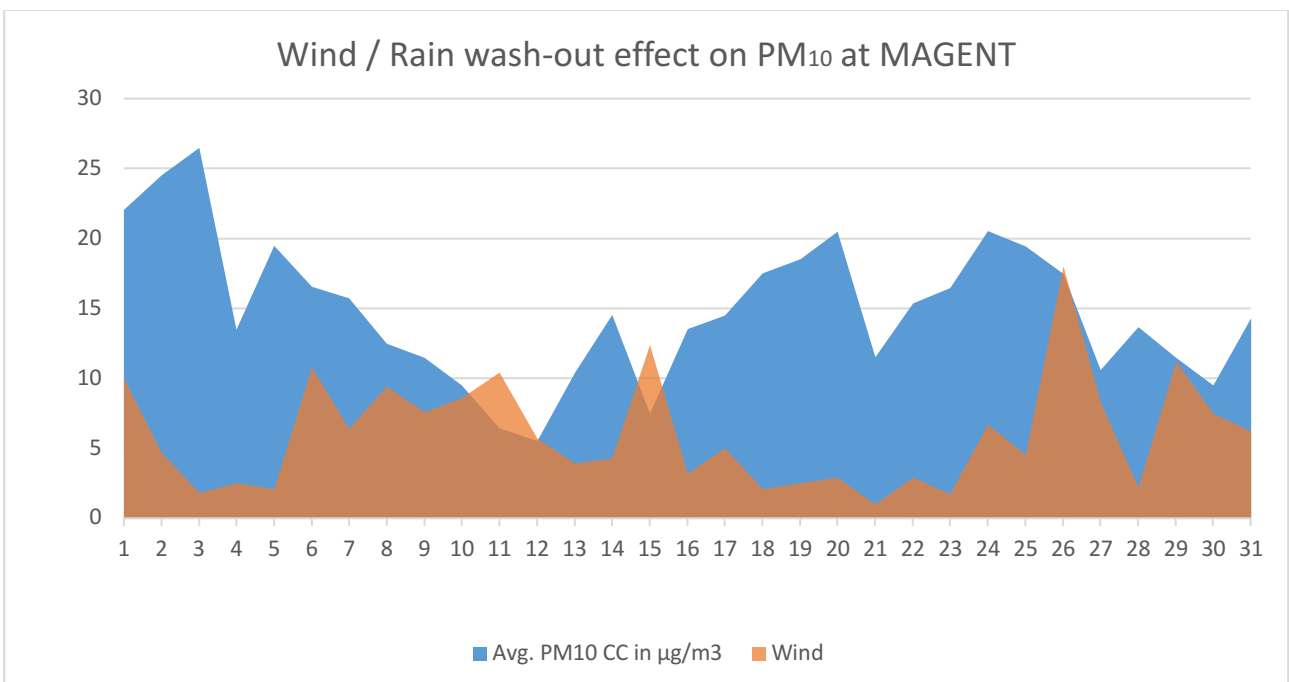
Source: Author

Figure 65: Sample from the dispersal of PM₁₀ sequence (20.3.2023)



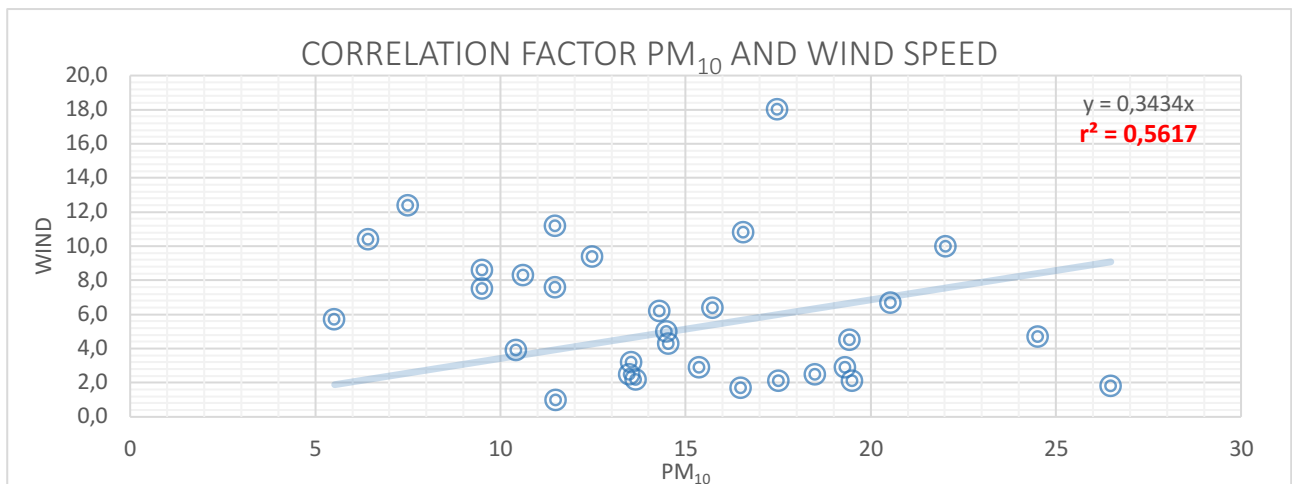
Source: Author

Graphic 19: Effect of wind and rain on the wash-out of PM₁₀ concentration at Magnet complex during March 2023.



Source: Author

Graphic 20: Correlation factor between concentration of PM₁₀ and Wind speed during February at Magnet Complex.



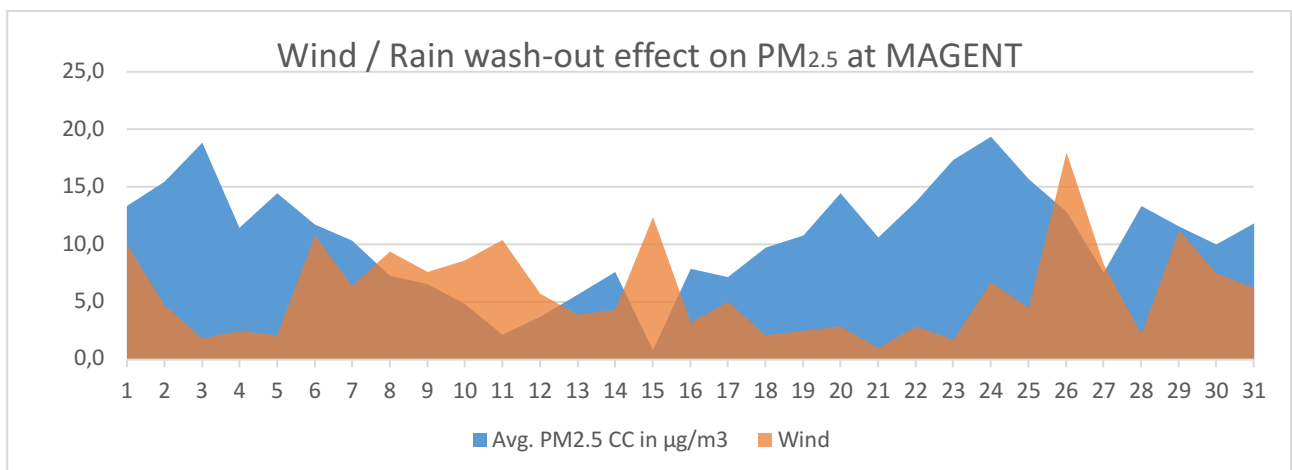
Source: Author

Table 21: PM_{2.5} concentrations and meteorological observations during March 2023 / Kontakt Magnet Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM2.5 CC in µg/m ³	Wind	8	Humidity	Weather	Monitorin	Daytime
1	14,7	13,0	12,8	12,2	13,9	12,6	14,7	11,2	13,9	13,3	10,0	E	63%	Cloudy / Rainy	2hrs	10.20 - 12.45
2	15,9	14,6	14,1	15,6	17,1	14,6	15,9	12,0	17,1	15,5	4,7	E	84%	Cloudy	2hrs	10.20 - 12.45
3	20,3	18,3	17,4	18,2	20,0	18,3	20,3	16,6	20,0	18,8	1,8	E	89%	Cloudy	2hrs	10.20 - 12.45
4	11,0	10,6	12,5	11,9	11,3	11,2	11,0	11,0	11,3	11,5	2,5	E	85%	Rainy	2hrs	10.20 - 12.45
5	14,8	14,3	13,2	14,0	15,9	14,0	14,8	12,0	15,9	14,4	2,1	E	90%	Cloudy	2hrs	10.20 - 12.45
6	12,1	12,9	11,8	11,6	10,2	10,5	12,1	10,7	10,2	11,7	10,8	SE	91%	Cloudy	2hrs	10.20 - 12.45
7	10,0	11,2	10,7	10,5	9,3	9,1	10,0	8,8	9,3	10,3	5,4	E	77%	Cloudy	2hrs	10.20 - 12.45
8	8,2	6,6	7,2	6,6	7,7	6,5	8,2	5,3	7,7	7,3	9,4	SE	93%	Rainy	2hrs	10.20 - 12.45
9	6,5	6,3	6,2	7,1	6,8	6,2	6,5	5,5	6,8	6,6	7,6	SE	71%	Cloudy	2hrs	10.20 - 12.45
10	4,7	4,0	5,0	5,5	5,0	4,0	4,7	3,0	5,0	4,8	8,6	SE	77%	Rainy	2hrs	10.20 - 12.45
11	2,0	2,2	2,1	2,4	2,2	1,6	2,0	1,0	2,2	2,2	10,4	SE	93%	Rainy	2hrs	10.20 - 12.45
12	3,8	3,8	3,4	3,8	3,8	3,2	3,8	2,5	3,8	3,7	5,7	E	92%	Cloudy	2hrs	10.20 - 12.45
13	5,4	6,1	5,3	5,9	5,6	5,0	5,4	4,3	5,6	5,7	3,9	E	67%	Sunny	2hrs	10.20 - 12.45
14	7,5	8,3	7,1	7,5	7,7	7,1	7,5	6,5	7,7	7,6	4,3	SE	55%	Cloudy	2hrs	10.20 - 12.45
15	1,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8	12,4	SE	74%	Rainy	2hrs	10.20 - 12.45
16	8,7	8,2	7,1	8,0	7,5	6,4	8,7	5,2	7,5	7,9	3,2	N	70%	Cloudy	2hrs	10.20 - 12.45
17	7,6	6,9	6,3	7,1	7,8	5,7	7,6	3,5	7,8	7,1	5,0	E	68%	Sunny	2hrs	10.20 - 12.45
18	10,4	9,1	8,2	9,6	11,4	9,5	10,4	7,6	11,4	9,7	2,1	E	72%	Sunny	2hrs	10.20 - 12.45
19	10,9	11,4	8,6	10,4	12,6	9,6	10,9	6,5	12,6	10,8	2,5	E	63%	Sunny	2hrs	10.20 - 12.45
20	14,8	13,9	11,5	14,2	17,8	14,2	14,8	10,5	17,8	14,4	2,9	E	82%	Sunny	2hrs	10.20 - 12.45
21	11,0	10,6	9,0	11,6	11,0	9,0	11,0	7,0	11,0	10,6	1,0	NE	91%	Rainy	2hrs	10.20 - 12.45
22	14,3	13,3	13,0	14,5	13,5	13,0	14,3	12,5	13,5	13,7	2,9	E	92%	Sunny	2hrs	10.20 - 12.45
23	18,1	17,7	15,5	17,1	18,4	16,7	18,1	14,9	18,4	17,4	1,7	E	67%	Sunny	2hrs	10.20 - 12.45
24	20,1	20,0	18,3	19,0	19,4	18,3	20,1	17,2	19,4	19,4	5,7	E	66%	Sunny	2hrs	10.20 - 12.45
25	17,2	16,0	14,2	15,9	15,2	14,2	17,2	13,1	15,2	15,7	4,5	NW	66%	Sunny	2hrs	10.20 - 12.45
26	14,2	14,1	11,8	13,5	10,5	10,4	14,2	10,2	10,5	12,8	18,0	NW	86%	Sunny	2hrs	10.20 - 12.45
27	8,0	7,3	7,3	7,8	7,5	6,3	8,0	5,0	7,5	7,6	8,3	NW	63%	Rainy	2hrs	10.20 - 12.45
28	13,0	12,2	12,8	14,6	14,1	12,8	13,0	11,4	14,1	13,3	2,2	N	83%	Sunny	2hrs	10.20 - 12.45
29	12,4	10,4	11,4	12,1	11,6	10,4	12,4	9,1	11,6	11,6	11,2	NE	55%	Sunny	2hrs	10.20 - 12.45
30	10,4	9,1	10,0	10,1	10,4	7,7	10,4	5,0	10,4	10,0	7,5	E	62%	Sunny	2hrs	10.20 - 12.45
31	14,4	10,2	14,5	10,4	9,8	16,5	14,4	21,5	21,8	11,9	5,2	E	76%	Sunny	2hrs	10.20 - 12.45
TOT	11,1	10,4	10,0	10,6	10,8	9,8	11,1	8,8	11,2	10,6	6,0					

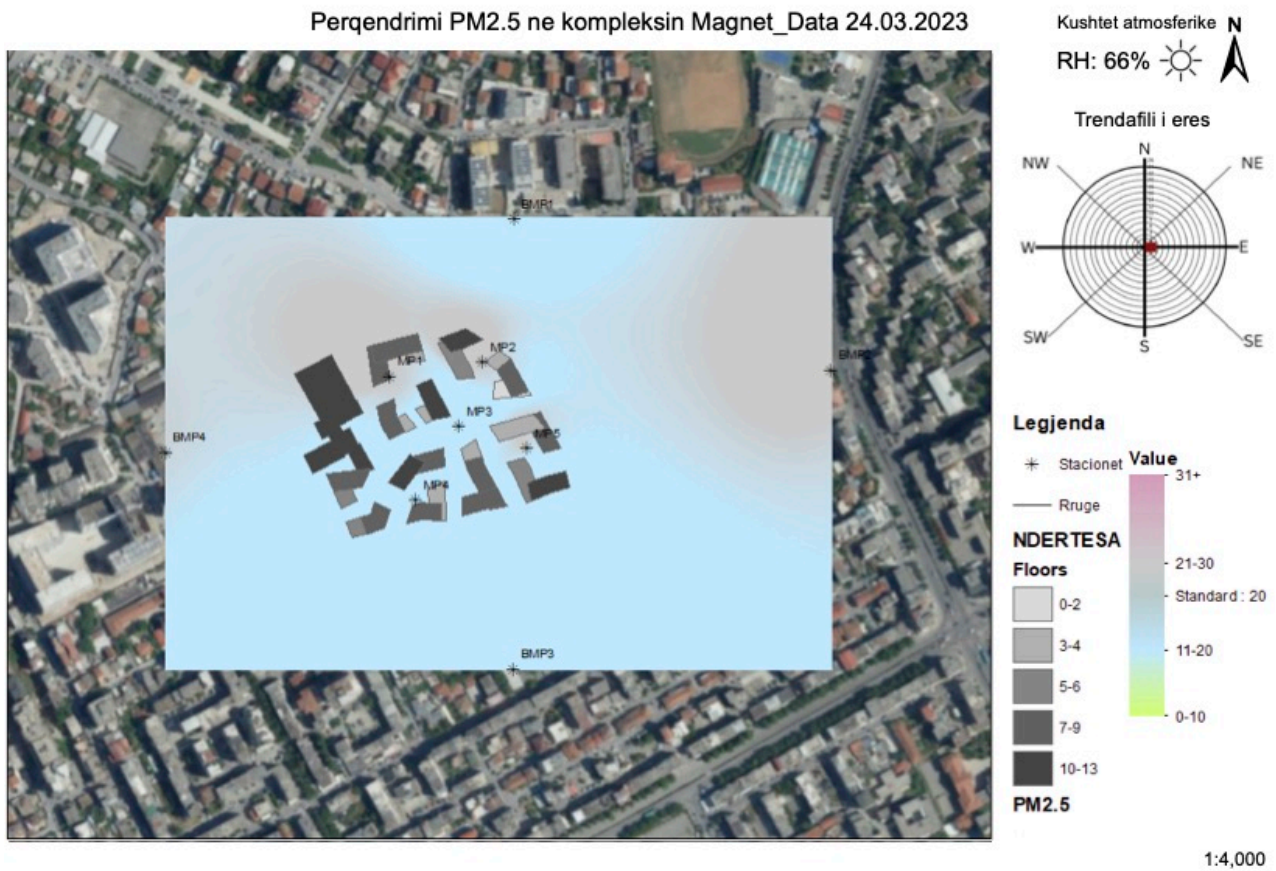
Source: Author

Graphic 21: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Magnet complex during March 2023



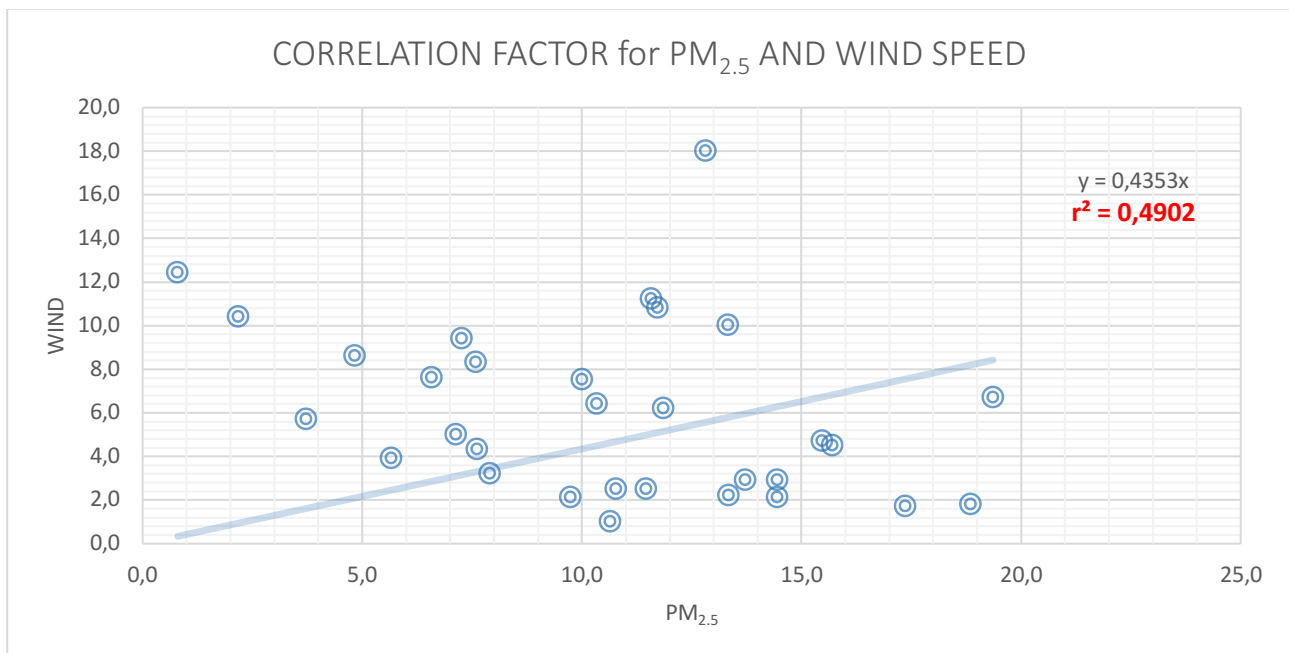
Source: Author

Figure 66: Sample from the dispersal of PM_{2.5} sequence (24.3.2023)



Source: Author

Graphic 22: Correlation factor between concentration of PM_{2.5} and Wind speed during March at Magnet Complex.



Source: Author

55% of the time the weather during March was characterized by rain. Therefore, the correlation factor results indicating the effect of wind speed on the natural dispersal of air pollution within Magnet Complex have an overall result of $r=0.54$, indicating a moderate correlation between these variables. If we deduct the results from the monitoring days with rain then the correlation factor between wind speed and pollution concentration in the area increases to $r=0.71$

Nevertheless, taking into consideration that the predominating wind directions are from East and North-East during January, it appears that the impact from the vortex effect to pollution retention in the monitored stations preserves the same pattern as in February.

Table 22: Number of days indicating the orientation of the wind during March at Magnet Complex

N	S	W	E	NW	NE	SE	SW
2	0	0	17	3	2	7	0
6%	0%	0%	55%	10%	6%	23%	0%

Source: Author

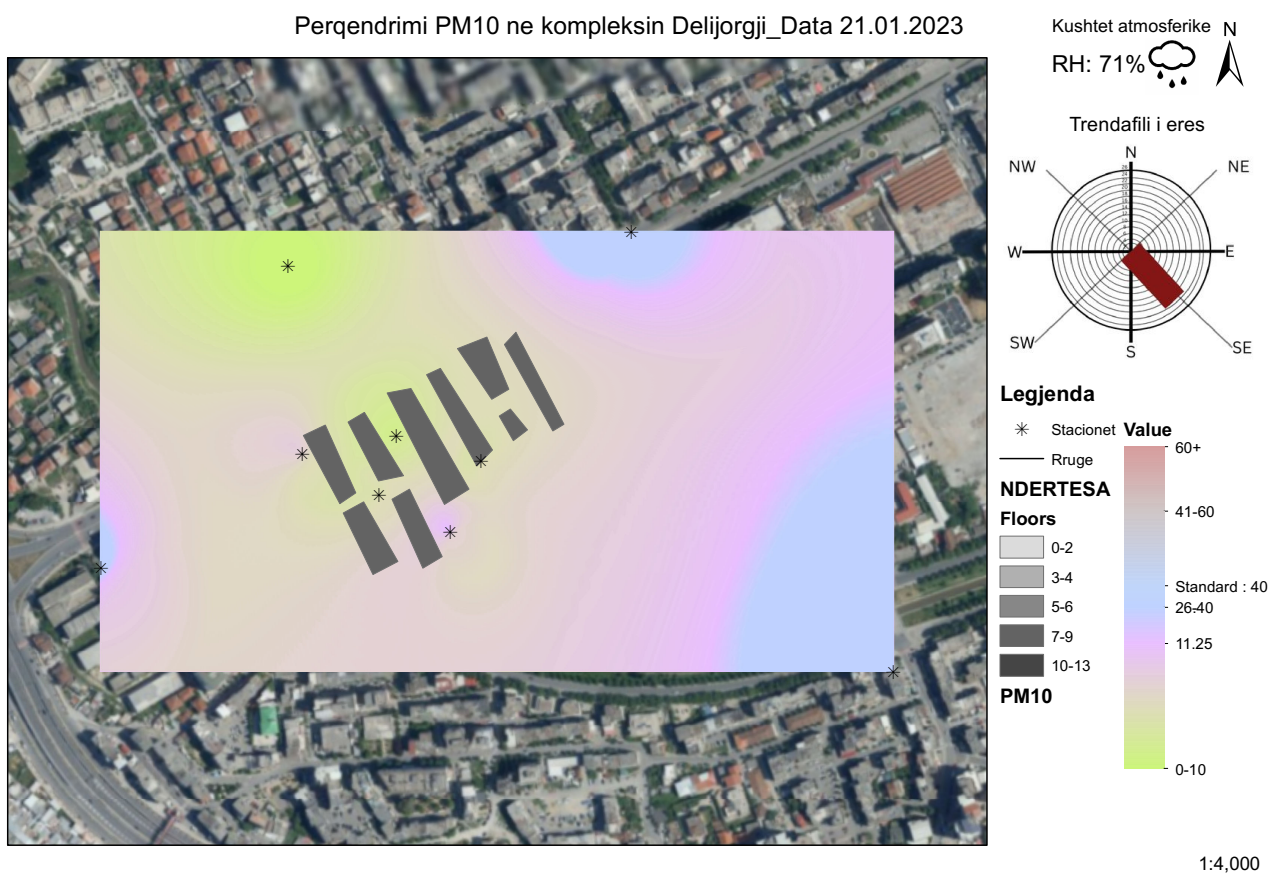
Concluding that the predominating wind patterns from East during March, and the dry weather during the second part of the month indicates MP.1, MP.4 and MP5 are to be considerably under the influence of Air Pollution Cavity Area. The build-up of this phenomena required 2-3 days more than the overall build-up of the pollution at the buffer areas or further in the city.

March registered the lowest impact compared with January and February but it is attributed also to the fact that wash-out effect from rain decreased the overall pollution concertation in the area.

DELIJORGJI COMPLEX.

Within the Delijorgji complex there were fixed 5 Monitoring Points out of which none was presumed to be affected by the vortex effect and that could retain pollution for a more prolonged time compared to other the monitoring location that were strategically position at the intersections whereas the urban morphology of the study area created wind corridors.

Figure 67: Pollution concentration map (1 sample out of 270 maps prepared for Delijorgji Area)



Source: Author

All the monitored components such as urban form, concentration of pollution, wind direction, wind speed, meteorological condition and relative humidity are expressed within the daily maps. These maps have been replicated under the same conditions also for the PM 2.5 and PM 10 pollutants. Herby there are 270 maps generated for this complex (90 per each pollutant) extracting and visualizing the data from 90 site monitoring sheets. These maps were later joined into a sequence per each pollutant indicating thus the potential cavity areas whereas natural dispersal of air pollutants is impacted by the urban form. All the monitoring practices at Delijorgji Complex were conducted between 07:00am in the morning until 10:00am at maximum. Covering at least 25

minutes of each monitoring point within the block whereas the author was looking for air pollution cavity areas and 7-10 minutes of monitoring for each buffer monitoring point.

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January began with extreme pollution concentration mainly due to the intense emission from the end of 2022. Such pollution accumulated from December was further aggravated by the firework celebration of the New Year eve and further by the fact that until 17th January there was a dry weather with minor wind. Therefore, since no significant wash-out effect occurred until mid-January, those minor winds present during this time frame account for a low dispersal of the pollution throughout the complex and further the city. Given that Delijorgji Complex has great wind tunnels from the positioning of its high dwellings, oriented from North to South the predominating wind patterns from North-West and South-East combined were not expected to contribute to a specific creation of the pollution retention phenomena in such particular meteorological circumstances.

Table 23: Number of days with sun, cloud and rain during January at Magnet complex.

Sun	Cloud	Rain
16	9	6
52%	29%	19%

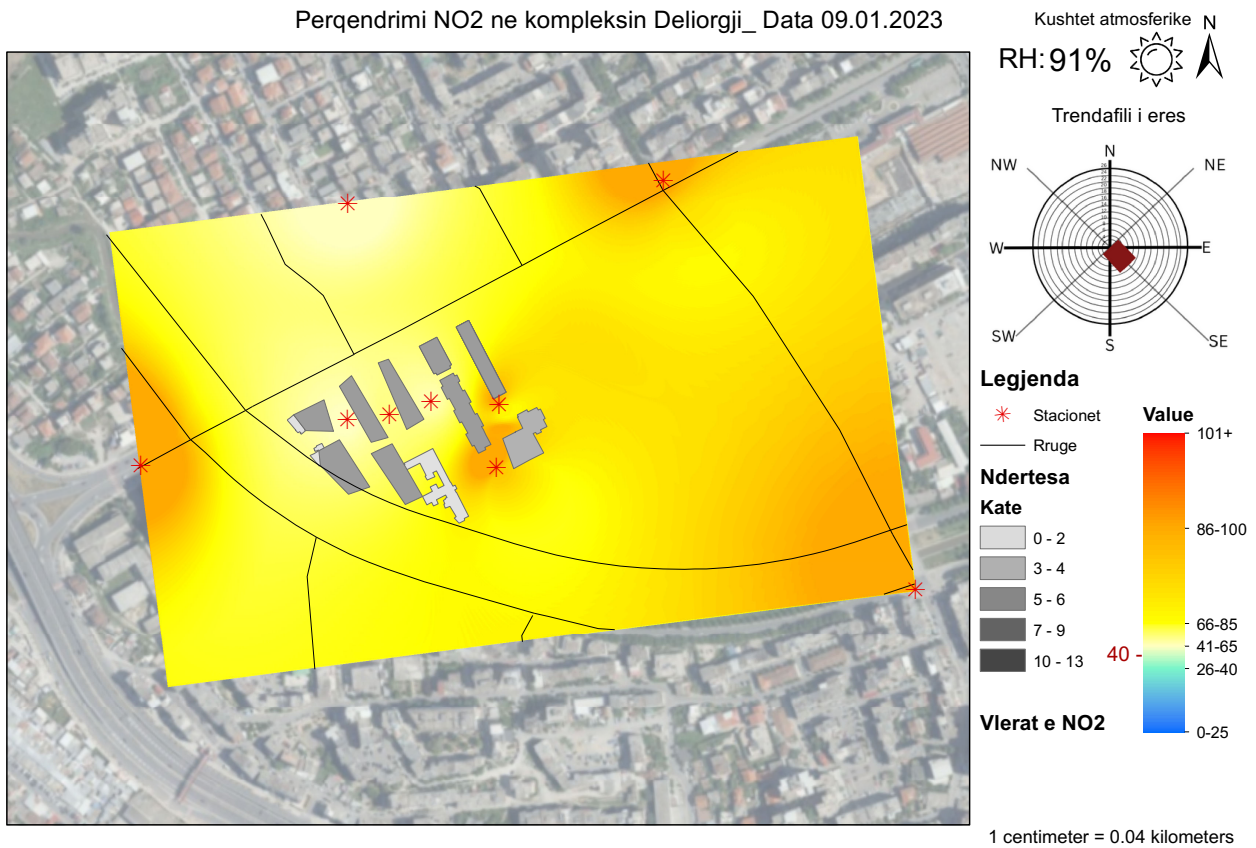
Source: Author

Table 24: NO₂ concentrations and meteorological observations during January 2023 / Delijorgji Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. NO2 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring length
1	155	156	149	156	160	168	172	158	144	155,2	2,4	E	77%	Sunny	2hrs 7.30-9.30
2	129	130	128	137	143	145	148	154	121	133,4	4,48	N	57%	Sunny	2hrs 7.30-9.30
3	150	152	156	166	171	189	185	193	147	159	3,04	E	72%	Sunny	2hrs 7.30-9.30
4	166	161	158	166	170	202	224	189	152	164,2	2,4	E	79%	Cloudy	2hrs 7.30-9.30
5	169	164	159	181	185	217	224	208	150	171,6	2,72	SE	85%	Sunny	2hrs 7.30-9.30
6	125	124	128	143	142	165	158	155	120	132,4	3,52	S	93%	Sunny	2hrs 7.30-9.30
7	117	119	126	136	135	151	149	142	114	126,6	3,2	NE	50%	Sunny	2hrs 7.30-9.30
8	88	93	97	110	117	120	109	105	78	101	4,96	E	43%	Sunny	2hrs 7.30-9.30
9	65	70	67	86	91	99	87	89	63	75,8	9,76	SE	91%	Sunny	2hrs 7.30-9.30
10	43	48	46	51	50	63	67	66	39	47,6	9,12	SE	88%	Cloudy	2hrs 7.30-9.30
11	51	56	50	67	73	88	81	77	49	59,4	4,16	E	77%	Cloudy	2hrs 7.30-9.30
12	70	69	73	85	92	93	95	96	71	77,8	3,36	NW	77%	Cloudy	2hrs 7.30-9.30
13	88	79	78	77	89	99	86	83	65	82,2	3,04	W	66%	Sunny	2hrs 7.30-9.30
14	67	64	57	72	77	87	88	87	53	67,4	4,8	NW	75%	Sunny	2hrs 7.30-9.30
15	64	61	52	58	57	78	74	79	41	58,4	4,48	W	81%	Sunny	2hrs 7.30-9.30
16	39	37	33	46	51	66	71	73	36	41,2	14,08	NW	64%	Cloudy	2hrs 7.30-9.30
17	27	22	19	28	28	31	32	31	19	24,8	17,6	NW	87%	Rainy	2hrs 7.30-9.30
18	21	19	17	19	19	21	25	20	17	19	18,08	NW	86%	Storm	2hrs 7.30-9.30
19	17	16	17	12	18	21	20	19	9	16	15,2	NW	92%	Rainy	2hrs 7.30-9.30
20	18	14	19	20	22	31	28	33	12	18,6	10,56	NW	90%	Rainy	2hrs 7.30-9.30
21	13	11	9	11	15	17	19	21	7	11,8	21,12	NW	71%	Rainy	2hrs 7.30-9.30
22	38	33	28	39	44	48	48	47	21	36,4	7,2	SW	77%	Cloudy	2hrs 7.30-9.30
23	34	31	31	34	35	46	41	47	27	33	7,52	SW	93%	Rainy	2hrs 7.30-9.30
24	54	55	59	71	73	76	75	77	39	62,4	2,56	E	89%	Sunny	2hrs 7.30-9.30
25	29	24	27	33	43	51	57	52	23	31,2	9,44	NW	77%	Cloudy	2hrs 7.30-9.30
26	44	49	55	67	68	84	79	88	37	56,6	9,92	E	66%	Cloudy	2hrs 7.30-9.30
27	66	69	71	81	82	94	99	101	57	73,8	2,72	NW	83%	Cloudy	2hrs 7.30-9.30
28	78	83	87	105	99	105	117	108	66	90,4	3,36	NW	73%	Sunny	2hrs 7.30-9.30
29	72	74	77	88	93	107	106	110	57	80,8	5,28	NW	79%	Sunny	2hrs 7.30-9.31
30	84	88	87	107	114	121	124	134	73	96	2,56	NW	58%	Sunny	2hrs 7.30-9.32
31	89	92	90	111	117	114	105	109	78	99,8	5,12	N	78%	Sunny	2hrs 7.30-9.33
TOT	73,2	73,0	72,6	82,7	86,2	96,7	96,5	95,2	64,0	77,5	7,0				

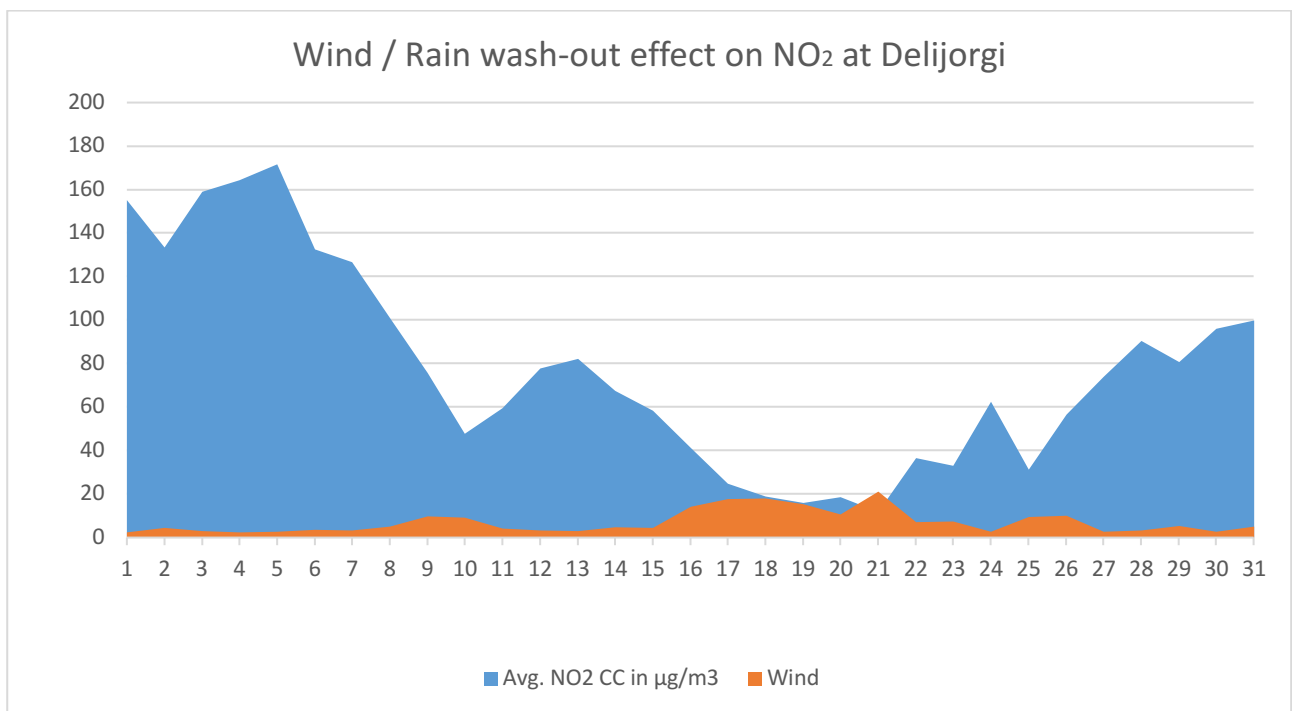
Source: Author

Figure 68: Sample from the dispersal of NO₂ sequence at Delijorgji (09.01.2023)



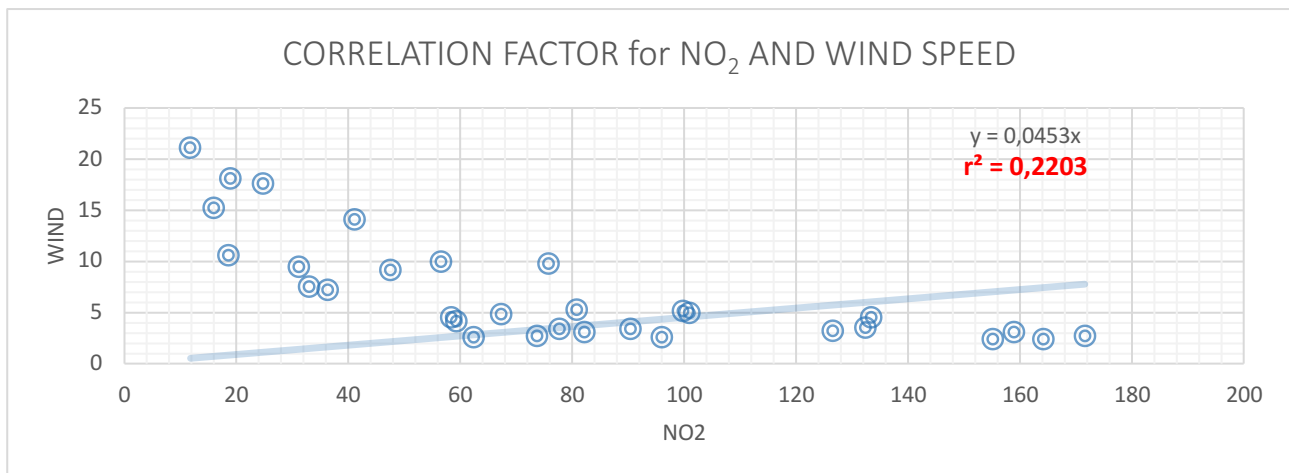
Source: Author

Graphic 23: Effect of wind and rain on the wash-out of NO₂ concentration at Delijorgji during January 2023.



Source: Author

Graphic 24: Correlation factor between concentration of NO₂ and Wind speed during January at Delijorgji Complex.



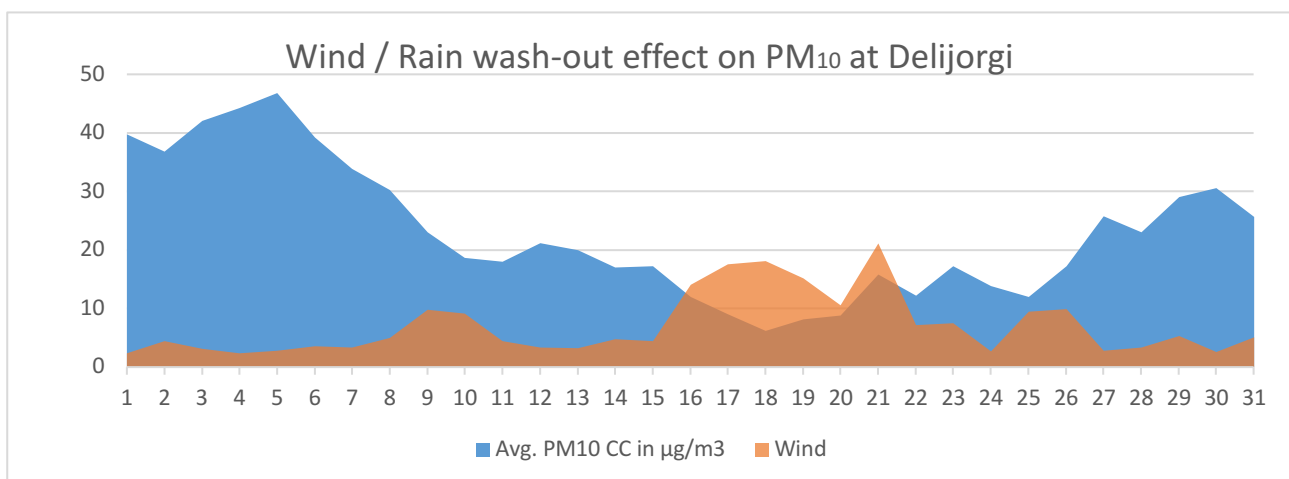
Source: Author

Table 25: PM₁₀ concentrations and meteorological observations during January 2023 / Delijorgji Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM10 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	40	40	38	40	41	43	44	41	37	40	2,40	E	77%	Sunny	2hrs	7.30-9.30
2	36	36	35	38	39	40	41	43	33	37	4,48	N	57%	Sunny	2hrs	7.30-9.30
3	40	40	41	44	45	50	49	51	39	42	3,15	E	72%	Sunny	2hrs	7.30-9.30
4	45	43	42	45	46	54	60	51	41	44	2,40	E	79%	Cloudy	2hrs	7.30-9.30
5	46	45	43	49	51	59	61	57	41	47	2,75	SE	85%	Sunny	2hrs	7.30-9.30
6	37	37	38	42	42	49	47	46	35	39	3,52	S	93%	Sunny	2hrs	7.30-9.30
7	31	32	34	36	36	40	40	38	31	34	3,30	NE	50%	Sunny	2hrs	7.30-9.30
8	26	28	29	33	35	36	32	31	23	30	4,96	E	43%	Sunny	2hrs	7.30-9.30
9	20	21	20	26	28	30	26	27	19	23	9,76	SE	91%	Sunny	2hrs	7.30-9.30
10	17	18	18	20	20	25	27	26	15	19	9,12	SE	88%	Cloudy	2hrs	7.30-9.30
11	16	17	15	20	22	27	25	23	15	18	4,40	E	77%	Cloudy	2hrs	7.30-9.30
12	19	19	20	23	25	25	26	26	19	21	3,36	NW	77%	Cloudy	2hrs	7.30-9.30
13	21	19	19	19	22	24	21	20	16	20	3,20	W	66%	Sunny	2hrs	7.30-9.30
14	17	16	14	18	20	22	22	22	13	17	4,80	NW	75%	Sunny	2hrs	7.30-9.30
15	19	18	15	17	17	23	22	23	12	17	4,48	W	81%	Sunny	2hrs	7.30-9.30
16	11	11	10	13	15	19	21	21	11	12	14,08	NW	64%	Cloudy	2hrs	7.30-9.30
17	10	8	7	10	10	11	12	11	7	9	17,60	NW	87%	Rainy	2hrs	7.30-9.30
18	7	6	6	6	6	7	8	7	6	6	18,08	NW	86%	Storm	2hrs	7.30-9.30
19	9	8	9	6	9	11	10	10	5	8	15,20	NW	92%	Rainy	2hrs	7.30-9.30
20	9	7	9	9	10	15	13	16	6	9	10,60	NW	90%	Rainy	2hrs	7.30-9.30
21	17	15	12	15	20	23	25	28	9	16	21,12	NW	71%	Rainy	2hrs	7.30-9.30
22	13	11	9	13	15	16	16	16	7	12	7,20	SW	77%	Cloudy	2hrs	7.30-9.30
23	18	16	16	18	18	24	21	24	14	17	7,52	SW	93%	Rainy	2hrs	7.30-9.30
24	12	12	13	16	16	17	17	17	9	14	2,70	E	89%	Sunny	2hrs	7.30-9.30
25	11	9	10	13	17	20	22	20	9	12	9,44	NW	77%	Cloudy	2hrs	7.30-9.30
26	13	15	17	20	21	26	24	27	11	17	9,92	E	66%	Cloudy	2hrs	7.30-9.30
27	23	24	25	28	29	33	35	35	20	26	2,80	NW	83%	Cloudy	2hrs	7.30-9.30
28	20	21	22	27	25	27	30	28	17	23	3,36	NW	73%	Sunny	2hrs	7.30-9.30
29	26	26	28	32	33	38	38	39	20	29	5,28	NW	79%	Sunny	2hrs	7.30-9.31
30	27	28	28	34	36	38	39	43	23	31	2,56	NW	58%	Sunny	2hrs	7.30-9.32
31	22	23	25	28	30	32	35	33	28	26	5,12	N	78%	Sunny	2hrs	7.30-9.33
TOT	21,9	21,6	21,5	24,5	25,8	29,2	29,3	29,0	19,1	23,0	7,05					

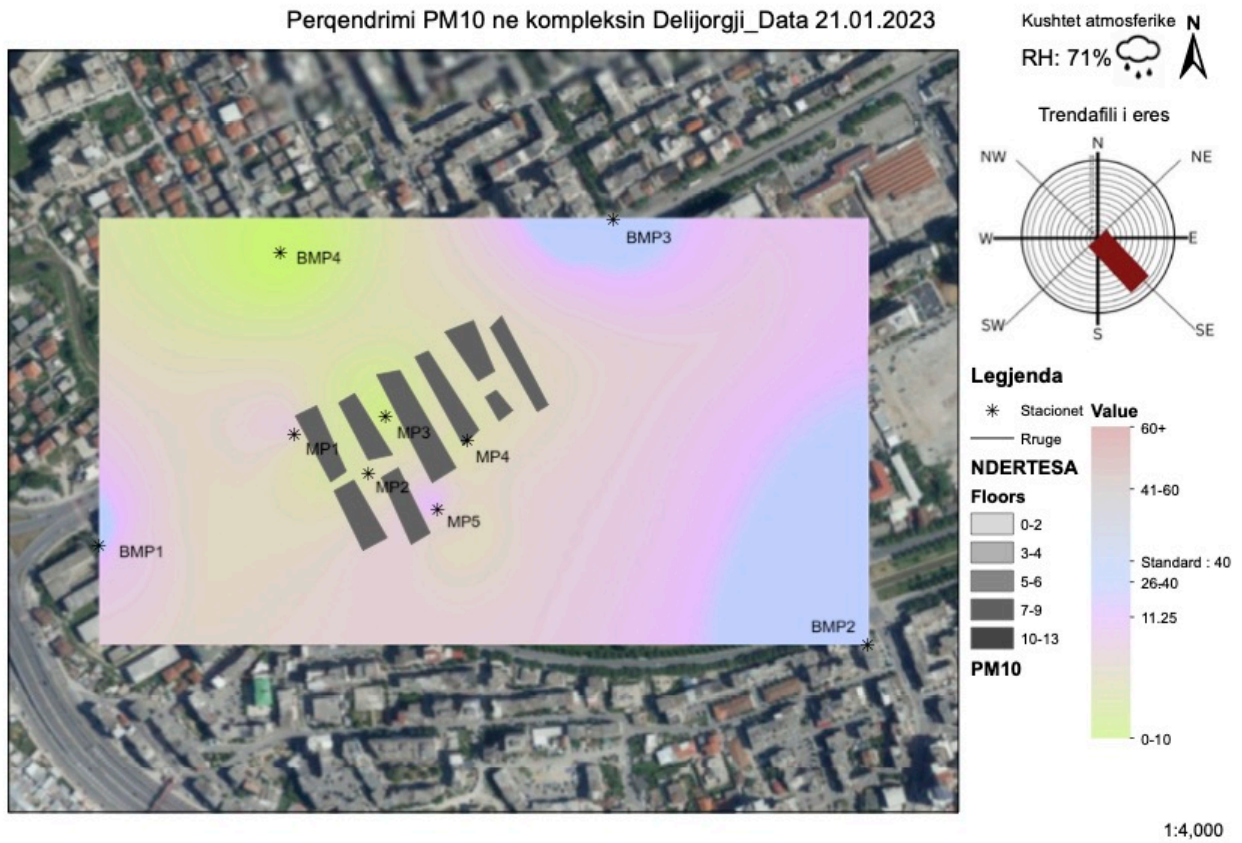
Source: Author

Graphic 25: Effect of wind and rain on the wash-out of PM₁₀ concentration at Delijorgji during January 2023



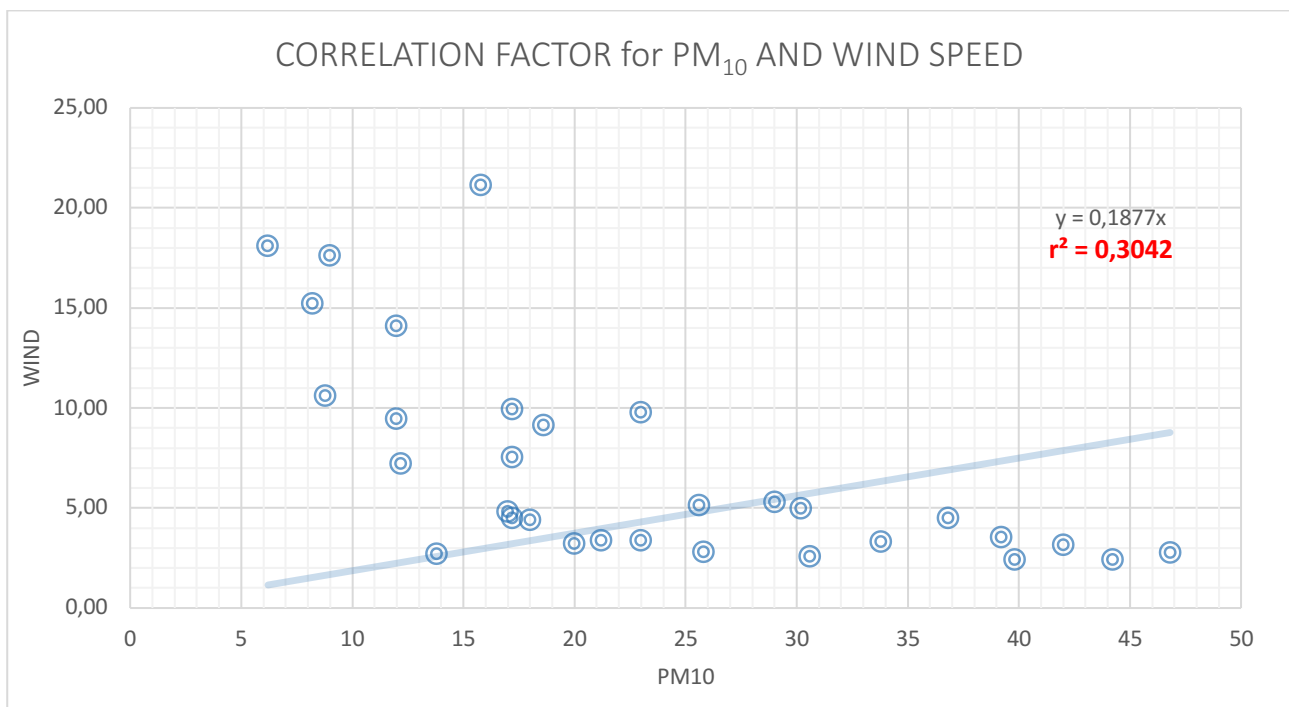
Source: Author

Figure 69: Sample from the dispersal of PM₁₀ sequence at Delijorgji (21.01.2023)



Source: Author

Graphic 26: Correlation factor between concentration of PM₁₀ and Wind speed during January at Delijorgji Complex.



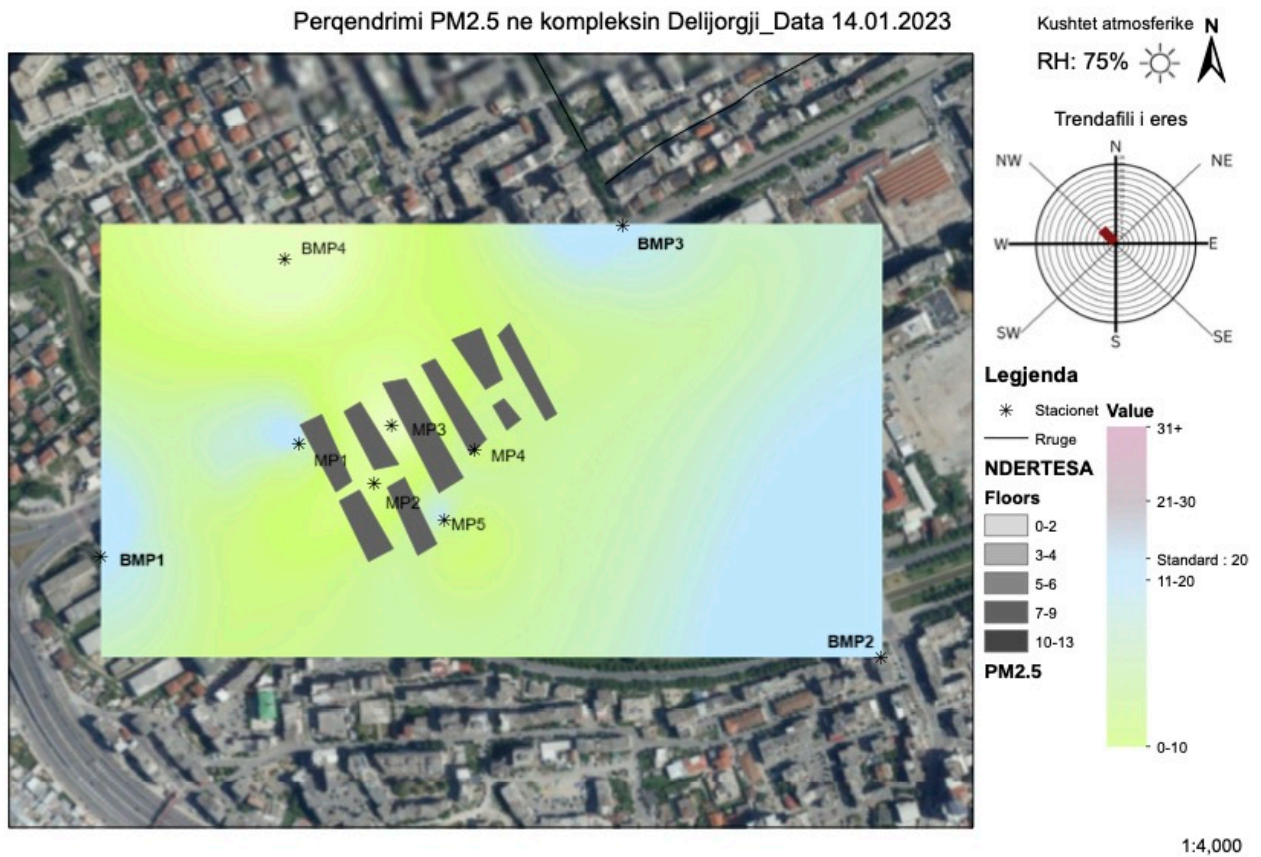
Source: Author

Table 26: PM_{2.5} concentrations and meteorological observations during January 2023 / Delijorgji Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM2.5 CC in µg/m ³	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	23	20	18	23	24	25	25	23	21	22	2,4	E	77%	Sunny	2hrs	7.30-9.30
2	20	20	17	22	23	23	23	24	19	20	4,48	N	57%	Sunny	2hrs	7.30-9.30
3	22	16	23	24	25	27	27	28	21	22	3,04	E	72%	Sunny	2hrs	7.30-9.30
4	25	25	24	26	26	31	34	29	23	25	2,4	E	79%	Cloudy	2hrs	7.30-9.30
5	26	25	24	27	28	33	34	32	24	26	2,72	SE	85%	Sunny	2hrs	7.30-9.30
6	21	18	21	25	24	28	26	26	20	22	3,52	S	93%	Sunny	2hrs	7.30-9.30
7	18	19	15	21	21	24	24	22	18	19	3,2	NE	50%	Sunny	2hrs	7.30-9.30
8	15	16	16	19	20	20	18	18	13	17	4,96	E	43%	Sunny	2hrs	7.30-9.30
9	13	8	13	17	18	21	17	18	12	14	9,76	SE	91%	Sunny	2hrs	7.30-9.30
10	12	13	13	14	14	17	18	17	11	13	9,12	SE	88%	Cloudy	2hrs	7.30-9.30
11	11	12	9	15	16	19	18	16	12	13	4,16	E	77%	Cloudy	2hrs	7.30-9.30
12	13	13	14	16	18	18	18	19	14	15	3,36	NW	77%	Cloudy	2hrs	7.30-9.30
13	14	12	12	12	14	16	14	13	10	13	3,04	W	66%	Sunny	2hrs	7.30-9.30
14	12	9	8	11	11	13	13	12	8	10	4,8	NW	75%	Sunny	2hrs	7.30-9.30
15	10	9	8	9	9	12	11	11	6	9	4,48	W	81%	Sunny	2hrs	7.30-9.30
16	7	6	9	8	12	11	12	12	6	8	14,08	NW	64%	Cloudy	2hrs	7.30-9.30
17	3	3	2	3	6	4	4	4	2	3	17,6	NW	87%	Rainy	2hrs	7.30-9.30
18	3	4	3	2	7	3	4	3	3	4	18,08	NW	86%	Storm	2hrs	7.30-9.30
19	7	4	8	8	11	5	5	5	2	8	15,2	NW	92%	Rainy	2hrs	7.30-9.30
20	3	2	3	3	4	5	5	6	2	3	10,56	NW	90%	Rainy	2hrs	7.30-9.30
21	7	6	5	6	8	9	10	11	4	6	21,12	NW	71%	Rainy	2hrs	7.30-9.30
22	9	8	7	10	11	12	12	12	5	9	7,2	SW	77%	Cloudy	2hrs	7.30-9.30
23	8	11	8	8	8	11	10	11	7	9	7,52	SW	93%	Rainy	2hrs	7.30-9.30
24	10	8	9	10	11	11	11	12	6	10	2,56	E	89%	Sunny	2hrs	7.30-9.30
25	9	13	9	11	14	16	18	17	7	11	9,44	NW	77%	Cloudy	2hrs	7.30-9.30
26	9	10	12	14	14	18	17	19	8	12	9,92	E	66%	Cloudy	2hrs	7.30-9.30
27	12	12	13	14	14	17	17	18	9	13	2,72	NW	83%	Cloudy	2hrs	7.30-9.30
28	14	15	15	19	18	19	21	19	12	16	3,36	NW	73%	Sunny	2hrs	7.30-9.30
29	13	14	14	16	17	20	20	20	11	15	5,28	NW	79%	Sunny	2hrs	7.30-9.31
30	15	16	15	19	20	21	22	24	13	17	2,56	NW	58%	Sunny	2hrs	7.30-9.32
31	12	13	17	15	19	18	19	17	15	15	5,12	N	78%	Sunny	2hrs	7.30-9.33
TOT	12,8	12,3	12,4	14,4	15,6	17,0	17,0	16,7	11,1	13,5	7,0					

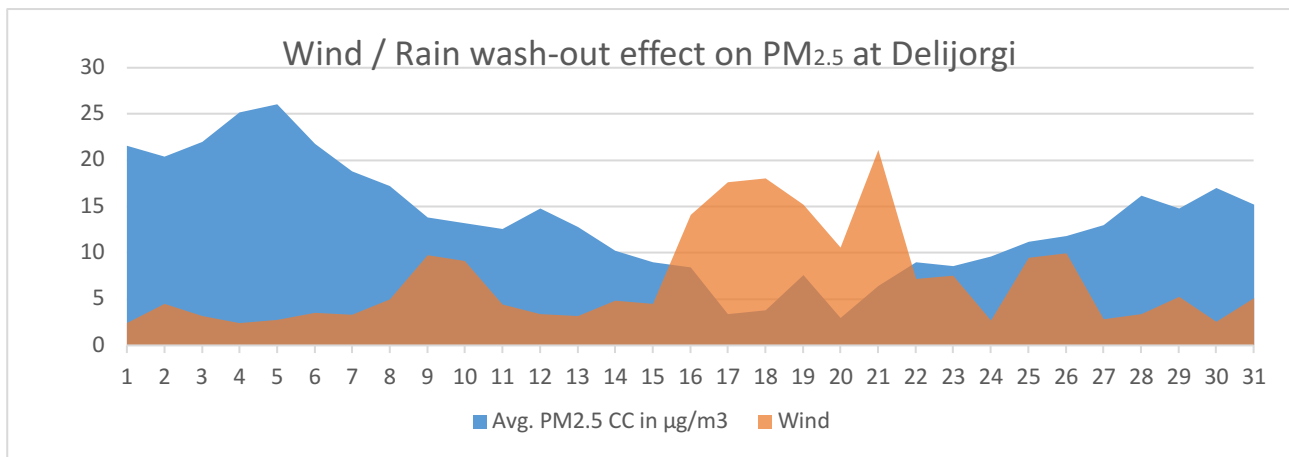
Source: Author

Figure 70: Sample from the dispersal of PM_{2.5} sequence at Delijorgji (14.01.2023)



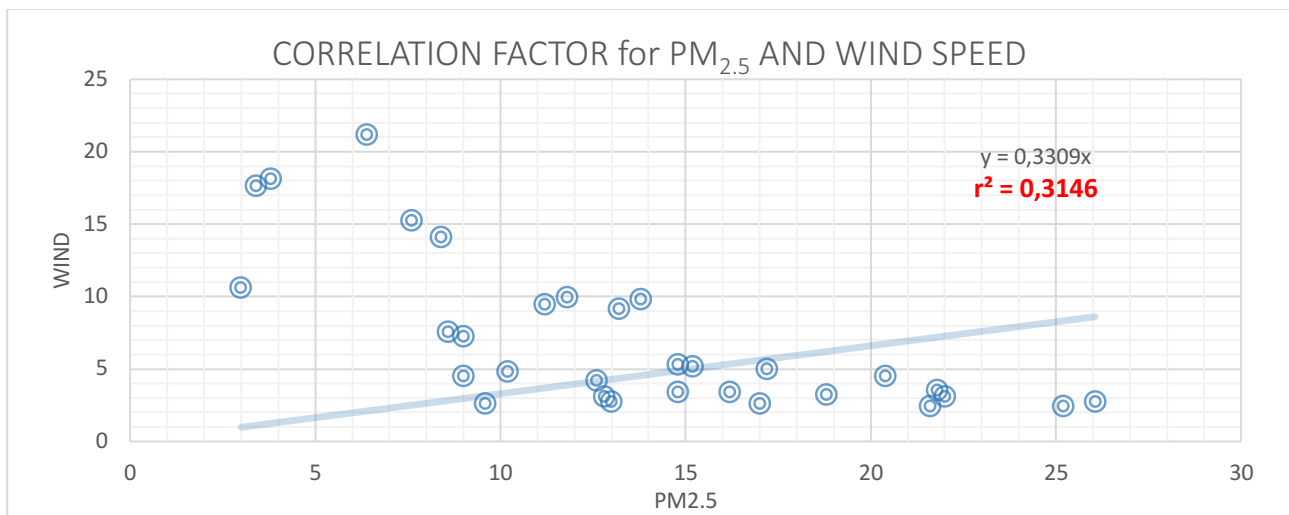
Source: Author

Graphic 27: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Delijorgji during January 2023



Source: Author

Graphic 28: Correlation factor between concentration of PM_{2.5} and Wind speed during January at Delijorgji Complex.



Source: Author

Meteorological conditions during January were characterized by a dry weather until middle of the month and then 5 consecutive days of rain and storm. Therefore, the correlation factor results indicating the effect of wind speed on the natural dispersal of air pollution within Delijorgji Complex have an overall result of $r=0.28$, nevertheless showing a moderate correlation between the two variables. If we exclude from the analysis the results of air monitoring from those 6 rainy days the correlation factor increases its result to $r=0.6$ indicating a strong correlation between these variables.

Nevertheless, taking into consideration that the predominating wind directions are from North-West it appears that overall urban form of the complex with immerse wind tunnels does not imply the creation of any vortex effect.

However, the results indicating increased concentration of pollutants at Monitoring Point 1, 4 and 5 are linked with the proximity that these locations have with construction sites nearby the monitoring area as well as with the Hoteleri-Turizem roundabout.

Table 27: Number of days indicating the orientation of the wind during January at Delijorgji Complex

N	S	W	E	NW	NE	SE	SW
2	1	2	7	13	1	3	2
6%	3%	6%	23%	42%	3%	10%	6%

Source: Author

Coming to the conclusion that the urban form of Delijorgji Complex eases even the vortex effect and Air Pollution Cavity Area created by the occurrence of Eastern or Western winds (which account for 29% of the total wind direction patterns during January).

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Also, for Delijorgji Complex, February represents the best monitoring conditions that the candidate could have expected. Throughout this month a light rain occurred only during 26th February. Herby 96% of the monitoring results indicate the direct correlation of wind on the dispersal of air pollutants within the Delijorgji Complex that could be also analysed in the context of how well natural ventilation occurs in this block of dwellings.

Table 28: Number of days with sun, cloud and rain during February at Delijorgji complex.

Sun	Cloud	Rain
14	13	1
50%	46%	4%

Source: Author

Table 29: Number of days indicating the orientation of the wind during February at Delijorgji Complex

N	S	W	E	NW	NE	SE	SW
7	2	1	8	2	4	3	1
25%	7%	4%	29%	7%	14%	11%	4%

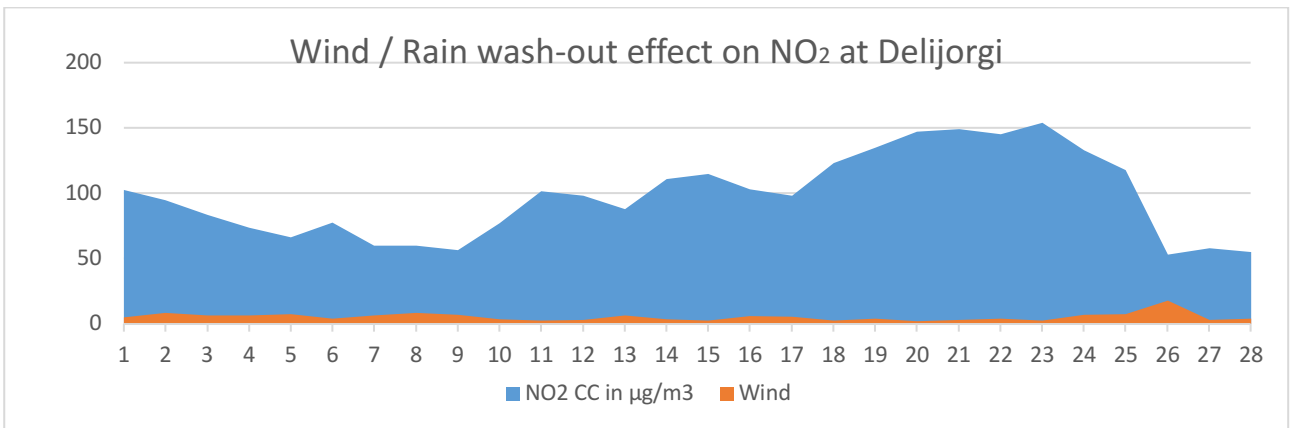
Source: Author

Table 30: NO₂ concentrations and meteorological observations during February 2023 / Delijorgji Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	NO2 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	97	94	93	107	123	133	128	135	89	102,8	5,1	E	66%	Sunny	2hrs	7.30-9.30
2	83	89	87	103	111	122	117	125	73	94,6	8,6	E	82%	Cloudy	2hrs	7.30-9.30
3	71	77	72	95	103	105	107	110	67	83,6	6,6	NW	89%	Cloudy	2hrs	7.30-9.30
4	65	71	68	84	81	94	98	105	52	73,8	5,7	NW	78%	Cloudy	2hrs	7.30-9.30
5	58	61	59	77	76	86	88	91	48	66,2	7,7	N	58%	Sunny	2hrs	7.30-9.30
6	68	71	75	86	89	82	84	91	37	77,8	4,0	S	55%	Sunny	2hrs	7.30-9.30
7	57	53	56	66	68	79	78	88	34	60	6,4	S	53%	Sunny	2hrs	7.30-9.30
8	49	52	57	69	73	82	79	81	43	60	8,6	E	43%	Sunny	2hrs	7.30-9.30
9	55	53	55	58	62	79	78	89	41	56,6	5,9	N	45%	Cloudy	2hrs	7.30-9.30
10	64	68	71	89	94	98	108	101	56	77,2	3,5	E	61%	Cloudy	2hrs	7.30-9.30
11	89	94	98	107	121	133	141	140	71	101,8	2,7	N	54%	Sunny	2hrs	7.30-9.30
12	93	92	95	99	111	125	129	121	77	98	3,4	E	44%	Cloudy	2hrs	7.30-9.30
13	83	87	88	89	93	103	110	108	65	88	5,7	W	67%	Sunny	2hrs	7.30-9.30
14	97	105	102	121	129	128	132	138	78	110,8	3,8	SW	66%	Sunny	2hrs	7.30-9.30
15	101	112	108	122	133	131	143	141	83	115	2,7	N	62%	Sunny	2hrs	7.30-9.30
16	97	89	99	113	117	124	132	138	66	103	6,1	N	75%	Sunny	2hrs	7.30-9.30
17	89	91	93	107	109	117	119	122	53	98	5,8	N	91%	Cloudy	2hrs	7.30-9.30
18	112	118	121	130	134	131	133	147	76	123	2,9	E	81%	Cloudy	2hrs	7.30-9.30
19	122	127	129	142	153	146	153	162	93	135	4,3	NE	86%	Cloudy	2hrs	7.30-9.30
20	137	144	139	156	157	157	159	174	89	147	1,9	NE	90%	Cloudy	2hrs	7.30-9.30
21	133	152	135	161	165	152	162	169	76	149	3,2	NE	66%	Sunny	2hrs	7.30-9.30
22	135	142	138	154	155	154	159	177	79	145	4,0	E	77%	Sunny	2hrs	7.30-9.30
23	147	154	139	163	168	172	177	182	92	154	2,6	N	88%	Cloudy	2hrs	7.30-9.30
24	128	133	131	136	139	144	148	154	82	133	7,0	SE	89%	Sunny	2hrs	7.30-9.30
25	109	110	112	121	137	127	133	139	70	118	7,7	SE	70%	Sunny	2hrs	7.30-9.30
26	48	52	43	57	66	89	87	94	53	53	17,9	SE	86%	Light Rain	2hrs	7.30-9.30
27	53	57	50	63	69	78	79	86	48	58	3,2	E	87%	Cloudy	2hrs	7.30-9.30
28	59	51	43	59	63	72	77	88	45	55	4,0	NE	67%	Cloudy	2hrs	7.30-9.30
TOT	89,3	92,8	91,3	104,8	110,7	115,8	119,2	124,9	65,6	97,8	5,5					

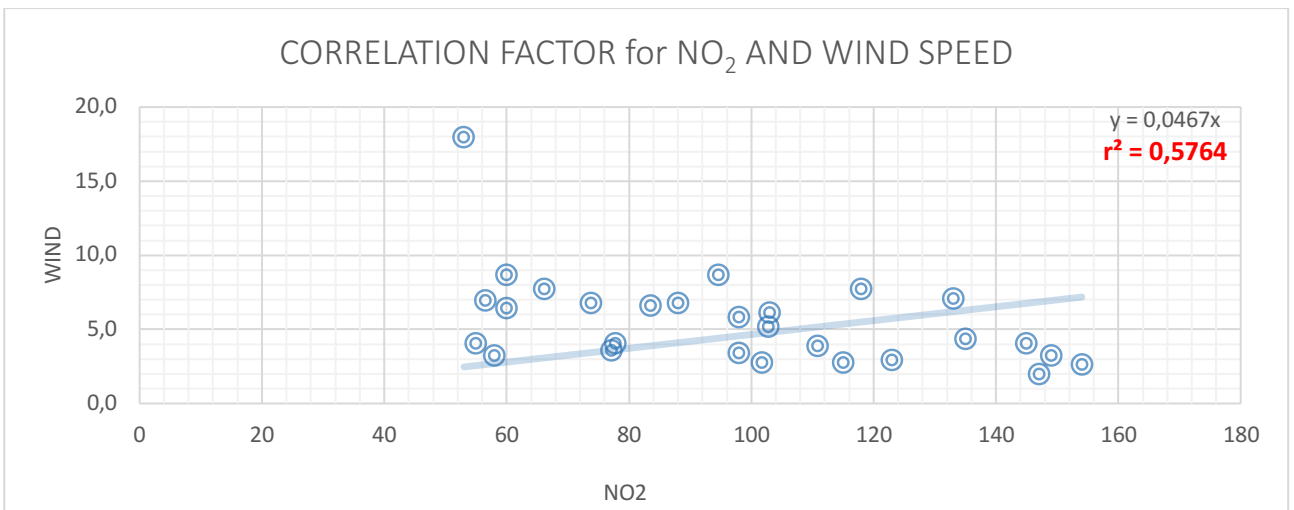
Source: Author

Graphic 29: Effect of wind and rain on the wash-out of NO₂ concentration at Delijorgji during February 2023.



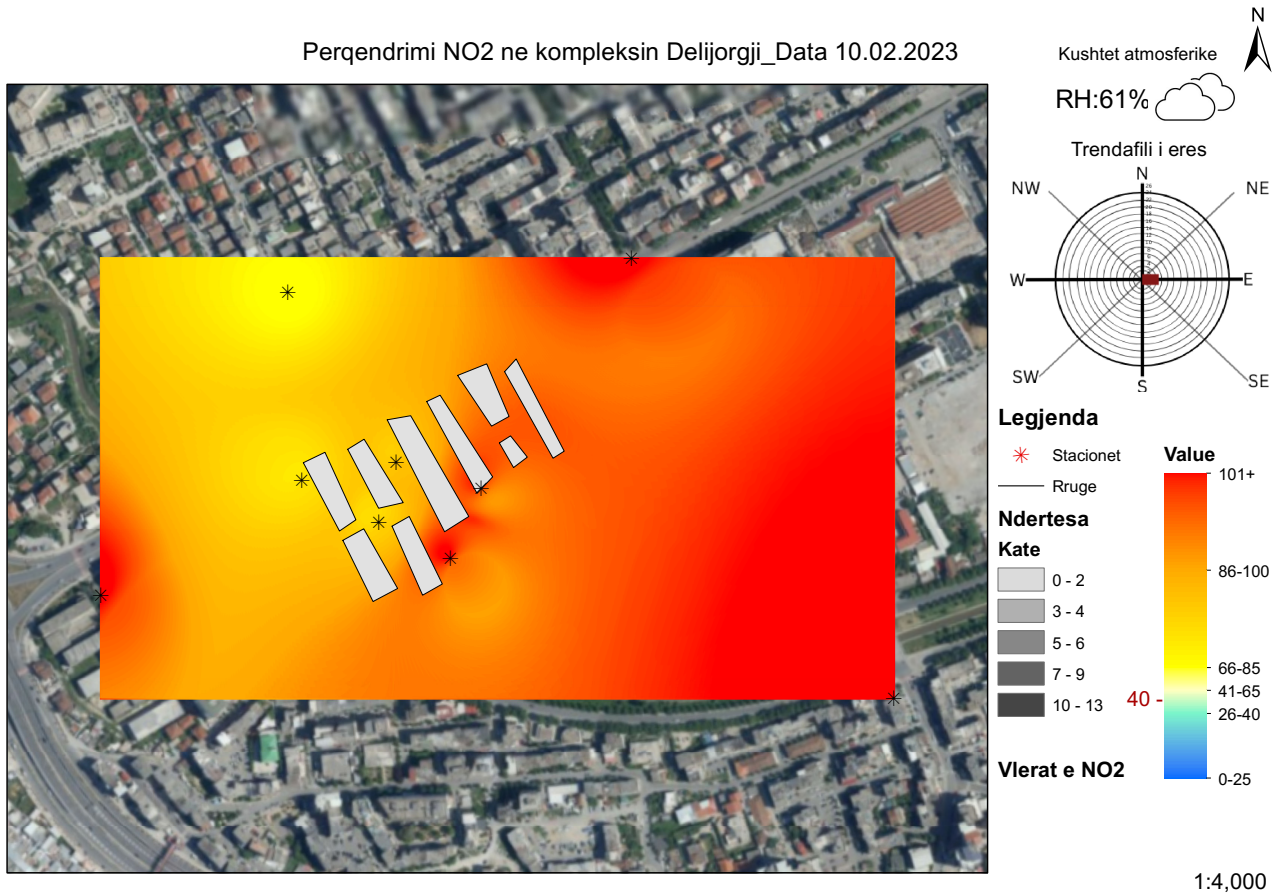
Source: Author

Graphic 30: Correlation factor between concentration of NO₂ and Wind speed during January at Delijorgji Complex.



Source: Author

Figure 71: Sample from the dispersal of NO₂ sequence at Delijorgji (10.02.2023)



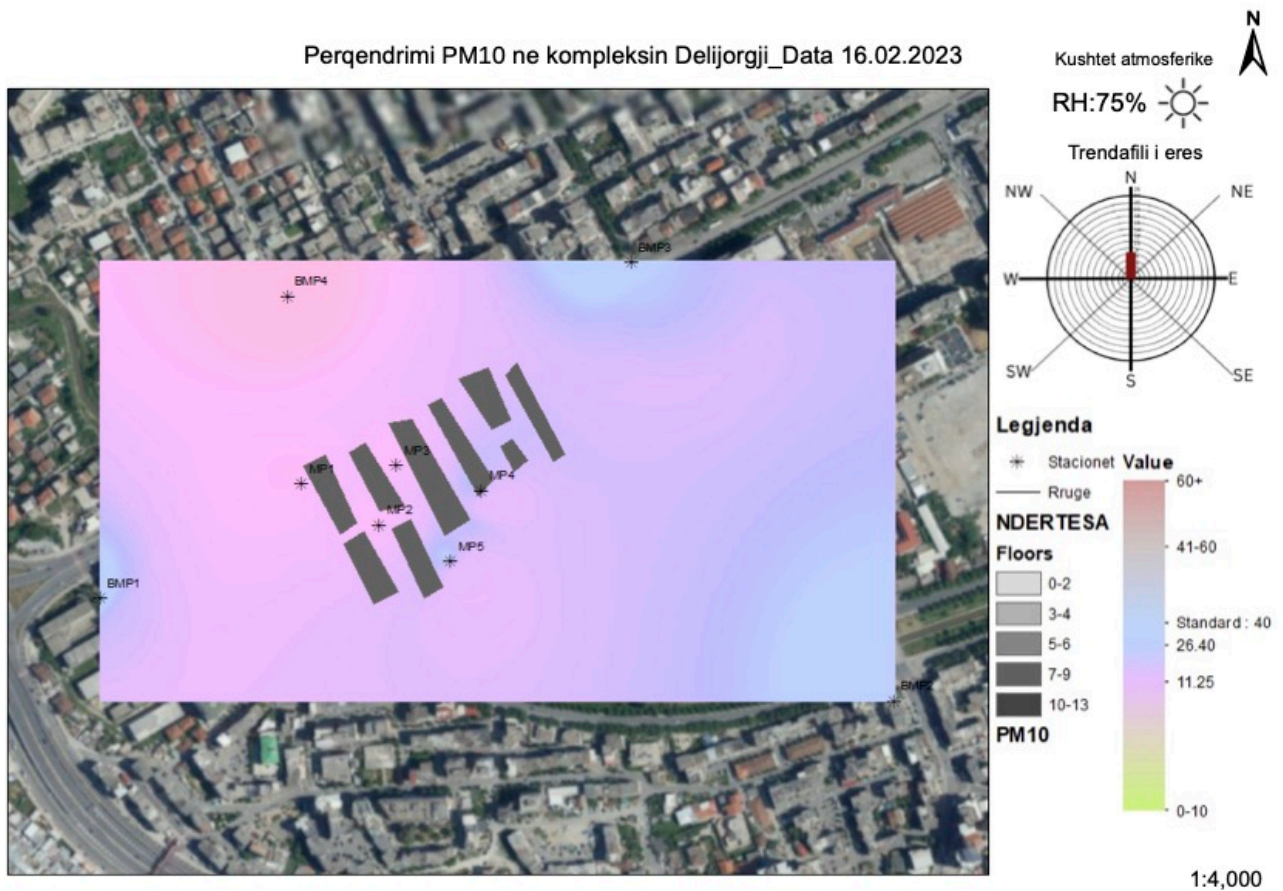
Source: Author

Table 31: PM₁₀ concentrations and meteorological observations during February 2023 / Delijorgji Complex

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m ³	Wind	Direction	Humidity	Weather	Monitoring	Daytime
1	26	28	26	32	37	37	35	38	23	30	5,1	E	66%	Sunny	2hrs	7.30-9.30
2	22	27	23	31	33	35	32	35	19	27	8,6	E	82%	Cloudy	2hrs	7.30-9.30
3	19	23	19	28	30	29	29	31	17	24	5,6	NW	89%	Cloudy	2hrs	7.30-9.30
4	17	21	17	24	23	26	25	29	13	20	5,7	NW	78%	Cloudy	2hrs	7.30-9.30
5	15	18	15	22	22	23	22	24	12	18	7,7	N	58%	Sunny	2hrs	7.30-9.30
6	18	21	19	25	26	27	28	30	11	22	4,0	S	55%	Sunny	2hrs	7.30-9.30
7	14	15	14	18	19	21	20	23	8	16	6,4	S	53%	Sunny	2hrs	7.30-9.30
8	12	16	15	19	20	22	20	21	10	16	8,6	E	43%	Sunny	2hrs	7.30-9.30
9	13	15	14	16	17	19	18	21	9	15	6,9	N	45%	Cloudy	2hrs	7.30-9.30
10	17	20	18	26	27	26	28	28	14	22	3,5	E	61%	Cloudy	2hrs	7.30-9.30
11	24	28	26	32	36	36	37	39	18	29	2,7	N	54%	Sunny	2hrs	7.30-9.30
12	25	29	25	30	33	35	35	34	20	28	3,4	E	44%	Cloudy	2hrs	7.30-9.30
13	22	26	23	26	28	31	31	33	18	25	6,7	W	67%	Sunny	2hrs	7.30-9.30
14	26	32	29	37	39	40	39	43	22	33	3,8	SW	66%	Sunny	2hrs	7.30-9.30
15	27	34	30	37	41	42	43	44	23	34	2,7	N	62%	Sunny	2hrs	7.30-9.30
16	26	27	27	34	35	38	37	42	18	30	6,1	N	75%	Sunny	2hrs	7.30-9.30
17	24	28	25	32	33	37	35	39	15	28	5,8	N	91%	Cloudy	2hrs	7.30-9.30
18	31	36	33	40	41	45	44	49	24	36	2,9	E	81%	Cloudy	2hrs	7.30-9.30
19	34	39	35	44	47	49	48	53	28	40	4,3	NE	86%	Cloudy	2hrs	7.30-9.30
20	38	45	39	49	49	55	53	59	28	44	1,9	NE	90%	Cloudy	2hrs	7.30-9.30
21	37	47	37	50	51	57	57	62	25	44	3,2	NE	66%	Sunny	2hrs	7.30-9.30
22	35	44	38	48	48	55	53	62	26	43	4,0	E	77%	Sunny	2hrs	7.30-9.30
23	41	48	39	51	52	59	58	63	28	46	2,6	N	88%	Cloudy	2hrs	7.30-9.30
24	35	41	36	42	43	49	48	54	26	39	7,0	SE	89%	Sunny	2hrs	7.30-9.30
25	30	35	30	37	42	44	43	47	22	35	7,7	SE	70%	Sunny	2hrs	7.30-9.30
26	12	14	11	15	18	18	16	18	9	14	17,9	SE	86%	Light Rain	2hrs	7.30-9.30
27	13	17	12	17	19	19	18	21	11	16	3,2	E	87%	Cloudy	2hrs	7.30-9.30
28	14	15	10	16	18	17	17	20	10	15	4,0	NE	67%	Cloudy	2hrs	7.30-9.30
TOT	23,8	28,2	24,5	31,4	33,1	35,4	34,6	37,9	18,1	28,2	5,5					

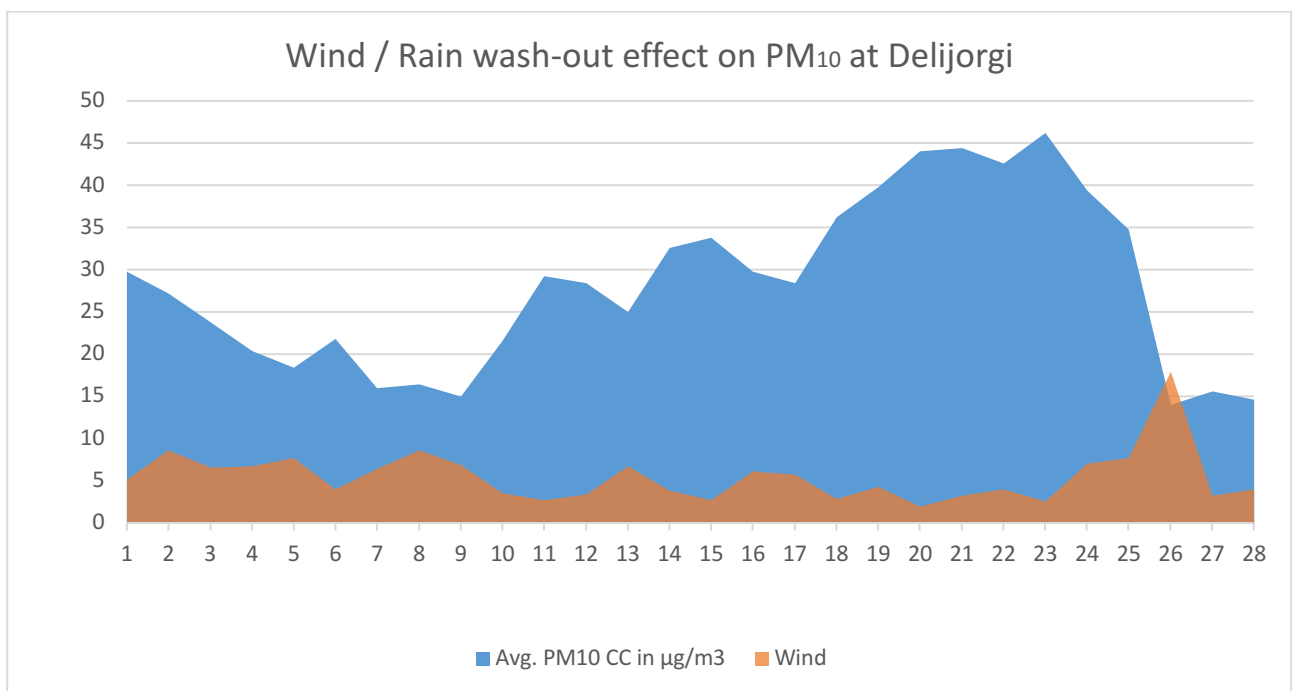
Source: Author

Figure 72: Sample from the dispersal of PM₁₀ sequence at Delijorgji (16.02.2023)



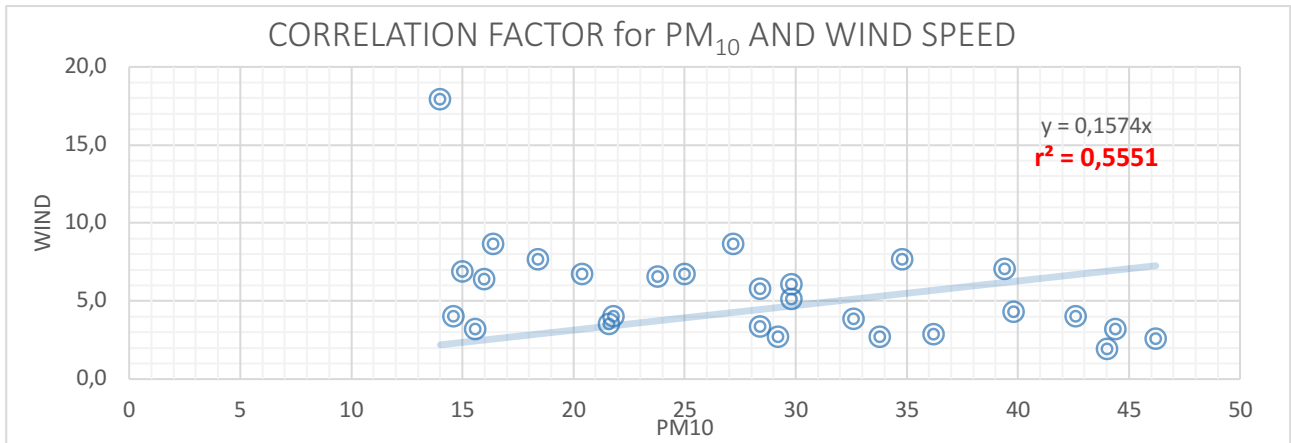
Source: Author

Graphic 31: Effect of wind and rain on the wash-out of PM₁₀ concentration at Delijorgji during February 2023.



Source: Author

Graphic 32: Correlation factor between concentration of PM₁₀ and Wind speed during January at Delijorgji Complex.



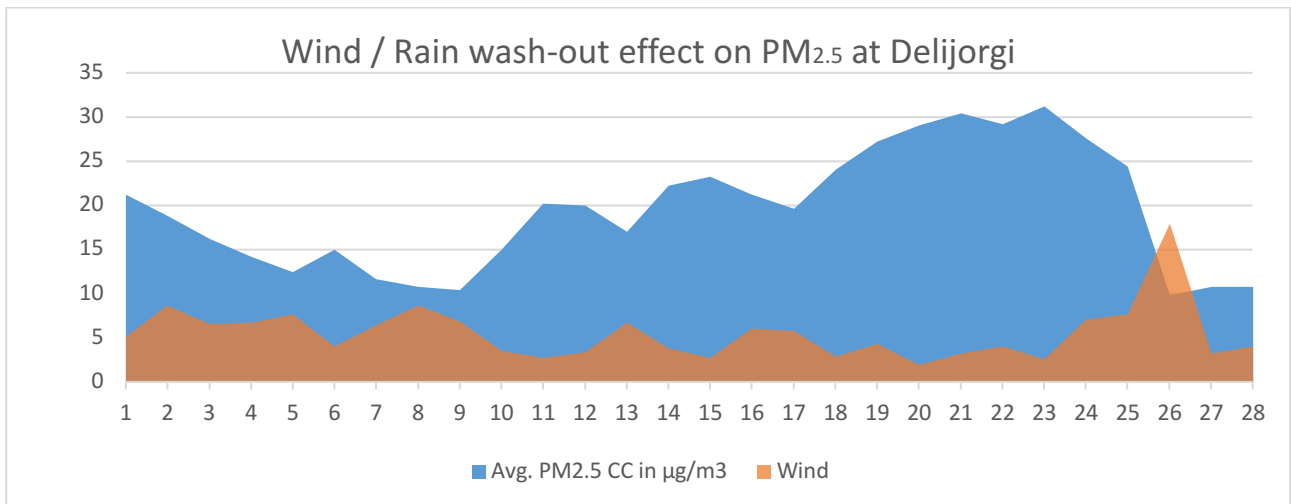
Source: Author

Table 32: PM_{2.5} concentrations and meteorological observations during February 2023 / Delijorgji Complex

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM2.5 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	20	18	16	22	30	26	24	32	15	21	5,1	E	66%	Sunny	2hrs	7.30-9.30
2	17	15	14	21	27	25	22	29	12	19	8,6	E	82%	Cloudy	2hrs	7.30-9.30
3	14	13	11	19	24	20	20	26	11	16	5,6	NW	89%	Cloudy	2hrs	7.30-9.30
4	13	12	10	17	19	18	17	25	8	14	5,7	NW	78%	Cloudy	2hrs	7.30-9.30
5	11	10	9	15	17	16	15	20	7	12	7,7	N	58%	Sunny	2hrs	7.30-9.30
6	14	12	11	17	21	19	19	24	9	15	4,0	S	55%	Sunny	2hrs	7.30-9.30
7	11	10	9	13	15	15	13	19	5	12	5,4	S	53%	Sunny	2hrs	7.30-9.30
8	9	8	7	14	16	16	14	17	6	11	8,6	E	43%	Sunny	2hrs	7.30-9.30
9	10	9	8	11	14	14	12	18	7	10	6,9	N	45%	Cloudy	2hrs	7.30-9.30
10	13	12	10	18	22	18	19	23	9	15	3,5	E	61%	Cloudy	2hrs	7.30-9.30
11	18	17	15	22	29	25	25	33	11	20	2,7	N	54%	Sunny	2hrs	7.30-9.30
12	19	18	16	20	27	26	24	28	13	20	3,4	E	44%	Cloudy	2hrs	7.30-9.30
13	17	15	13	18	22	22	21	27	11	17	6,7	W	67%	Sunny	2hrs	7.30-9.30
14	20	18	16	25	32	29	27	35	14	22	3,8	SW	66%	Sunny	2hrs	7.30-9.30
15	21	19	17	26	33	30	29	37	15	23	2,7	N	62%	Sunny	2hrs	7.30-9.30
16	20	18	16	24	28	27	25	36	11	21	6,1	N	75%	Sunny	2hrs	7.30-9.30
17	18	17	15	22	26	26	24	32	10	20	5,8	N	91%	Cloudy	2hrs	7.30-9.30
18	24	21	19	28	28	32	31	34	15	24	2,9	E	81%	Cloudy	2hrs	7.30-9.30
19	26	23	21	30	36	36	33	40	18	27	4,3	NE	86%	Cloudy	2hrs	7.30-9.30
20	29	26	23	33	34	41	36	42	17	29	1,9	NE	90%	Cloudy	2hrs	7.30-9.30
21	29	27	24	35	37	40	39	46	16	30	3,2	NE	66%	Sunny	2hrs	7.30-9.30
22	31	26	23	33	33	39	36	43	15	29	4,0	E	77%	Sunny	2hrs	7.30-9.30
23	32	28	25	35	36	42	39	44	18	31	2,6	N	88%	Cloudy	2hrs	7.30-9.30
24	27	25	22	29	35	35	34	44	16	28	7,0	SE	89%	Sunny	2hrs	7.30-9.30
25	23	21	18	26	34	31	29	39	14	24	7,7	SE	70%	Sunny	2hrs	7.30-9.30
26	9	8	7	11	14	13	11	15	6	10	17,9	SE	86%	Light Rain	2hrs	7.30-9.30
27	10	9	8	12	15	14	12	18	7	11	3,2	E	87%	Cloudy	2hrs	7.30-9.30
28	11	10	9	11	13	12	16	17	7	11	4,0	NE	67%	Cloudy	2hrs	7.30-9.30
TOT	18,4	16,6	14,7	21,7	25,6	25,3	23,8	30,1	11,5	19,4	5,5					

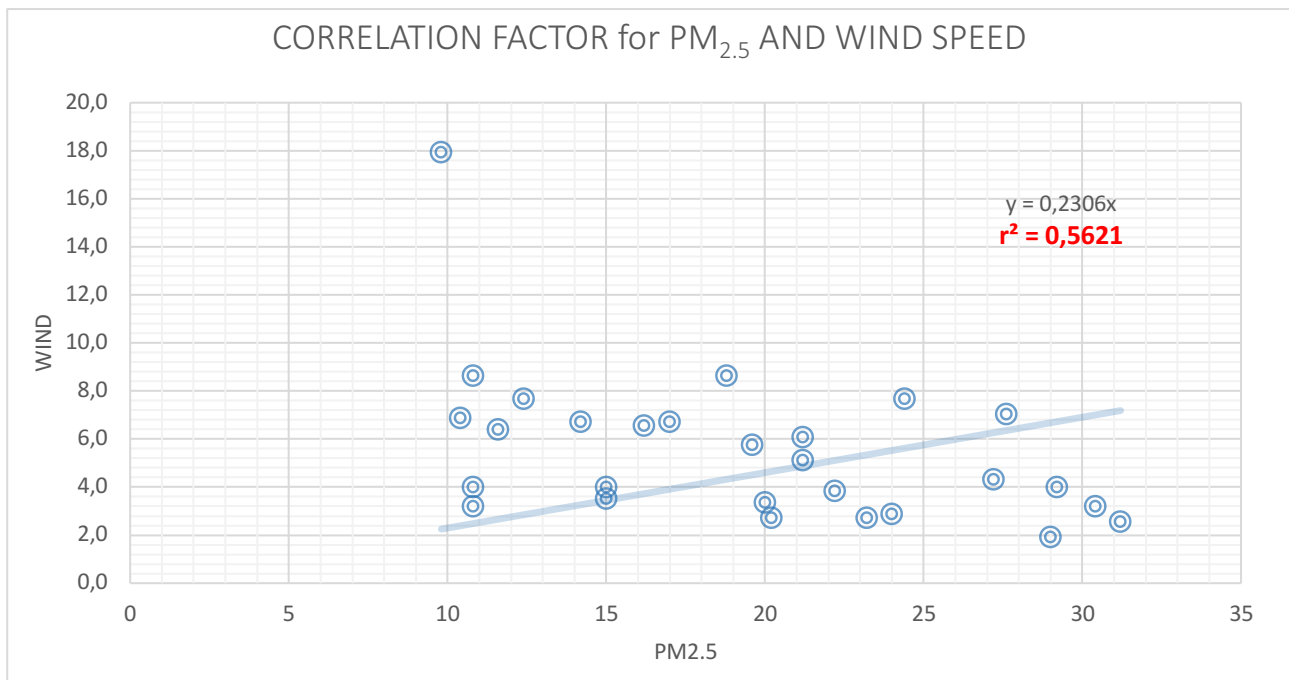
Source: Author

Graphic 33: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Delijorgji during February 2023.



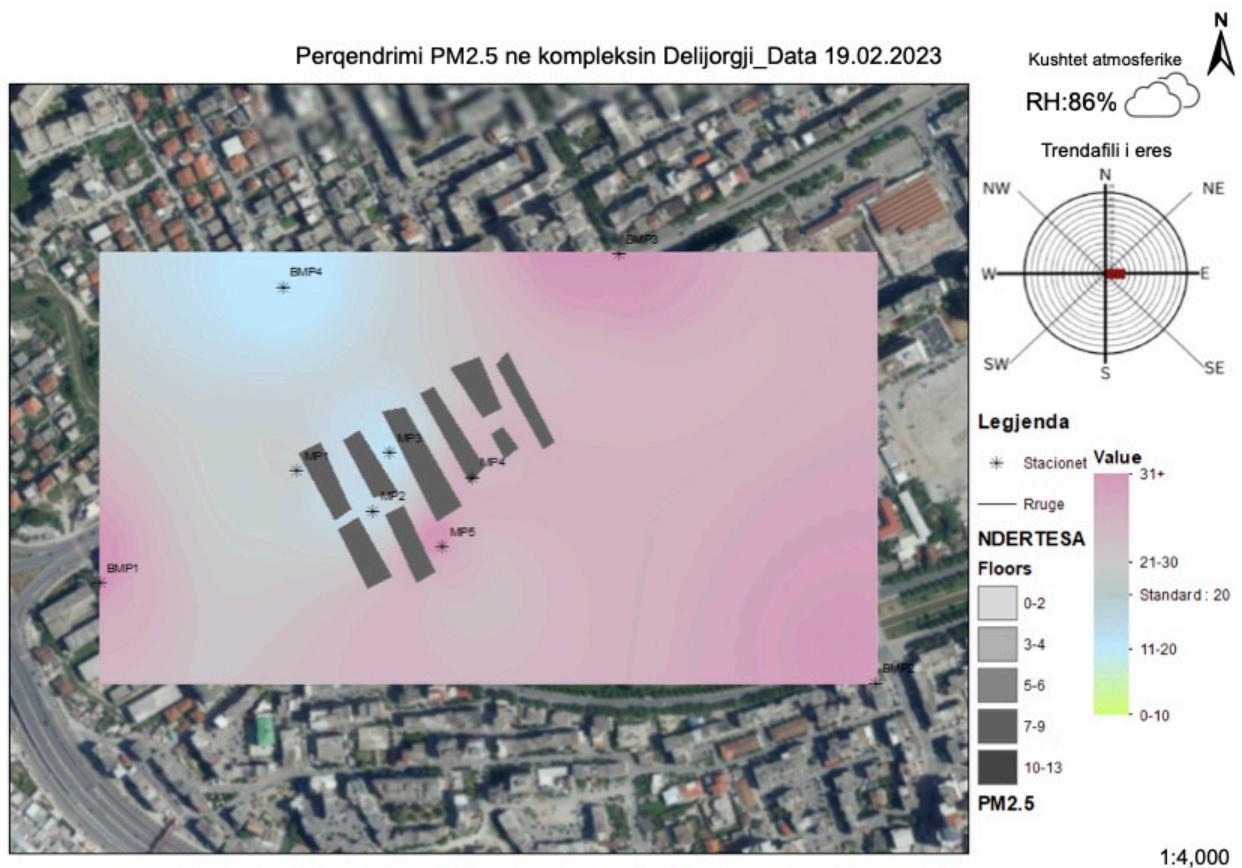
Source: Author

Graphic 34: Correlation factor between concentration of PM_{2.5} and Wind speed during January at Delijorgji Complex



Source: Author

Figure 73: Sample from the dispersal of PM_{2.5} sequence at Delijorgji (19.02.2023)



Source: Author

Given that during February 96% of the time was characterized by dry weather the correlation factor results indicating the effect of wind speed on the natural dispersal of air pollution within Magnet Complex have an overall result of $r=0.56$, indicating a strong correlation between these variables.

Nevertheless, taking into consideration that the predominating wind directions change and alter more frequently in comparison to January, yet there is no actual sign that an Air Pollution Cavity Area is created at Delijorgji due to its urban form.

Herby concluding that even by frequent change on wind directions during February, also the dry weather did not contribute to any artificial increased of any pollution concentration within the block. With regard to the results of MP5 being higher to the other MP it could be linked to the fact that this station is the nearest to a construction site.

DELIJORGJI _ MARCH 2023:

March on the other hand reserved another interesting meteorological pattern for this research. Taking into consideration the fact that during the first half of the month, the weather was either cloudy or rainy there was an absolute pollution wash-out effect that decreased levels of NOx and PM to the WHO limits (an occurrence very unlikely for Tirana). Such occurrence contributed to an overall reduction of all pollutant concentration at the area, providing thus the possibility for the research to obtain results where both scenarios when pollution accumulated from February was totally washed out and latter build up during the second part of the month. Such a temporal perspective of the pollution concentration build-up is crucial when assessing the presence or initial phasis of the creation of the pollution retention phenomena given the particular meteorological circumstances. Nevertheless, the urban form and positioning of Delijorgji Complex is among the best naturally ventilated in the City. Herby the phenomena of APCA is very unlikely.

Table 33: Number of days with sun, cloud and rain during March at Delijorgji complex.

Sun	Cloud	Rain
13	11	7
42%	35%	23%

Source: Author

Notably the wind orientation at this location is quite diverse and often at ground-level it is affected by a larger influence of Tirana’s Urban Form. North to the complex is situated one of the largest and oldest wind canyons of Tirana, the one affected by the urban form of Kavaja street. To the from North-West towards the south of the complex, winds are directed and re-oriented by Lana River.

Aside of considering the complex form and positioning only as an advantage given it's natural ventilation properties and natural pollution dispersal, we might also take into consideration that well ventilated areas are also prone to higher exposure given the emissions occurring in the surrounding areas and further being channelled into and out of the complex. Wind wash-out effect of the pollution exposes those that are situated along it's trajectory with a vast mix of pollutants being emitted even 10-20km far away.

Table 34: Number of days indicating the orientation of the wind during March at Delijorgji Complex

N	S	W	E	NW	NE	SE	SW
2	2	2	5	9	8	2	2
6%	6%	6%	16%	29%	26%	6%	6%

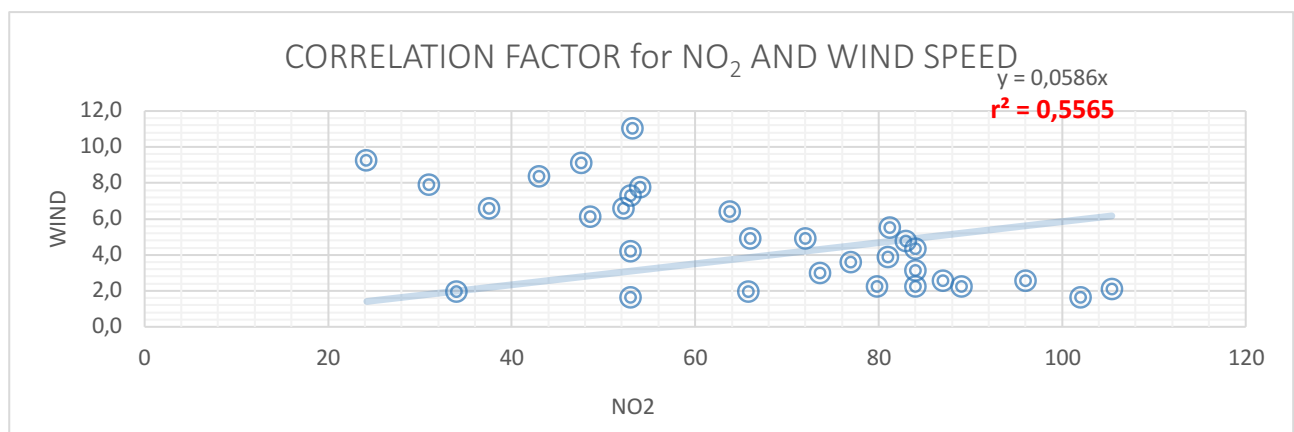
Source: Author

Table 35: NO₂ concentrations and meteorological observations during March 2023 / Delijorgji Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	NO2 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring length	Daytime
1	43	47	42	51	55	63	67	70	38	48	9,1	NE	63%	Cloudy / Rainy	2hrs	7.30-9.30
2	48	52	47	57	61	69	73	74	51	53	4,2	NE	84%	Cloudy	2hrs	7.30-9.30
3	78	86	77	93	101	110	105	102	72	87	2,5	NE	89%	Cloudy	2hrs	7.30-9.30
4	31	34	30	36	39	50	49	51	29	34	1,9	W	85%	Rainy	2hrs	7.30-9.30
5	59	65	58	71	76	88	87	81	54	66	1,9	W	90%	Cloudy	2hrs	7.30-9.30
6	57	53	49	58	53	73	76	79	38	54	7,7	NW	91%	Cloudy	2hrs	7.30-9.30
7	53	51	46	56	55	78	73	72	33	52	6,6	E	77%	Cloudy	2hrs	7.30-9.30
8	39	42	38	46	50	62	62	66	31	43	8,3	NW	93%	Rainy	2hrs	7.30-9.30
9	34	35	34	41	44	54	57	59	34	38	6,6	NW	71%	Cloudy	2hrs	7.30-9.30
10	27	30	31	32	35	51	46	50	29	31	7,9	NW	77%	Rainy	2hrs	7.30-9.30
11	22	24	21	26	28	37	39	35	19	24	9,2	NW	93%	Rainy	2hrs	7.30-9.30
12	65	71	64	77	83	89	95	82	52	72	4,9	S	92%	Cloudy	2hrs	7.30-9.30
13	69	76	68	83	89	94	100	92	66	77	3,6	S	67%	Sunny	2hrs	7.30-9.30
14	73	80	71	87	94	98	105	103	71	81	3,9	SE	55%	Cloudy	2hrs	7.30-9.30
15	47	51	46	56	66	67	71	77	43	53	11,0	SE	74%	Rainy	2hrs	7.30-9.30
16	66	72	64	78	88	90	96	83	69	74	3,0	N	70%	Cloudy	2hrs	7.30-9.30
17	76	83	74	90	97	101	108	94	79	84	4,3	E	68%	Cloudy	2hrs	7.30-9.30
18	80	88	79	95	103	106	114	100	82	89	2,2	E	72%	Sunny	2hrs	7.30-9.30
19	86	95	85	103	111	114	122	115	89	96	2,5	SW	63%	Sunny	2hrs	7.30-9.30
20	95	104	93	113	122	125	132	128	94	105	2,1	SW	82%	Sunny	2hrs	7.30-9.30
21	48	52	47	57	61	68	72	71	52	53	1,6	NE	91%	Rainy	2hrs	7.30-9.30
22	71	78	70	85	95	97	102	99	69	80	2,2	NE	92%	Sunny	2hrs	7.30-9.30
23	76	83	74	90	97	105	108	109	74	84	3,1	NE	67%	Sunny	2hrs	7.30-9.30
24	92	101	90	109	118	121	130	127	81	102	1,6	E	66%	Sunny	2hrs	7.30-9.30
25	75	82	73	89	96	100	108	102	68	83	4,8	NW	66%	Sunny	2hrs	7.30-9.30
26	65	64	64	68	69	72	77	75	47	66	4,9	NW	86%	Sunny	2hrs	7.30-9.30
27	48	52	47	57	61	67	72	77	42	53	7,3	NW	63%	Rainy	2hrs	7.30-9.30
28	76	83	74	90	97	101	108	105	56	84	2,2	N	83%	Sunny	2hrs	7.30-9.30
29	73	80	71	87	95	98	105	101	49	81	5,5	NE	55%	Sunny	2hrs	7.30-9.31
30	58	63	56	69	73	80	95	89	32	64	6,4	NE	62%	Sunny	2hrs	7.30-9.32
31	44	48	42	53	56	65	68	67	29	49	6,1	E	76%	Sunny	2hrs	7.30-9.33
TOT	60,5	65,3	58,9	71,1	76,4	83,6	87,8	85,0	53,9	66,4	4,8					

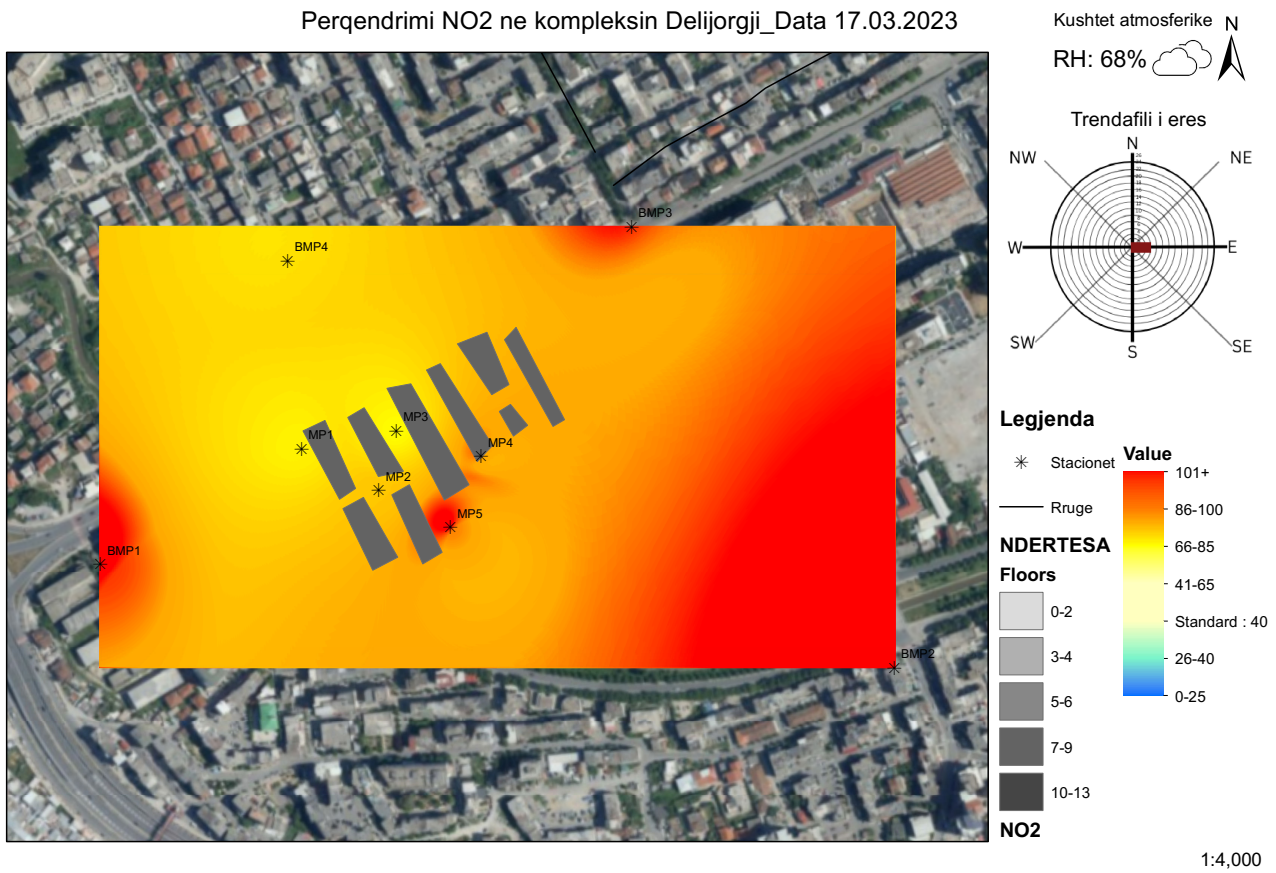
Source: Author

Graphic 35: Correlation factor between concentration of PM_{2.5} and Wind speed during March at Delijorgji Complex



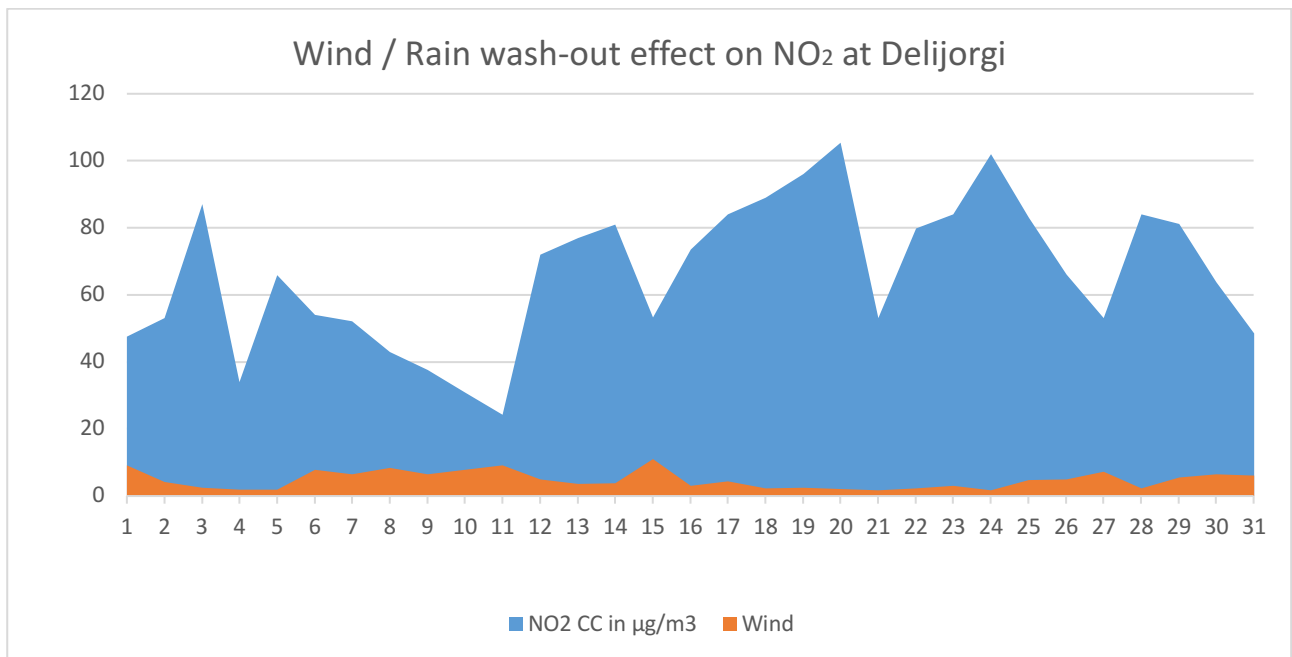
Source: Author

Figure 74: Sample from the dispersal of NO₂ sequence at Delijorgji (17.03.2023)



Source: Author

Graphic 36: Effect of wind and rain on the wash-out of NO₂ concentration at Delijorgji during March 2023.



Source: Author

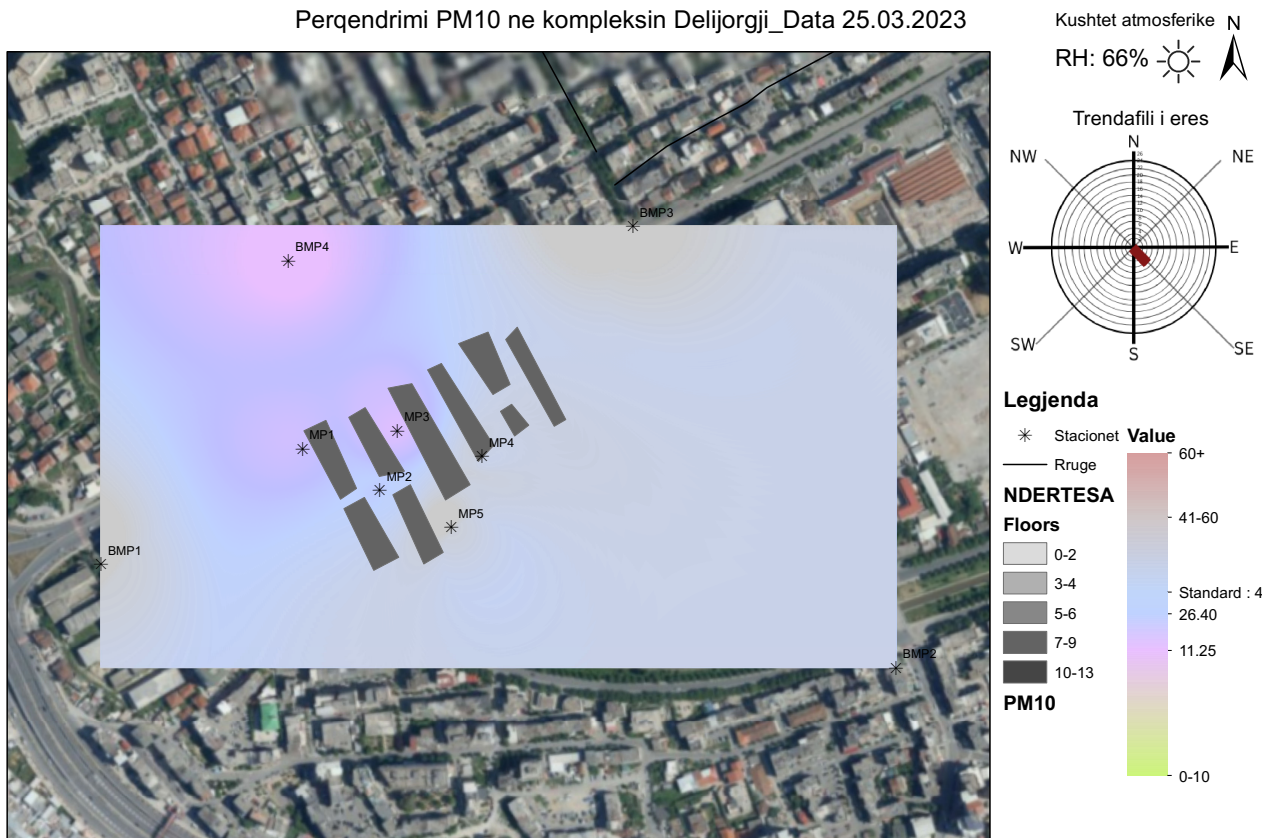
Table 36: PM₁₀ concentrations and meteorological observations during March 2023 / Delijorgji Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	PM10 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring length	Daytime
1	10	13	9	21	22	25	29	24	11	15	9,1	NE	63%	Cloudy / Rainy	2hrs	7.30-9.30
2	13	16	13	24	25	29	33	28	13	18	4,2	NE	84%	Cloudy	2hrs	7.30-9.30
3	17	21	18	23	27	28	35	30	15	21	2,5	NE	89%	Cloudy	2hrs	7.30-9.30
4	21	24	20	25	29	30	38	32	17	24	1,9	W	85%	Rainy	2hrs	7.30-9.30
5	19	22	18	26	29	31	38	32	16	23	1,9	W	90%	Cloudy	2hrs	7.30-9.30
6	10	13	11	18	22	22	29	24	10	15	7,7	NW	91%	Cloudy	2hrs	7.30-9.30
7	8	11	7	19	24	23	31	26	10	14	6,6	E	77%	Cloudy	2hrs	7.30-9.30
8	6	8	6	16	19	19	25	21	8	11	8,3	NW	93%	Rainy	2hrs	7.30-9.30
9	7	10	6	18	22	22	29	24	9	13	6,6	NW	71%	Cloudy	2hrs	7.30-9.30
10	5	7	4	12	17	14	22	19	6	9	7,9	NW	77%	Rainy	2hrs	7.30-9.30
11	3	4	3	7	9	8	12	10	4	5	9,2	NW	93%	Rainy	2hrs	7.30-9.30
12	7	10	6	18	19	22	25	21	8	12	4,9	S	92%	Cloudy	2hrs	7.30-9.30
13	10	13	9	21	24	25	31	26	11	15	3,6	S	67%	Sunny	2hrs	7.30-9.30
14	11	14	10	22	25	26	33	28	11	16	3,9	SE	55%	Cloudy	2hrs	7.30-9.30
15	4	5	4	7	9	8	12	10	4	6	11,0	SE	74%	Rainy	2hrs	7.30-9.30
16	13	16	12	21	24	25	31	26	12	17	3,0	N	70%	Cloudy	2hrs	7.30-9.30
17	10	13	11	18	24	22	31	26	11	15	4,3	E	68%	Cloudy	2hrs	7.30-9.30
18	16	19	15	23	25	28	33	28	14	20	2,2	E	72%	Sunny	2hrs	7.30-9.30
19	20	23	19	29	32	35	42	35	17	25	2,5	SW	63%	Sunny	2hrs	7.30-9.30
20	22	25	21	31	35	37	46	39	19	27	2,1	SW	82%	Sunny	2hrs	7.30-9.30
21	26	29	25	34	34	41	44	37	21	30	1,6	NE	91%	Rainy	2hrs	7.30-9.30
22	30	33	28	38	41	46	53	45	24	34	2,2	NE	92%	Sunny	2hrs	7.30-9.30
23	28	31	26	36	44	43	57	48	23	33	3,1	NE	67%	Sunny	2hrs	7.30-9.30
24	34	37	32	42	48	50	62	53	27	39	1,6	E	66%	Sunny	2hrs	7.30-9.30
25	27	30	25	35	41	42	34	45	22	32	4,8	NW	66%	Sunny	2hrs	7.30-9.30
26	19	22	17	28	26	34	25	29	16	22	4,9	NW	86%	Sunny	2hrs	7.30-9.30
27	11	14	10	17	19	20	38	21	10	14	7,3	NW	63%	Rainy	2hrs	7.30-9.30
28	20	23	18	27	29	32	31	30	16	23	2,2	N	83%	Sunny	2hrs	7.30-9.30
29	15	18	13	21	24	25	31	24	13	18	5,5	NE	0,55	Sunny	2hrs	7.30-9.31
30	12	15	10	21	24	25	22	23	10	16	6,4	NE	0,62	Sunny	2hrs	7.30-9.32
31	10	12	8	15	19	18	20	19	7	13	6,1	E	0,76	Sunny	2hrs	7.30-9.33
TOT	15,0	17,8	14,0	23,0	26,2	27,6	33,0	28,5	13,4	19,2	4,8					

Source: Author

Figure 75: Sample from the dispersal of PM₁₀ sequence at Delijorgji (25.03.2023)

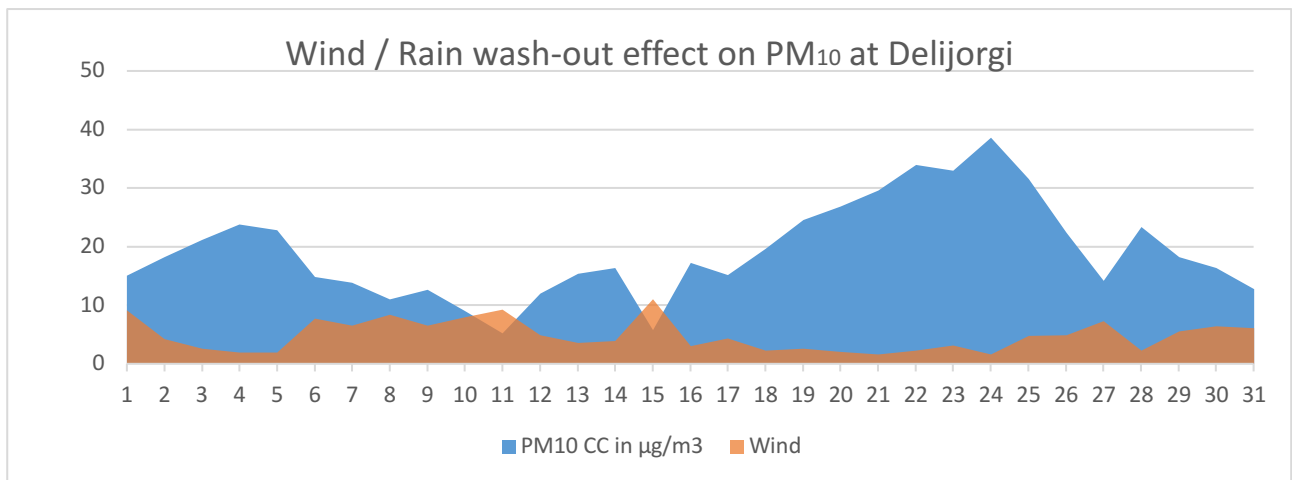
Perqendrimi PM10 ne kompleksin Delijorgji_Data 25.03.2023



1:4,000

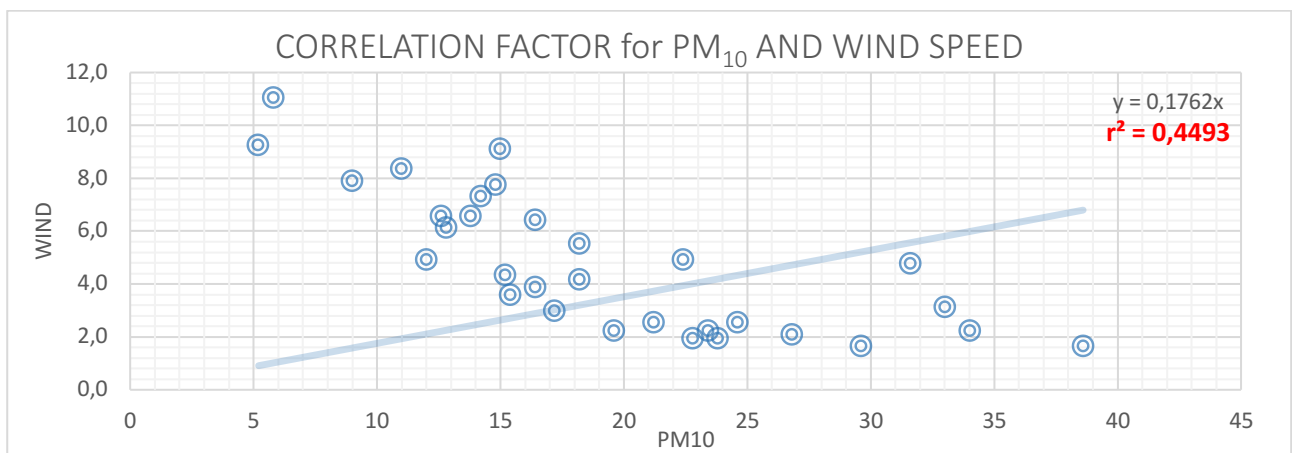
Source: Author

Graphic 37: Effect of wind and rain on the wash-out of PM₁₀ concentration at Delijorgji during March 2023.



Source: Author

Graphic 38: Correlation factor between concentration of PM₁₀ and Wind speed during March at Delijorgji Complex

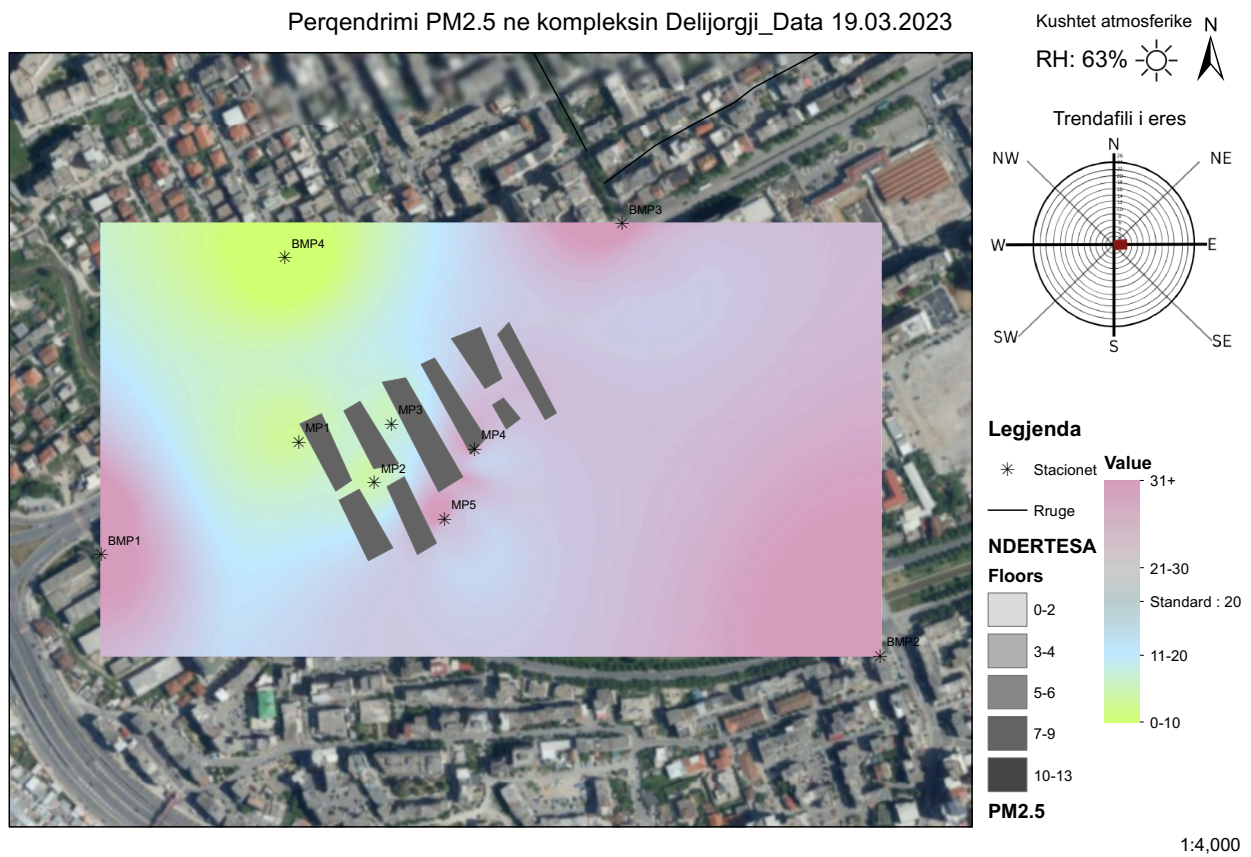


Source: Author

Table 37: PM_{2.5} concentrations and meteorological observations during March 2023 / Delijorgji Complex.

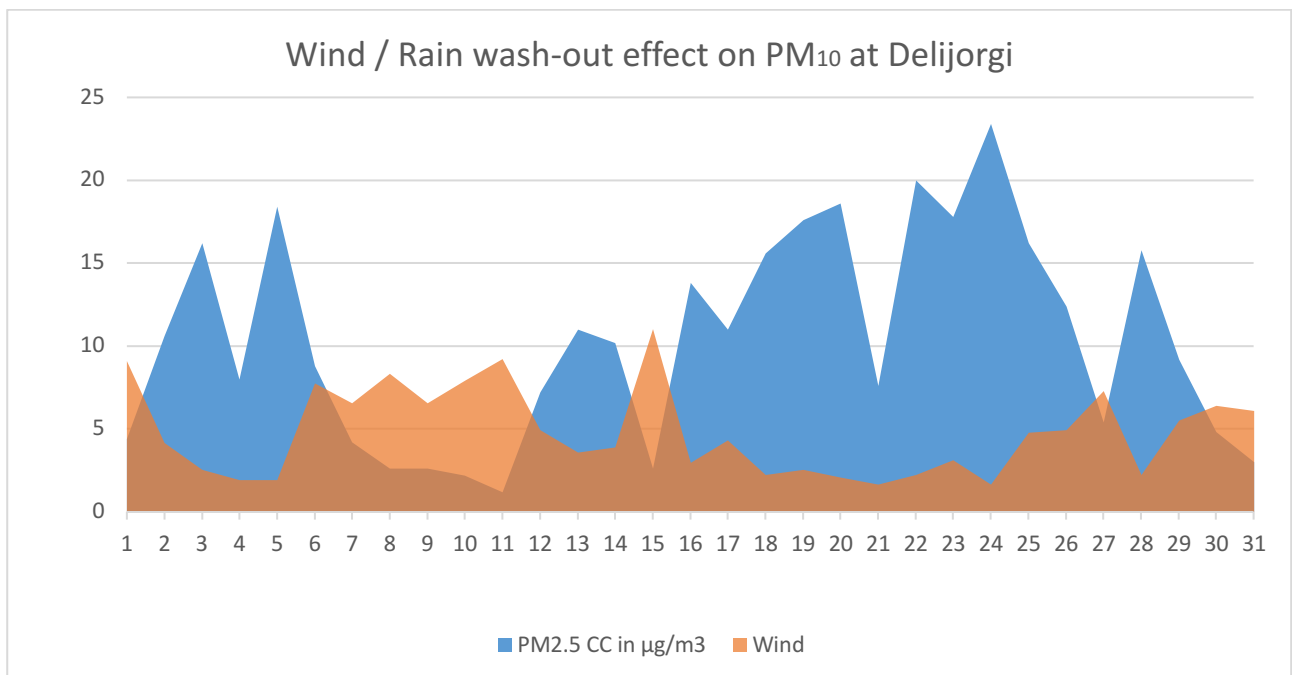
Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	PM2.5 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitoring length	Daytime
1	3	5	2	5	7	9	11	8	3	4	9,1	NE	63%	Cloudy / Rainy	2hrs	7.30-9.30
2	7	10	8	12	16	19	18	17	5	11	4,2	NE	84%	Cloudy	2hrs	7.30-9.30
3	14	16	13	17	21	27	22	2	8	16	2,5	NE	89%	Cloudy	2hrs	7.30-9.30
4	5	8	6	10	11	13	15	11	4	8	1,9	W	85%	Rainy	2hrs	7.30-9.30
5	15	17	16	21	23	28	27	25	12	18	1,9	W	90%	Cloudy	2hrs	7.30-9.30
6	8	8	7	11	10	11	18	9	6	9	7,7	NW	91%	Cloudy	2hrs	7.30-9.30
7	3	5	2	6	5	6	7	5	2	4	6,6	E	77%	Cloudy	2hrs	7.30-9.30
8	2	3	2	3	3	3	4	1	1	3	8,3	NW	93%	Rainy	2hrs	7.30-9.30
9	2	3	1	4	3	4	4	3	0	3	6,6	NW	71%	Cloudy	2hrs	7.30-9.30
10	2	2	2	2	3	4	5	2	1	2	7,9	NW	77%	Rainy	2hrs	7.30-9.30
11	1	0	1	2	2	2	1	2	0	1	9,2	NW	93%	Rainy	2hrs	7.30-9.30
12	6	8	5	10	7	9	11	7	2	7	4,9	S	92%	Cloudy	2hrs	7.30-9.30
13	9	12	7	15	12	18	22	18	3	11	3,6	S	67%	Sunny	2hrs	7.30-9.30
14	7	9	8	12	15	23	20	20	3	10	3,9	SE	55%	Cloudy	2hrs	7.30-9.30
15	1	2	1	4	5	6	7	5	0	3	11,0	SE	74%	Rainy	2hrs	7.30-9.30
16	12	15	10	15	17	26	25	24	4	14	3,0	N	70%	Cloudy	2hrs	7.30-9.30
17	8	11	7	13	16	22	21	22	6	11	4,3	E	68%	Cloudy	2hrs	7.30-9.30
18	11	14	13	19	21	32	33	32	7	16	2,2	E	72%	Sunny	2hrs	7.30-9.30
19	13	14	15	22	24	29	24	25	9	18	2,5	SW	63%	Sunny	2hrs	7.30-9.30
20	15	17	13	23	25	35	29	31	8	19	2,1	SW	82%	Sunny	2hrs	7.30-9.30
21	5	8	6	10	9	13	15	13	3	8	1,6	NE	91%	Rainy	2hrs	7.30-9.30
22	17	21	16	24	22	33	34	30	5	20	2,2	NE	92%	Sunny	2hrs	7.30-9.30
23	14	20	18	18	19	25	27	24	14	18	3,1	NE	67%	Sunny	2hrs	7.30-9.30
24	19	22	18	28	30	42	48	44	17	23	1,6	E	66%	Sunny	2hrs	7.30-9.30
25	15	14	17	17	18	27	31	23	12	16	4,8	NW	66%	Sunny	2hrs	7.30-9.30
26	11	9	12	14	16	21	24	19	9	12	4,9	NW	86%	Sunny	2hrs	7.30-9.30
27	3	5	4	8	7	9	9	8	2	5	7,3	NW	63%	Rainy	2hrs	7.30-9.30
28	13	17	12	18	19	30	29	28	8	16	2,2	N	83%	Sunny	2hrs	7.30-9.30
29	9	8	9	9	11	12	17	15	5	9	5,5	NE	0,55	Sunny	2hrs	7.30-9.31
30	4	4	3	5	8	9	11	11	3	5	6,4	NE	0,62	Sunny	2hrs	7.30-9.32
31	2	3	3	5	2	6	8	12	4	3	6,1	E	0,76	Sunny	2hrs	7.30-9.33
TOT	8,3	10,0	8,3	12,3	13,1	17,8	18,6	16,0	5,4	10,4	4,8					

Figure 76: Sample from the dispersal of PM_{2.5} sequence at Delijorgji (19.03.2023)



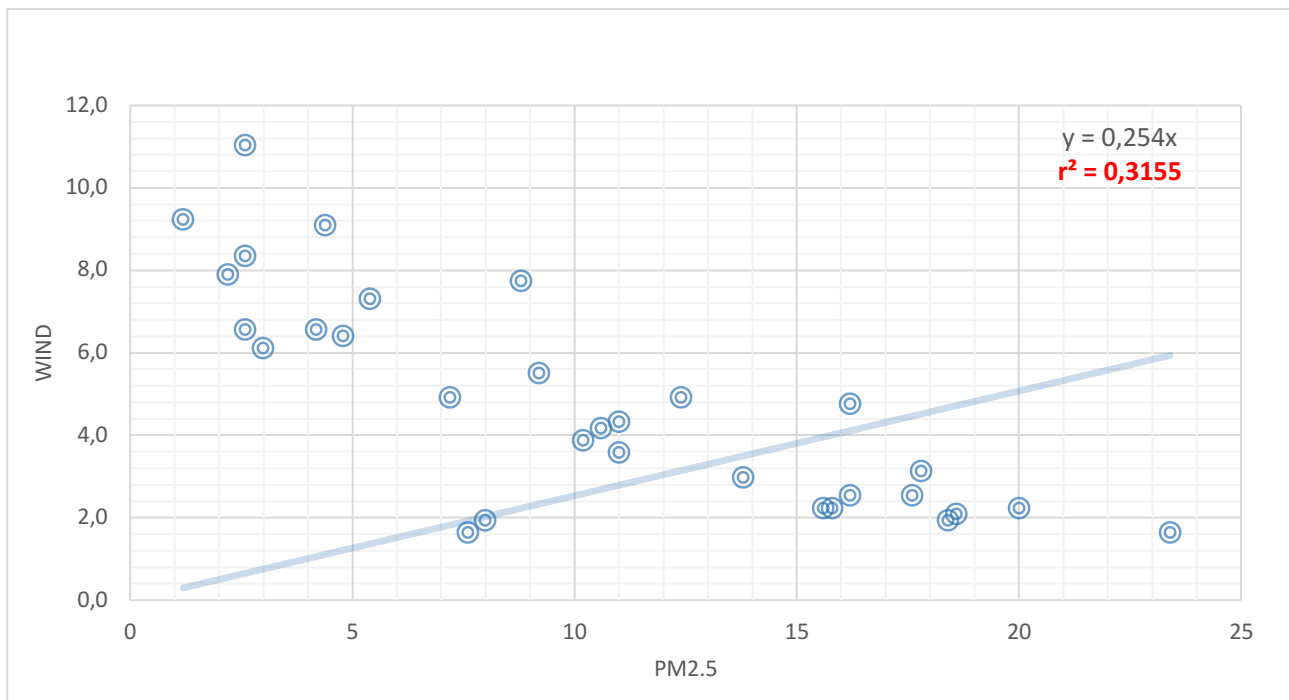
Source: Author

Graphic 39: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Delijorgji during March 2023.



Source: Author

Graphic 40: Correlation factor between concentration of PM_{2.5} and Wind speed during March at Delijorgji Complex



Source: Author

March meteorological conditions registered during the morning practices were quite unstable and often raining during the first two weeks. However, the stable second part of the month, reflected a correlation factor indicating the effect of wind speed on the natural dispersal of air pollution within Delijorgji Complex to be around $r=0.44$, indicating a moderate correlation between these variables. If we deduct the results from *the* monitoring days with rain then the correlation factor between wind speed and pollution concentration in the area increases to $r=0.77$

On the other hand, considering that wind directions change and/or alter more frequently in comparison to January (quite similar yet different also from February) **there is no actual indication that an Air Pollution Cavity Area is created at Delijorgji due to its urban form**, this from any of the occurred wind direction during the monitoring period.

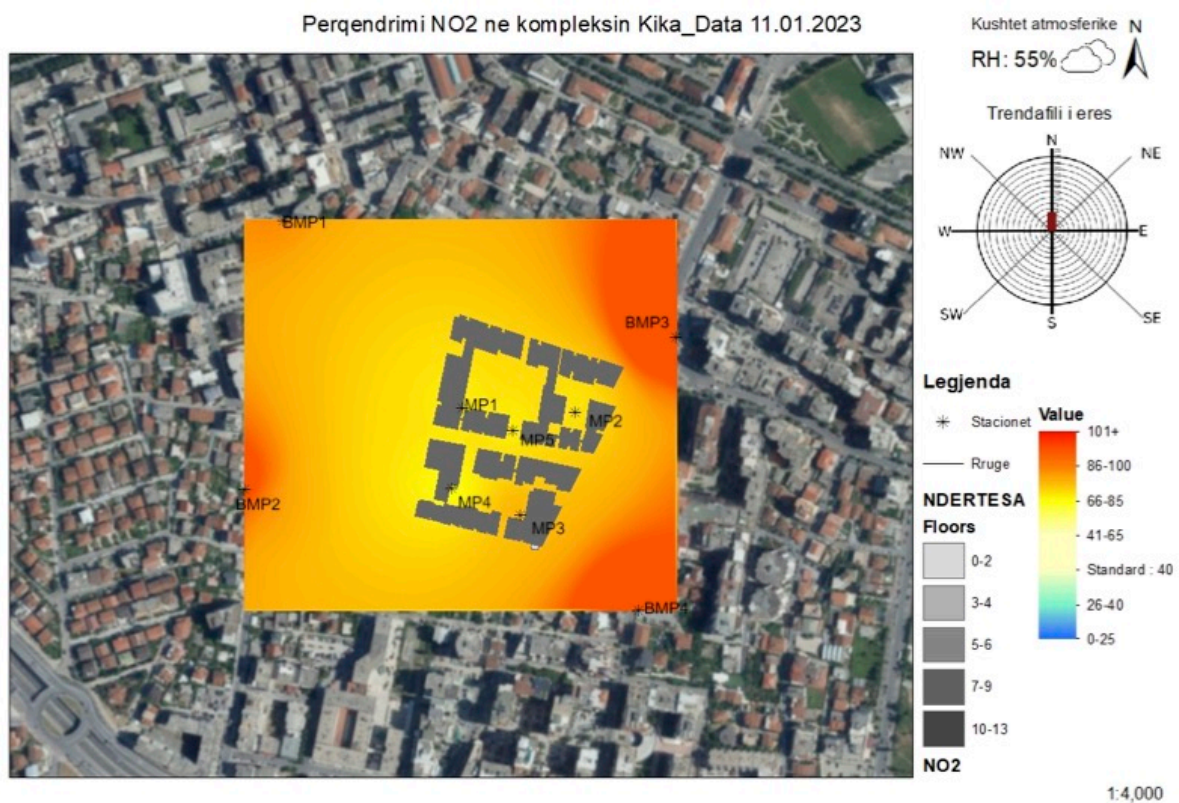
Herby concluding that even by frequent change on wind directions during February and March, also adding the nuanced weather of March and the extreme dry weather of February. None of this influenced nor contributed to any artificial increased of any pollution concentration within the block. With regard to the results of MP5 being higher to the other MP it could be linked to the fact that this station is the nearest to a construction site. Herby we can conclude that the urban form of Delijorgji's with parallel dwellings, creating wind tunnels from North-West to South-East is the best orientation to for the natural ventilation and dispersal of air pollution. This only applicable to Tirana's micro-climate patterns.

Re-confirming that also at Delijorgji, during March were registered the lowest impact compared with January and February. Such occurrence is directly attributed to the fact that wash-out effect from rain decreased the overall pollution concentration in the area and throughout the city or region.

KIKA COMPLEX.

Based on the same methodology applied to all monitoring areas, also at KIKA Complex there were fixed 5 Monitoring Points out of which 3 were presumed to be affected by the vortex effect and that could retain pollution for a more prolonged time compared to other the monitoring location that were strategically position at the intersections whereas the urban morphology of the study area created wind corridors.

Figure 77: Pollution concentration map (1 sample out of 270 maps prepared for Kikai Area)



Source: Author

All the monitored components such as urban form, concentration of pollution, wind direction, wind speed, meteorological condition and relative humidity are expressed within the daily maps. These maps have been replicated under the same conditions also for the PM 2.5 and PM 10 pollutants. Herby there are 270 maps generated for this complex (90 per each pollutant) extracting and visualizing the data from 90 site monitoring sheets.

These maps were later joined into a sequence per each pollutant indicating thus the potential cavity areas whereas natural dispersal of air pollutants is impacted by the urban form.

All the monitoring points at KIKA Complex were conducted between 13:30 until 16:00 at maximum. Covering at least 25 minutes of each monitoring point within the block whereas the author was looking for air pollution cavity areas and 7-10 minutes of monitoring for each buffer monitoring point.

KIKA _ JANUARY 2023:

Same with the other monitoring locations January began with extreme pollution concentration mainly due to the intense emission from the activities carried out throughout the city during Christmas Holiday period. Such pollution accumulated from December was further aggravated by the firework celebration of the New Year eve and further by the fact that until 10th January there was a dry weather with minor winds. Therefore, since no significant wash-out effect occurred until mid-January, those minor winds present during this time frame account for a low dispersal of the pollution throughout the complex and further the city. The urban form of KIKA Complex represents an isolated block throughout its whole perimeter, with small tunnels positioned in-between the high dwellings and oriented from North to South and West to East, therefore each of wind patterns facing this block, penetrates in its inner part.

Given to the closed corners of this block and the fact that it is position nearby an area with high pollution arising from both construction and traffic, such urban form is expected to contribute into the creation of the pollution retention phenomena. Preliminary it is expected that at least 2 of 5 monitoring points prove that there are air pollution cavity areas within KIKA complex.

Table 38: Number of days with sun, cloud and rain during January at KIKA complex.

Sun	Cloud	Rain
15	11	5
48%	35%	16%

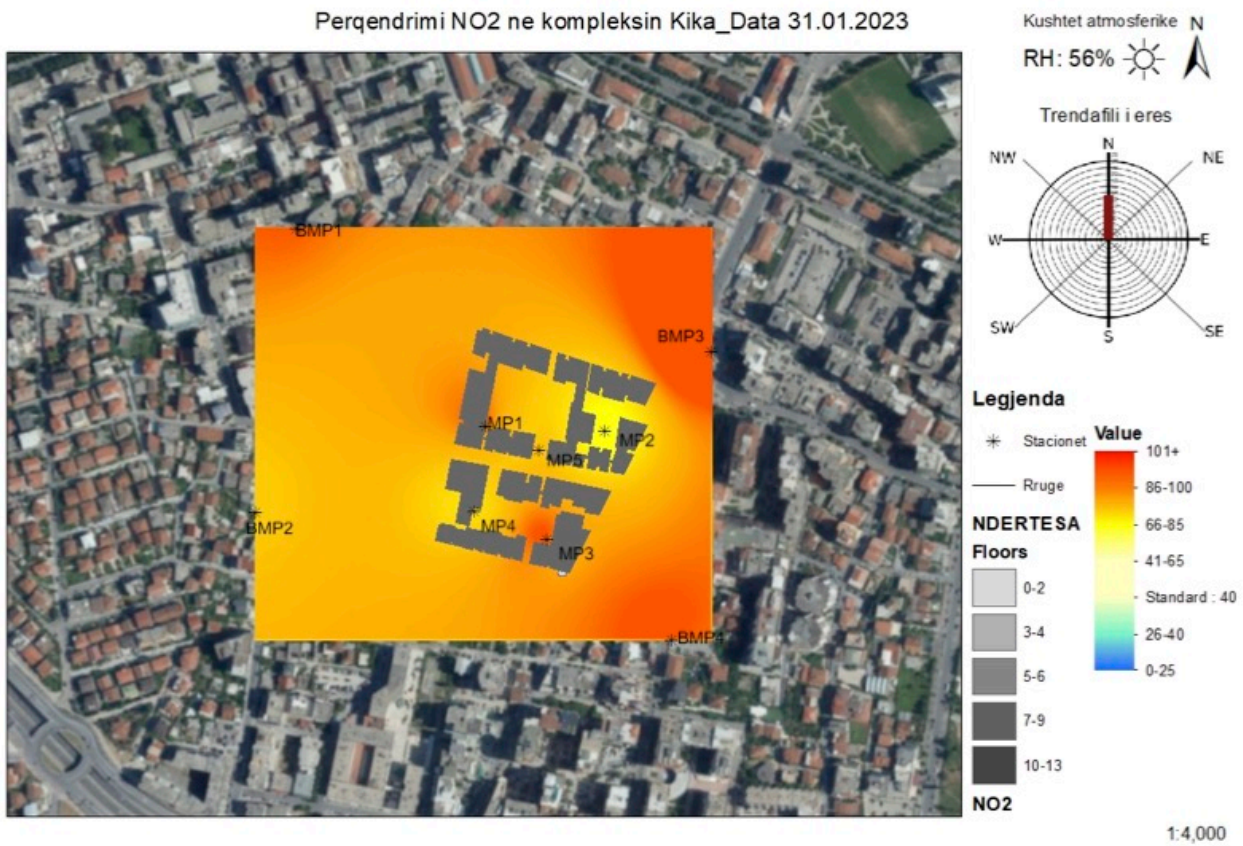
Source: Author

Table 39: NO₂ concentrations and meteorological observations during January 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. NO2 CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	107	103	111	107	105	108	102	113	135	107	4,0	E	61%	Sunny	2hrs 13:30-16:00
2	110	107	113	106	109	109	108	117	141	109	3,5	W	58%	Sunny	2hrs 13:30-16:00
3	97	92	99	92	91	92	94	99	123	94	6,9	NW	74%	Sunny	2hrs 13:30-16:00
4	103	93	100	91	92	95	96	97	128	96	4,0	W	75%	Cloudy	2hrs 13:30-16:00
5	104	89	101	89	86	96	93	96	132	94	5,5	W	66%	Sunny	2hrs 13:30-16:00
6	99	85	102	87	83	93	90	93	127	91	5,5	NW	71%	Sunny	2hrs 13:30-16:00
7	104	87	104	91	92	99	94	94	136	96	4,3	W	50%	Sunny	2hrs 13:30-16:00
8	108	90	103	94	93	102	99	105	144	98	4,7	SW	61%	Sunny	2hrs 13:30-16:00
9	91	83	92	87	80	89	91	85	112	87	19,8	S	63%	Cloudy	2hrs 13:30-16:00
10	68	65	69	61	67	75	77	73	88	66	5,8	NW	80%	Rainy	2hrs 13:30-16:00
11	73	74	79	71	73	83	88	94	100	74	4,7	N	55%	Cloudy	2hrs 13:30-16:00
12	76	72	72	68	69	82	80	84	94	71	6,9	NW	50%	Sunny	2hrs 13:30-16:00
13	80	74	74	65	71	86	88	91	111	73	5,0	W	52%	Sunny	2hrs 13:30-16:00
14	84	70	69	66	73	89	91	93	119	72	4,7	NW	57%	Sunny	2hrs 13:30-16:00
15	92	77	82	76	83	97	99	105	132	82	2,6	SW	48%	Sunny	2hrs 13:30-16:00
16	75	59	73	60	66	81	80	88	103	67	17,7	SE	60%	Cloudy	2hrs 13:30-16:00
17	49	43	50	47	45	52	49	63	70	47	20,1	S	82%	Rainy	2hrs 13:30-16:00
18	21	18	22	17	17	28	27	31	39	19	15,4	S	89%	Storm	2hrs 13:30-16:00
19	15	17	15	12	21	14	17	15	22	16	18,7	S	91%	Rainy	2hrs 13:30-16:00
20	42	43	42	43	47	60	66	65	79	43	10,8	S	79%	Cloudy	2hrs 13:30-16:00
21	41	38	44	42	52	66	69	72	81	43	15,8	SE	65%	Cloudy	2hrs 13:30-16:00
22	46	41	40	41	55	70	68	77	89	45	12,2	SE	44%	Cloudy	2hrs 13:30-16:00
23	24	22	20	19	22	50	48	52	55	21	10,5	E	85%	Rainy	2hrs 13:30-16:00
24	33	32	37	25	28	58	61	59	78	31	4,7	W	57%	Sunny	2hrs 13:30-16:00
25	54	39	49	41	42	66	67	69	85	45	5,0	E	58%	Cloudy	2hrs 13:30-16:00
26	51	31	46	29	31	54	55	62	76	38	12,2	E	64%	Cloudy	2hrs 13:30-16:00
27	66	48	67	52	50	77	81	79	93	57	2,9	NW	56%	Cloudy	2hrs 13:30-16:00
28	68	45	72	47	55	78	73	105	111	57	6,1	W	53%	Sunny	2hrs 13:30-16:00
29	83	75	89	71	82	99	91	108	124	80	3,5	W	44%	Sunny	2hrs 13:30-16:00
30	78	69	83	65	71	82	82	88	105	73	9,0	NW	50%	Sunny	2hrs 13:30-16:00
31	78	63	79	69	72	79	71	80	94	72	13,4	N	56%	Sunny	2hrs 13:30-16:00
TOT	71,6	62,7	70,9	62,3	65,3	77,7	77,3	82,3	100,8	66,6	8,6				

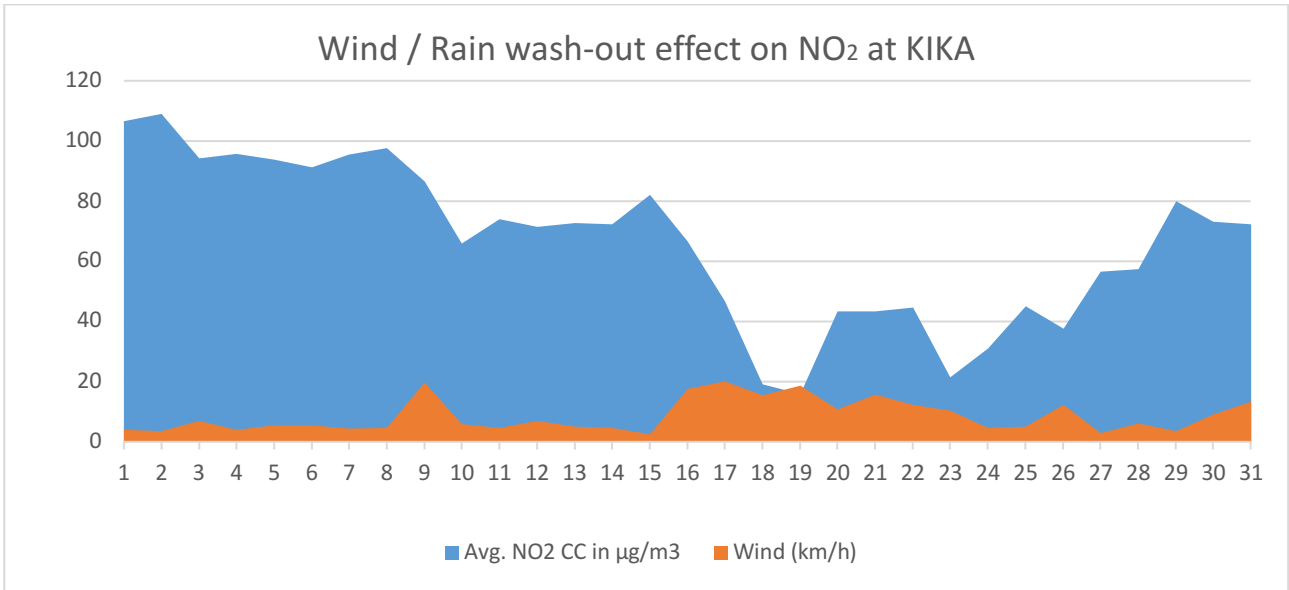
Source: Author

Figure 78: Sample from the dispersal of NO₂ sequence at KIKA Complex (31.01.2023)



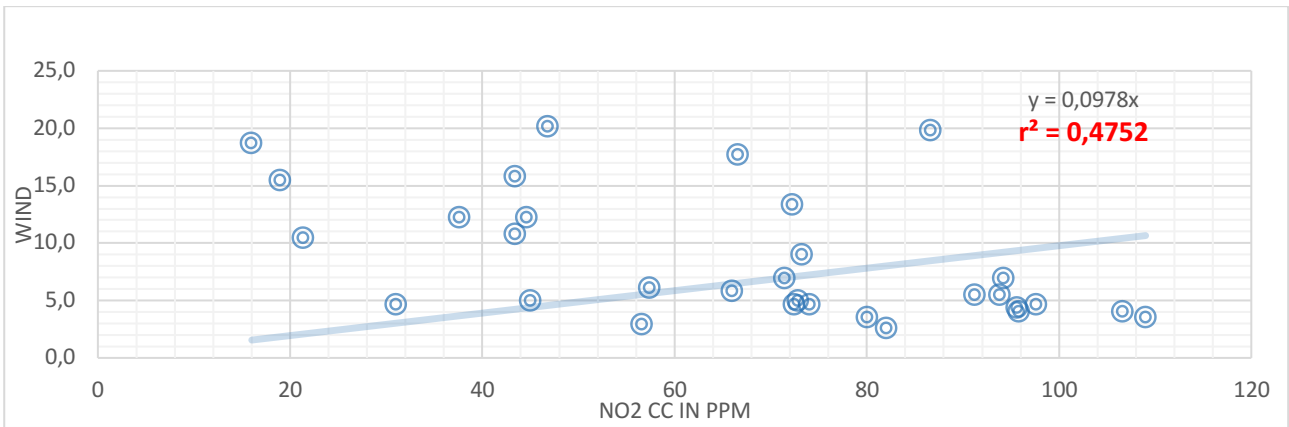
Source: Author

Graphic 41: Effect of wind and rain on the wash-out of NO₂ concentration at KIKA Complex during January 2023



Source: Author

Graphic 42: Correlation factor between concentration of NO₂ and Wind speed during January at KIKA Complex



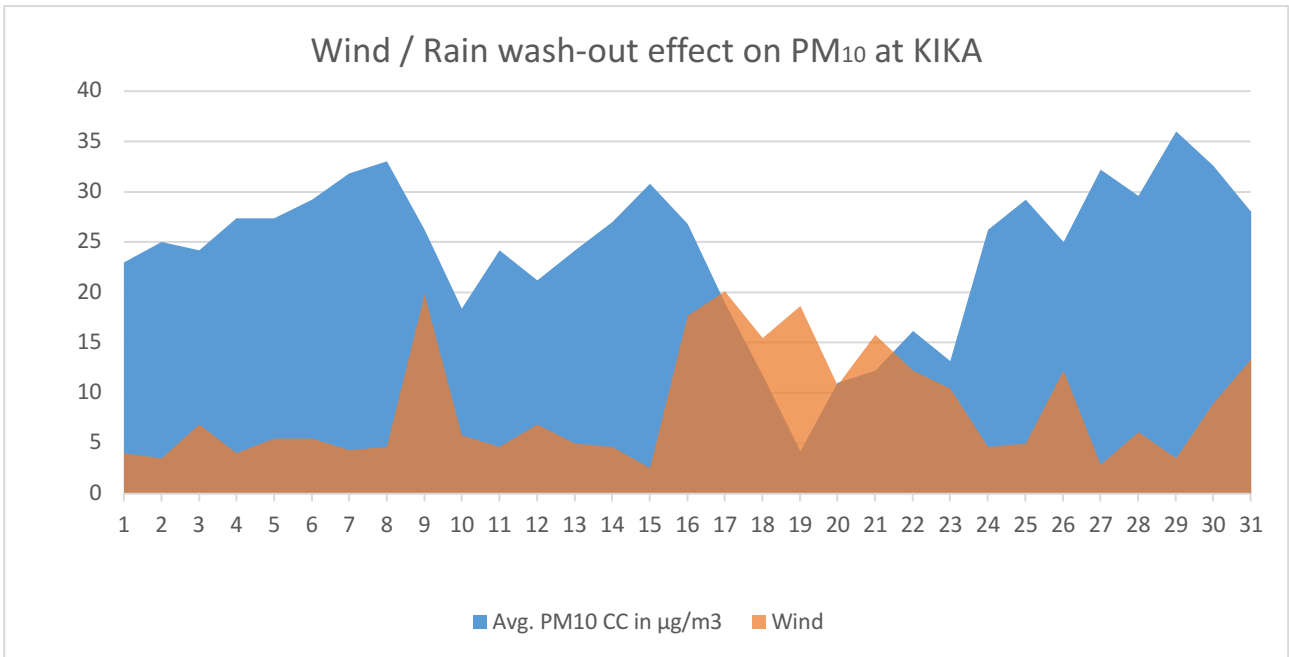
Source: Author

Table 40: PM₁₀ concentrations and meteorological observations during January 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	24	22	25	23	21	26	25	26	33	23	4,0	E	61%	Sunny	2hrs	13:30 - 16:00
2	28	25	27	22	23	27	28	28	37	25	3,5	W	58%	Sunny	2hrs	13:30 - 16:00
3	27	22	26	23	23	25	24	29	39	24	6,9	NW	74%	Sunny	2hrs	13:30 - 16:00
4	30	25	29	26	27	30	28	32	44	27	4,0	W	75%	Cloudy	2hrs	13:30 - 16:00
5	31	24	32	25	25	28	31	31	48	27	5,5	W	66%	Sunny	2hrs	13:30 - 16:00
6	34	26	33	26	27	30	29	33	51	29	5,5	NW	71%	Sunny	2hrs	13:30 - 16:00
7	38	25	35	31	30	33	35	37	52	32	4,3	W	50%	Sunny	2hrs	13:30 - 16:00
8	41	26	36	30	32	37	34	36	57	33	4,7	SW	61%	Sunny	2hrs	13:30 - 16:00
9	34	20	31	22	24	25	29	32	50	26	19,8	S	63%	Cloudy	2hrs	13:30 - 16:00
10	22	17	20	16	17	22	24	26	29	18	5,8	NW	80%	Rainy	2hrs	13:30 - 16:00
11	27	22	25	24	23	31	28	32	41	24	4,7	N	55%	Cloudy	2hrs	13:30 - 16:00
12	26	20	21	20	19	30	25	29	44	21	6,9	NW	50%	Sunny	2hrs	13:30 - 16:00
13	28	21	22	24	26	34	29	32	52	24	5,0	W	52%	Sunny	2hrs	13:30 - 16:00
14	32	25	29	23	26	33	32	35	58	27	4,7	NW	57%	Sunny	2hrs	13:30 - 16:00
15	39	28	33	25	29	41	44	49	68	31	2,6	SW	48%	Sunny	2hrs	13:30 - 16:00
16	35	23	29	26	21	37	31	36	62	27	17,7	SE	60%	Cloudy	2hrs	13:30 - 16:00
17	21	19	19	17	19	25	22	28	29	19	20,1	S	82%	Rainy	2hrs	13:30 - 16:00
18	12	11	13	11	12	12	14	12	18	12	15,4	S	89%	Storm	2hrs	13:30 - 16:00
19	4	6	5	1	5	10	9	12	12	4	18,7	S	91%	Rainy	2hrs	13:30 - 16:00
20	11	14	11	10	9	18	15	18	22	11	10,8	S	79%	Cloudy	2hrs	13:30 - 16:00
21	12	13	15	11	10	22	17	23	30	12	15,8	SE	65%	Cloudy	2hrs	13:30 - 16:00
22	21	14	18	13	15	24	20	28	34	16	12,2	SE	44%	Cloudy	2hrs	13:30 - 16:00
23	16	12	16	10	12	17	16	15	21	13	10,5	E	85%	Rainy	2hrs	13:30 - 16:00
24	28	22	31	24	26	25	22	26	32	26	4,7	W	57%	Sunny	2hrs	13:30 - 16:00
25	34	27	30	28	27	35	32	37	41	29	5,0	E	58%	Cloudy	2hrs	13:30 - 16:00
26	29	24	28	22	22	36	32	34	42	25	12,2	E	64%	Cloudy	2hrs	13:30 - 16:00
27	35	30	31	32	33	42	40	37	56	32	2,9	NW	56%	Cloudy	2hrs	13:30 - 16:00
28	38	28	27	28	27	43	39	41	62	30	6,1	W	53%	Sunny	2hrs	13:30 - 16:00
29	43	32	38	32	35	49	41	44	66	36	3,5	W	44%	Sunny	2hrs	13:30 - 16:00
30	40	28	37	27	31	32	30	33	54	33	9,0	NW	50%	Sunny	2hrs	13:30 - 16:00
31	37	25	31	22	25	29	27	28	51	28	13,4	N	56%	Sunny	2hrs	13:30 - 16:00
TOT	28,3	21,8	25,9	21,7	22,6	29,3	27,4	30,3	43,1	24,1	8,6					

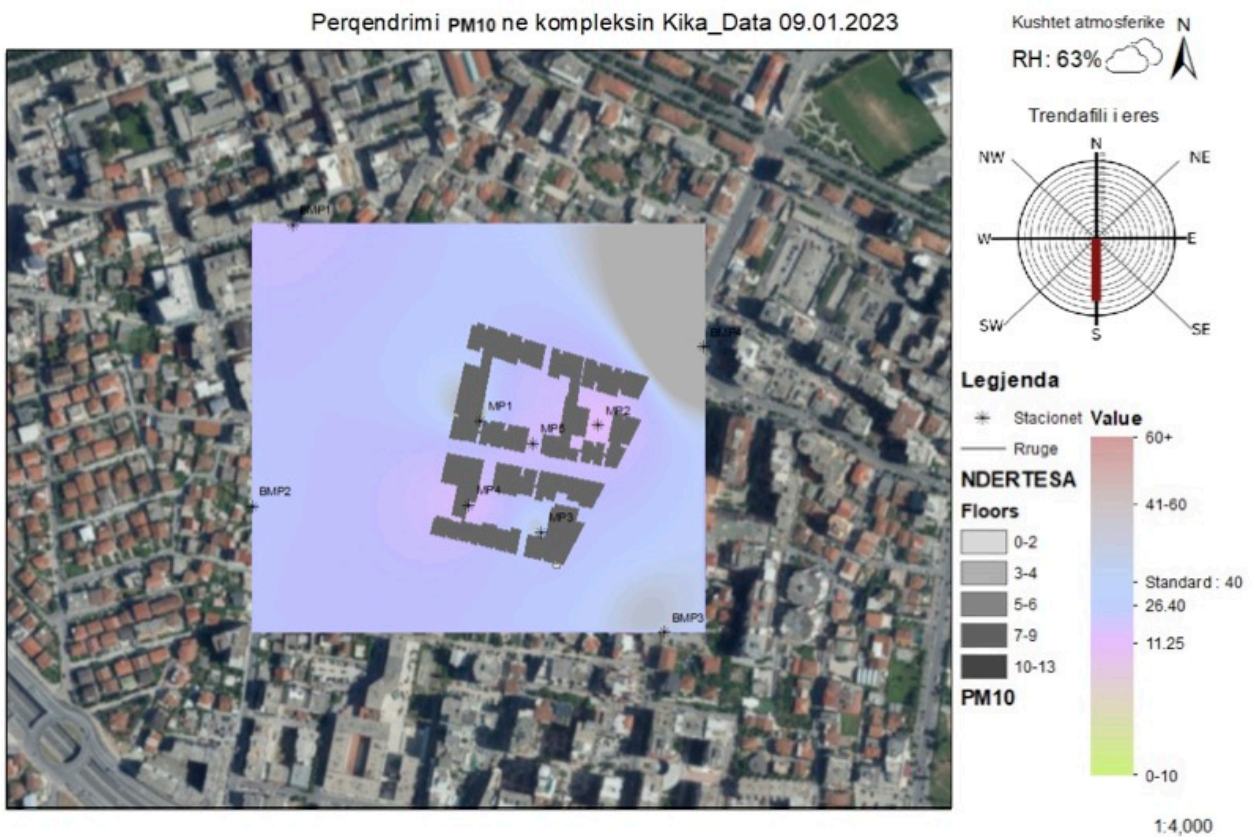
Source: Author

Graphic 43: Effect of wind and rain on the wash-out of PM₁₀ concentration at KIKA Complex during January 2023



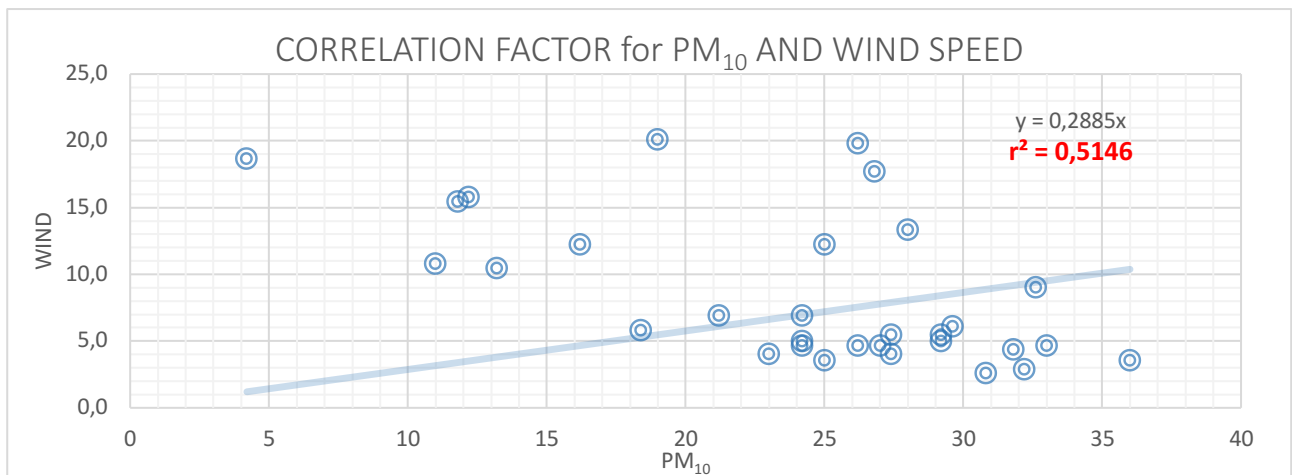
Source: Author

Figure 79: Sample from the dispersal of PM₁₀ sequence at KIKA Complex (9.01.2023)



Source: Author

Graphic 44: Correlation factor between concentration of PM₁₀ and Wind speed during January at KIKA Complex



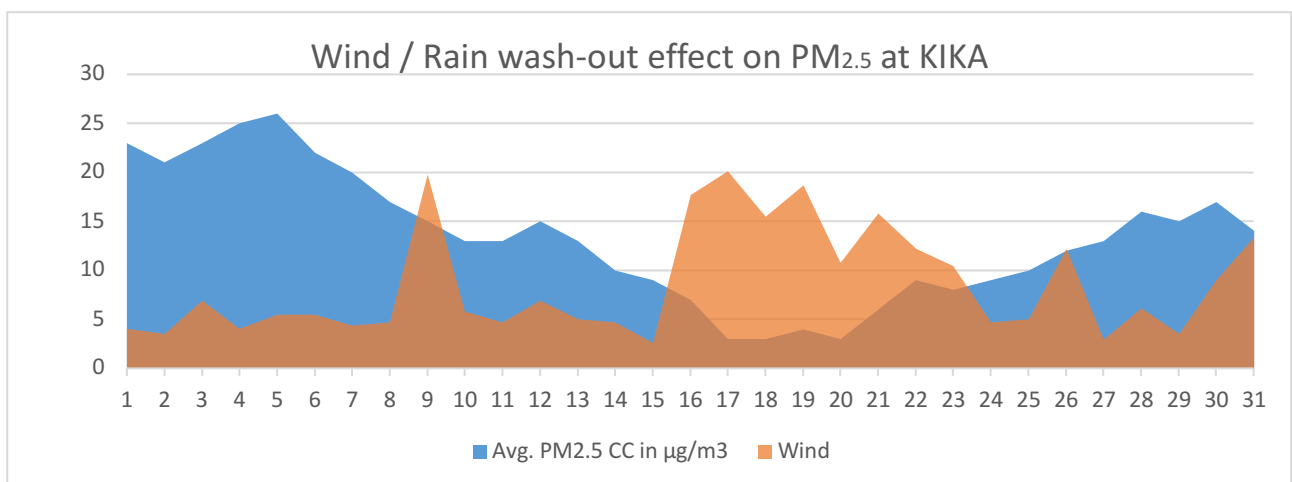
Source: Author

Table 41: PM_{2.5} concentrations and meteorological observations during January 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM2.5 CC in µg/m3	Wind	Direction	Humidity	Weather	Monitorin	Daytime
1	19,1	16,6	18,4	15,3	16,8	21,0	18,0	23,0	27,0	17,2	4,0	E	61%	Sunny	2hrs	13:30 - 16:00
2	24,2	18,7	22,2	18,8	19,7	23,0	19,5	22,0	30,3	20,7	3,5	W	58%	Sunny	2hrs	13:30 - 16:00
3	21,7	17,2	20,4	16,7	17,2	22,0	20,0	21,0	33,0	18,6	6,9	NW	74%	Sunny	2hrs	13:30 - 16:00
4	25,8	19,6	24,1	21,1	22,3	27,4	22,2	23,4	37,7	22,6	4,0	W	75%	Cloudy	2hrs	13:30 - 16:00
5	26,6	21,2	25,3	22,1	22,6	27,0	21,4	23,2	41,0	23,6	5,5	W	66%	Sunny	2hrs	13:30 - 16:00
6	29,4	23,3	26,7	23,4	26,0	31,3	26,4	33,4	43,2	25,8	5,5	NW	71%	Sunny	2hrs	13:30 - 16:00
7	32,5	26,8	27,8	28,5	27,9	32,5	25,2	31,7	44,7	28,7	4,3	W	50%	Sunny	2hrs	13:30 - 16:00
8	34,3	27,1	29,2	28,1	29,4	32,7	26,0	32,2	50,0	29,6	4,7	SW	61%	Sunny	2hrs	13:30 - 16:00
9	26,5	23,8	27,0	22,9	24,8	27,6	27,2	29,5	46,7	25,0	19,8	S	63%	Cloudy	2hrs	13:30 - 16:00
10	15,7	13,2	15,4	13,4	14,1	13,5	14,5	16,0	16,8	14,4	5,8	NW	80%	Rainy	2hrs	13:30 - 16:00
11	18,9	15,8	17,7	16,3	17,1	20,2	17,1	21,1	22,9	17,2	4,7	N	55%	Cloudy	2hrs	13:30 - 16:00
12	18,0	13,8	16,4	13,9	15,0	21,2	16,5	20,5	30,4	15,4	6,9	NW	50%	Sunny	2hrs	13:30 - 16:00
13	19,2	14,2	18,2	13,6	15,2	23,9	15,5	22,5	33,2	16,1	5,0	W	52%	Sunny	2hrs	13:30 - 16:00
14	23,8	16,2	21,3	17,7	21,4	27,0	21,2	26,5	40,7	20,1	4,7	NW	57%	Sunny	2hrs	13:30 - 16:00
15	27,3	21,1	24,6	20,2	22,3	29,3	23,5	27,7	43,2	23,1	2,6	SW	48%	Sunny	2hrs	13:30 - 16:00
16	21,2	16,2	19,9	18,7	19,2	26,2	21,4	22,8	36,8	19,0	17,7	SE	60%	Cloudy	2hrs	13:30 - 16:00
17	15,7	12,8	14,8	13,4	12,5	15,2	14,1	16,3	20,2	13,8	20,1	S	82%	Rainy	2hrs	13:30 - 16:00
18	9,3	7,2	8,6	7,7	7,0	11,3	9,8	10,2	12,0	8,0	15,4	S	89%	Storm	2hrs	13:30 - 16:00
19	5,4	3,1	4,4	3,2	5,0	6,5	8,0	9,0	9,0	4,2	18,7	S	91%	Rainy	2hrs	13:30 - 16:00
20	13,2	8,9	14,4	9,4	11,3	13,4	12,7	15,0	17,6	11,4	10,8	S	79%	Cloudy	2hrs	13:30 - 16:00
21	10,6	7,3	10,1	6,8	7,3	12,5	12,8	11,2	13,3	8,4	15,8	SE	65%	Cloudy	2hrs	13:30 - 16:00
22	11,2	7,7	10,2	8,3	8,8	14,0	12,3	15,2	17,7	9,2	12,2	SE	44%	Cloudy	2hrs	13:30 - 16:00
23	4,1	2,4	2,2	2,0	3,4	6,1	3,9	8,8	5,1	2,8	10,5	E	85%	Rainy	2hrs	13:30 - 16:00
24	15,7	11,3	14,2	10,7	11,0	17,5	12,7	18,0	22,4	12,6	4,7	W	57%	Sunny	2hrs	13:30 - 16:00
25	17,2	12,1	14,9	11,0	12,4	19,3	18,0	21,2	26,3	13,5	5,0	E	58%	Cloudy	2hrs	13:30 - 16:00
26	16,4	10,5	13,3	11,7	12,5	21,5	22,0	26,0	27,0	12,9	12,2	E	64%	Cloudy	2hrs	13:30 - 16:00
27	21,2	15,3	18,8	14,9	16,2	29,4	31,0	28,5	34,0	17,3	2,9	NW	56%	Cloudy	2hrs	13:30 - 16:00
28	22,2	14,1	17,2	15,0	15,0	27,5	23,8	27,0	29,7	16,7	6,1	W	53%	Sunny	2hrs	13:30 - 16:00
29	26,8	18,0	21,2	19,3	22,0	32,4	29,3	31,4	40,6	21,5	3,5	W	44%	Sunny	2hrs	13:30 - 16:00
30	25,3	16,8	22,2	18,0	17,6	31,1	30,2	32,5	37,4	20,0	9,0	NW	50%	Sunny	2hrs	13:30 - 16:00
31	25,0	13,7	20,4	16,7	15,4	29,4	28,2	28,4	33,0	18,2	13,4	N	56%	Sunny	2hrs	13:30 - 16:00
TOT	20,1	15,0	18,1	15,4	16,4	22,4	19,5	22,4	29,8	17,0	8,6					

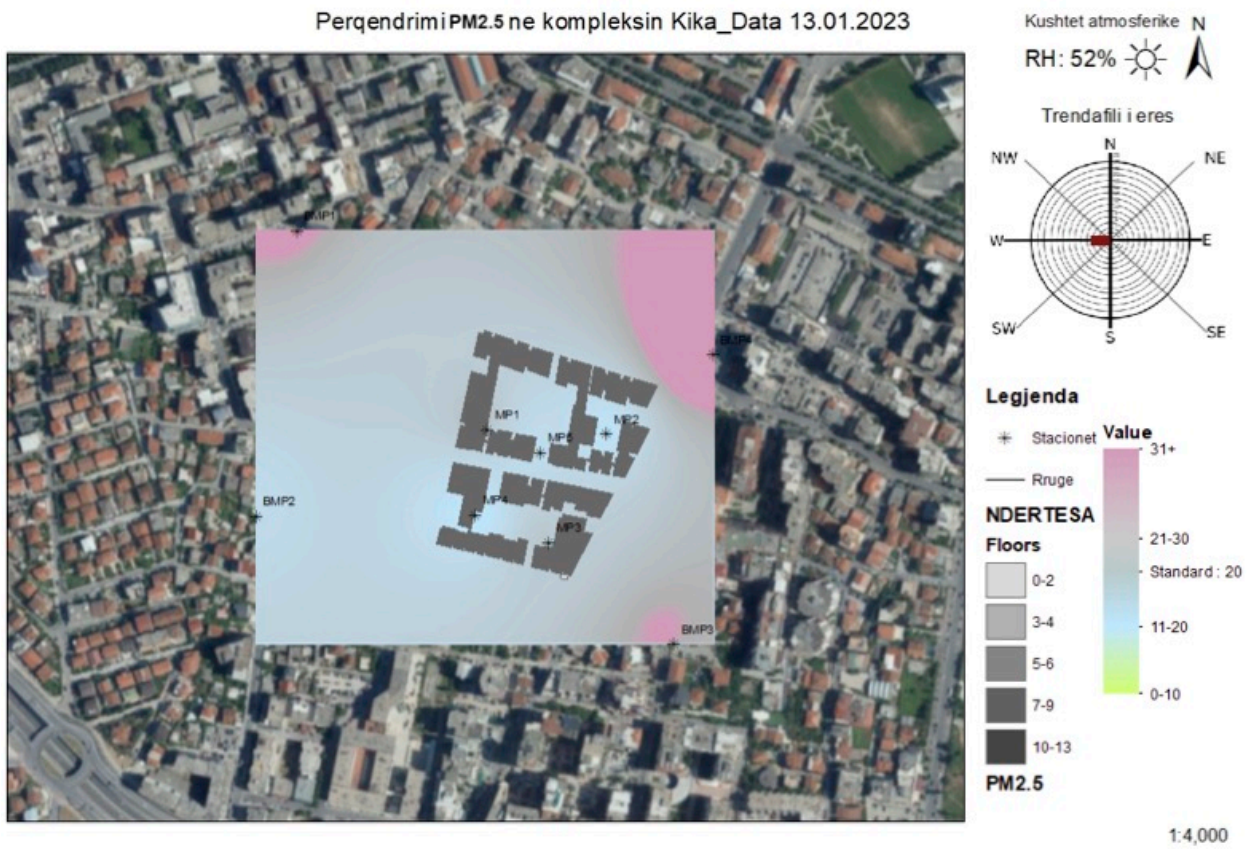
Source: Author

Graphic 45: Effect of wind and rain on the wash-out of PM_{2.5} concentration at KIKA Complex during January 2023



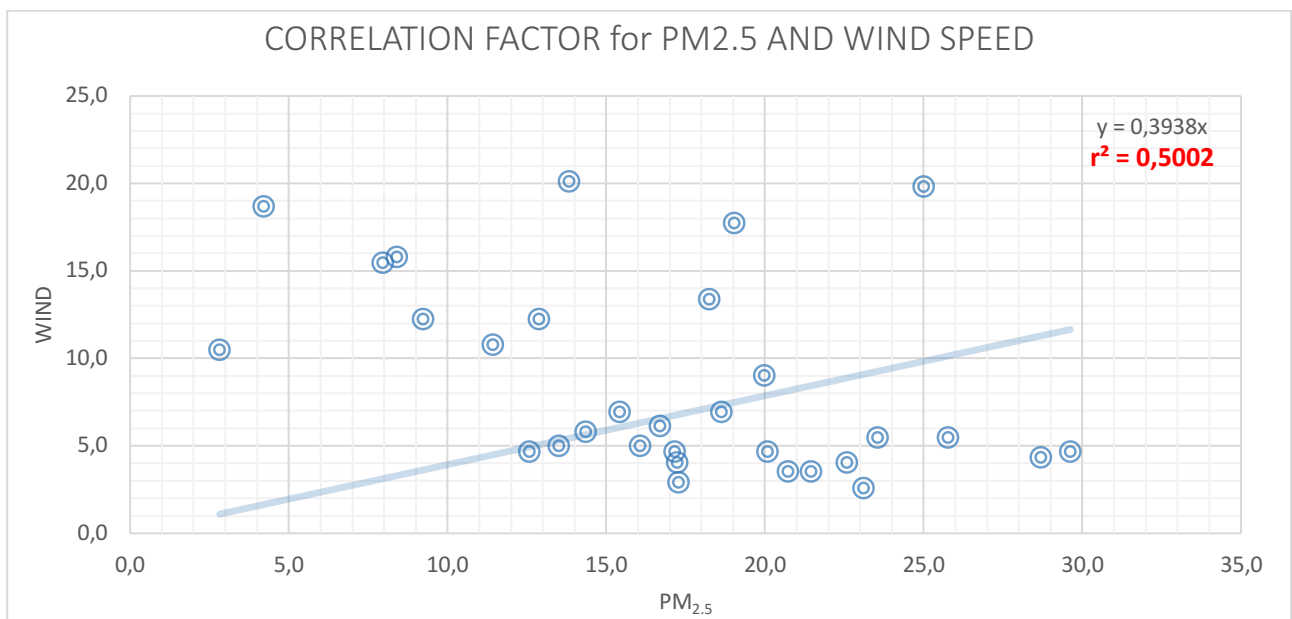
Source: Author

Figure 80: Sample from the dispersal of PM_{2.5} sequence at KIKA Complex (13.01.2023)



Source: Author

Graphic 46: Correlation factor between concentration of PM_{2.5} and Wind speed during January at KIKA Complex



Source: Author

Given that during January 16% of the time was characterized by rain, the correlation factor results were impacted indicating the effect of wind speed on the natural dispersal of air pollution within KIKA Complex to have an overall result of $r=0.5$ showing a moderate correlation between the two variables. If we exclude from the analysis the results of air monitoring from those 5 rainy days the correlation factor increases its result to $r=0.75$ indicating a strong correlation between these variables.

Nevertheless, taking into consideration that the predominating wind directions are from North-West and East / South-East it appears that the assumptions on the creation of the vortex effect due to urban form near Monitoring Point 1 and 3 are correct.

Table 42: Number of days indicating the orientation of the wind during January at KIKA Complex

N	S	W	E	NW	NE	SE	SW
2	5	8	4	7	0	3	2
6%	16%	26%	13%	23%	0%	10%	6%

Source: Author

Concluding that MP1 and MP3 could be considered Air Pollution Cavity Area given that the average concentration is at least 8% higher during January than all other nearby monitoring points exposed.

KIKA _ FEBRUARY 2023:

As mentioned earlier February represented the best monitoring conditions that the candidate could have expected. Throughout this month, for the monitoring period on which the practice was conducted at KIKA, a light rain occurred only during 26th and 27th of February. Herby 96% of the monitoring results indicate the direct correlation of wind on the dispersal of air pollutants within the KIKA Complex that could be also analysed in the context of how well natural ventilation occurs in this block of dwellings. Given to the closed corners of this block and the fact that it is position nearby an area with high pollution arising from both construction and traffic, such urban form is expected to contribute into the creation of the pollution retention phenomena. Preliminary it is expected that at least 2 of 5 monitoring points prove that there are air pollution cavity areas within KIKA complex.

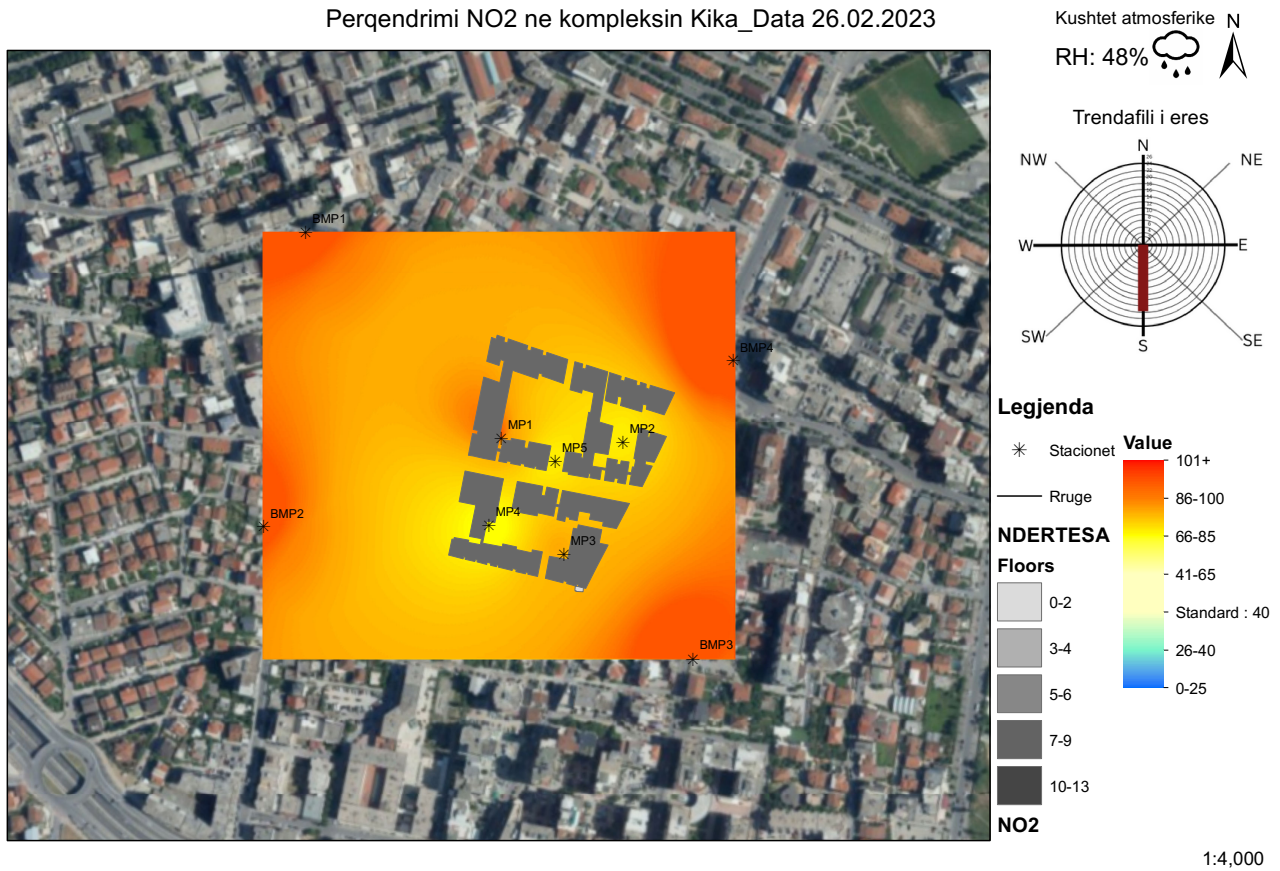
Table 43: Number of days with sun, cloud and rain during February at KIKA complex.

Sun	Cloud	Rain
15	11	2
54%	39%	7%

Source: Author

Figure 81: Sample from the dispersal of NO₂ sequence at KIKA Complex (26.02.2023)

Perqendrimi NO₂ ne kompleksin Kika_Data 26.02.2023



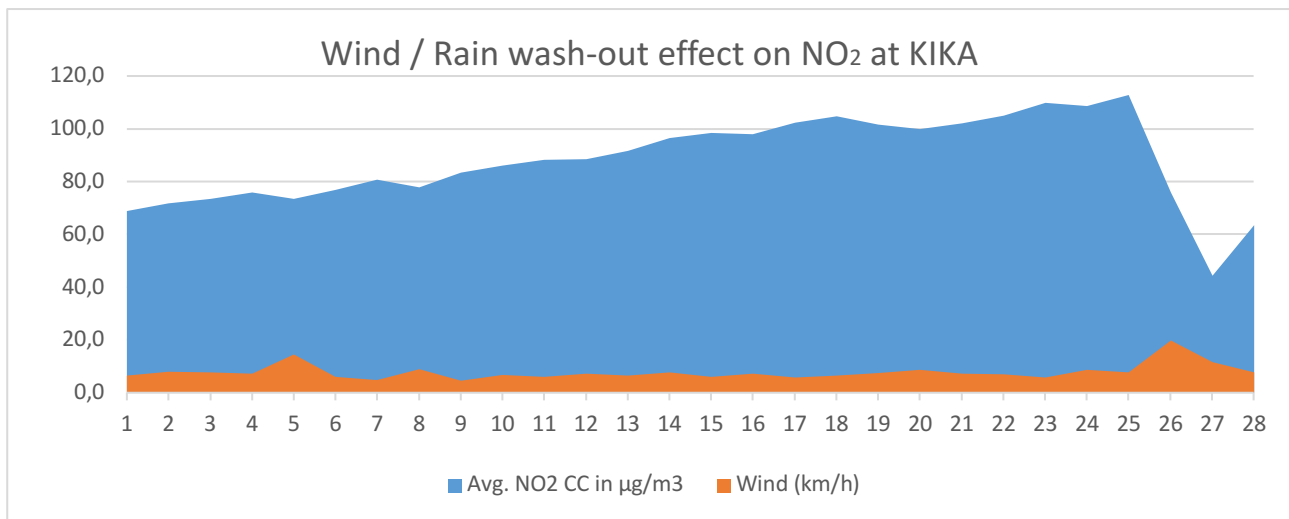
1:4,000

Table 44: NO₂ concentrations and meteorological observations during February 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. NO2 CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	107	103	111	107	105	108	102	113	135	107	4,0	E	61%	Sunny	2hrs 13:30-16:00
2	110	107	113	106	109	109	108	117	141	109	3,5	W	58%	Sunny	2hrs 13:30-16:00
3	97	92	99	92	91	92	94	99	123	94	6,9	NW	74%	Sunny	2hrs 13:30-16:00
4	103	93	100	91	92	95	96	97	128	96	4,0	W	75%	Cloudy	2hrs 13:30-16:00
5	104	89	101	89	86	96	93	96	132	94	5,5	W	66%	Sunny	2hrs 13:30-16:00
6	99	85	102	87	83	93	90	93	127	91	5,5	NW	71%	Sunny	2hrs 13:30-16:00
7	104	87	104	91	92	99	94	94	136	96	4,3	W	50%	Sunny	2hrs 13:30-16:00
8	108	90	103	94	93	102	99	105	144	98	4,7	SW	61%	Sunny	2hrs 13:30-16:00
9	91	83	92	87	80	89	91	85	112	87	19,8	S	63%	Cloudy	2hrs 13:30-16:00
10	68	65	69	61	67	75	77	73	88	66	5,8	NW	80%	Rainy	2hrs 13:30-16:00
11	73	74	79	71	73	83	88	94	100	74	4,7	N	55%	Cloudy	2hrs 13:30-16:00
12	76	72	72	68	69	82	80	84	94	71	6,9	NW	50%	Sunny	2hrs 13:30-16:00
13	80	74	74	65	71	86	88	91	111	73	5,0	W	52%	Sunny	2hrs 13:30-16:00
14	84	70	69	66	73	89	91	93	119	72	4,7	NW	57%	Sunny	2hrs 13:30-16:00
15	92	77	82	76	83	97	99	105	132	82	2,6	SW	48%	Sunny	2hrs 13:30-16:00
16	75	59	73	60	66	81	80	88	103	67	17,7	SE	60%	Cloudy	2hrs 13:30-16:00
17	49	43	50	47	45	52	49	63	70	47	20,1	S	82%	Rainy	2hrs 13:30-16:00
18	21	18	22	17	17	28	27	31	39	19	15,4	S	89%	Storm	2hrs 13:30-16:00
19	15	17	15	12	21	14	17	15	22	16	18,7	S	91%	Rainy	2hrs 13:30-16:00
20	42	43	42	43	47	60	66	65	79	43	10,8	S	79%	Cloudy	2hrs 13:30-16:00
21	41	38	44	42	52	66	69	72	81	43	15,8	SE	65%	Cloudy	2hrs 13:30-16:00
22	46	41	40	41	55	70	68	77	89	45	12,2	SE	44%	Cloudy	2hrs 13:30-16:00
23	24	22	20	19	22	50	48	52	55	21	10,5	E	85%	Rainy	2hrs 13:30-16:00
24	33	32	37	25	28	58	61	59	78	31	4,7	W	57%	Sunny	2hrs 13:30-16:00
25	54	39	49	41	42	66	67	69	85	45	5,0	E	58%	Cloudy	2hrs 13:30-16:00
26	51	31	46	29	31	54	55	62	76	38	12,2	E	64%	Cloudy	2hrs 13:30-16:00
27	66	48	67	52	50	77	81	79	93	57	2,9	NW	56%	Cloudy	2hrs 13:30-16:00
28	68	45	72	47	55	78	73	105	111	57	6,1	W	53%	Sunny	2hrs 13:30-16:00
29	83	75	89	71	82	99	91	108	124	80	3,5	W	44%	Sunny	2hrs 13:30-16:00
30	78	69	83	65	71	82	82	88	105	73	9,0	NW	50%	Sunny	2hrs 13:30-16:00
31	78	63	79	69	72	79	71	80	94	72	13,4	N	56%	Sunny	2hrs 13:30-16:00
TOT	71,6	62,7	70,9	62,3	65,3	77,7	77,3	82,3	100,8	66,6	8,6				

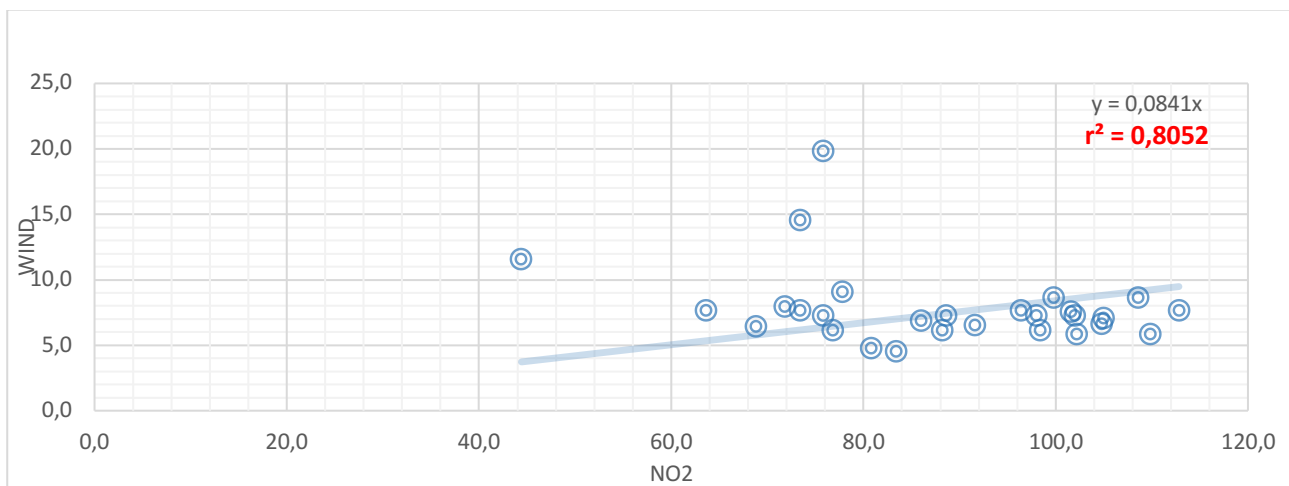
Source: Author

Graphic 47: Effect of wind and rain on the wash-out of NO₂ concentration at KIKA Complex during February 2023



Source: Author

Graphic 48: Correlation factor between concentration of NO₂ and Wind speed during February at KIKA Complex



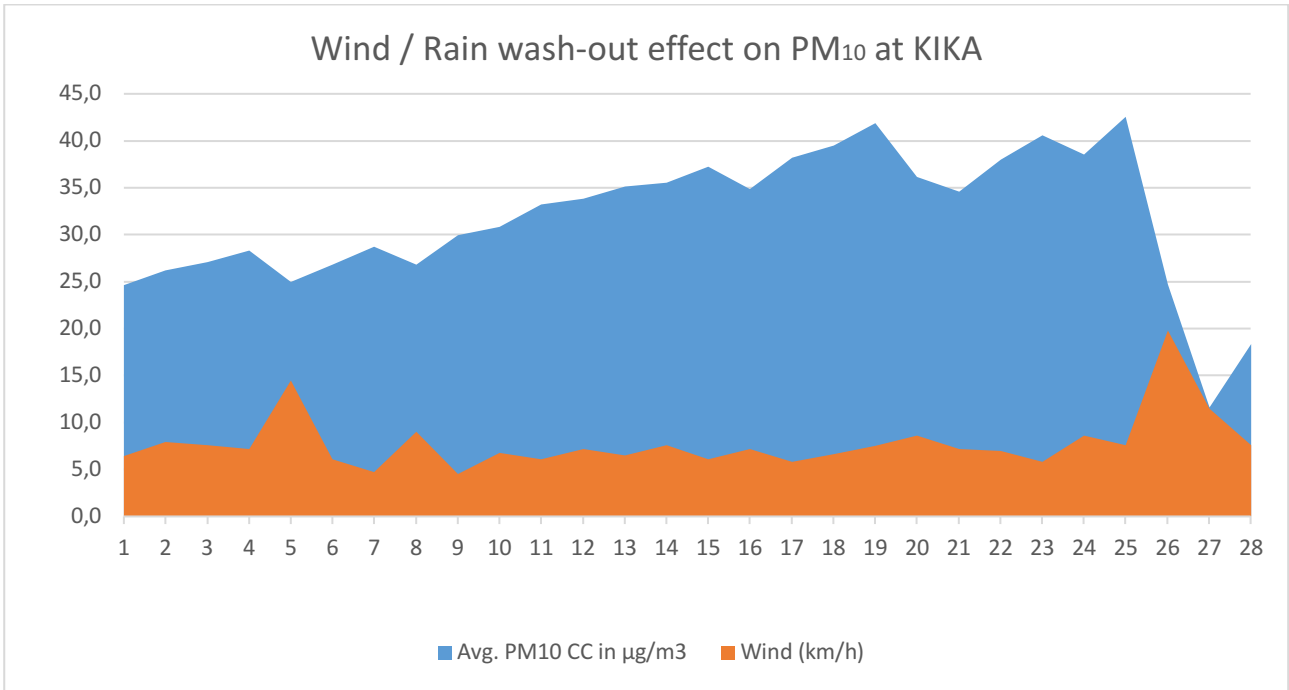
Source: Author

Table 45: PM₁₀ concentrations and meteorological observations during February 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM10 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length	Daytime
1	26,5	22,2	25,8	24,1	24,6	26,5	25,1	28,2	32,2	24,6	6,4	W	42%	Sunny	2hrs	13:30 - 16:00
2	28,1	23,8	27,4	25,7	26,2	28,0	26,5	29,8	33,8	26,2	7,9	NW	58%	Cloudy	2hrs	13:30 - 16:00
3	28,9	24,6	28,2	26,5	27,0	27,3	24,8	29,0	33,0	27,1	7,6	NW	74%	Cloudy	2hrs	13:30 - 16:00
4	30,2	25,9	29,5	27,8	28,3	27,7	26,1	30,0	34,0	28,3	7,2	E	68%	Cloudy	2hrs	13:30 - 16:00
5	28,9	22,1	29,0	23,0	22,0	23,3	22,2	24,2	28,2	25,0	14,5	N	34%	Sunny	2hrs	13:30 - 16:00
6	30,7	23,5	30,0	24,8	25,1	28,2	26,5	30,3	34,3	26,8	6,1	N	28%	Sunny	2hrs	13:30 - 16:00
7	32,8	25,6	32,1	26,2	27,0	28,3	26,7	30,3	34,3	28,7	4,7	NE	29%	Sunny	2hrs	13:30 - 16:00
8	31,5	23,1	29,0	23,4	27,0	24,7	23,5	26,1	30,1	26,8	9,0	E	28%	Sunny	2hrs	13:30 - 16:00
9	34,2	28,2	33,5	26,0	27,7	29,3	27,6	31,6	35,6	29,9	4,5	E	29%	Cloudy	2hrs	13:30 - 16:00
10	35,6	27,6	34,9	28,0	28,2	27,4	25,8	30,2	34,2	30,8	6,8	NW	38%	Cloudy	2hrs	13:30 - 16:00
11	36,7	29,5	36,0	31,4	32,6	28,8	26,9	31,1	35,1	33,2	6,1	W	55%	Sunny	2hrs	13:30 - 16:00
12	36,9	31,1	36,2	33,2	31,6	27,0	25,5	32,7	36,7	33,8	7,2	NW	45%	Sunny	2hrs	13:30 - 16:00
13	38,5	32,8	37,8	32,7	33,9	27,7	26,2	35,5	39,5	35,1	6,5	NW	43%	Sunny	2hrs	13:30 - 16:00
14	41,0	31,5	40,3	30,4	34,3	26,8	25,4	34,4	38,4	35,5	7,6	NW	46%	Sunny	2hrs	13:30 - 16:00
15	42,1	32,2	41,4	34,6	36,1	28,1	26,6	36,3	40,3	37,3	6,1	W	38%	Sunny	2hrs	13:30 - 16:00
16	41,7	30,7	40,2	31,2	30,6	24,3	23,2	37,5	41,5	34,9	7,2	W	55%	Sunny	2hrs	13:30 - 16:00
17	44,1	32,8	43,4	34,7	36,0	29,5	27,8	40,7	44,7	38,2	5,8	W	59%	Sunny	2hrs	13:30 - 16:00
18	45,4	33,5	44,7	36,4	37,3	27,7	25,7	42,2	46,2	39,5	6,6	W	60%	Cloudy	2hrs	13:30 - 16:00
19	43,8	39,5	43,1	41,4	41,9	28,7	26,5	43,8	47,8	41,9	7,5	W	57%	Cloudy	2hrs	13:30 - 16:00
20	40,7	32,5	39,4	34,6	33,7	21,3	20,8	42,3	46,3	36,2	8,6	NW	59%	Cloudy	2hrs	13:30 - 16:00
21	41,5	30,2	37,7	32,1	31,4	25,1	23,7	42,6	46,6	34,6	7,2	W	52%	Sunny	2hrs	13:30 - 16:00
22	43,2	32,8	44,7	34,9	34,5	29,6	27,4	45,2	49,2	38,0	7,0	W	62%	Sunny	2hrs	13:30 - 16:00
23	48,1	35,3	47,4	36,1	36,1	28,8	27,1	49,4	53,4	40,6	5,8	W	64%	Cloudy	2hrs	13:30 - 16:00
24	47,4	33,0	46,3	32,7	33,4	24,7	23,2	42,8	46,8	38,6	8,6	W	55%	Sunny	2hrs	13:30 - 16:00
25	51,0	36,8	49,0	37,2	38,8	30,0	28,9	32,5	36,5	42,6	7,6	S	54%	Cloudy	2hrs	13:30 - 16:00
26	27,0	24,7	25,8	23,6	22,4	10,7	9,7	20,1	24,1	24,7	19,8	S	48%	Light Rain	2hrs	13:30 - 16:00
27	12,1	9,4	13,0	11,3	12,5	15,0	13,4	11,2	15,2	11,6	11,5	SE	70%	Rain	2hrs	13:30 - 16:00
28	21,2	16,8	19,7	16,5	17,5	22,4	21,2	23,5	27,5	18,3	7,6	SE	32%	Cloudy	2hrs	13:30 - 16:00
TOT	36,1	28,3	35,2	29,3	29,9	26,0	24,4	33,3	37,3	31,7	7,8					

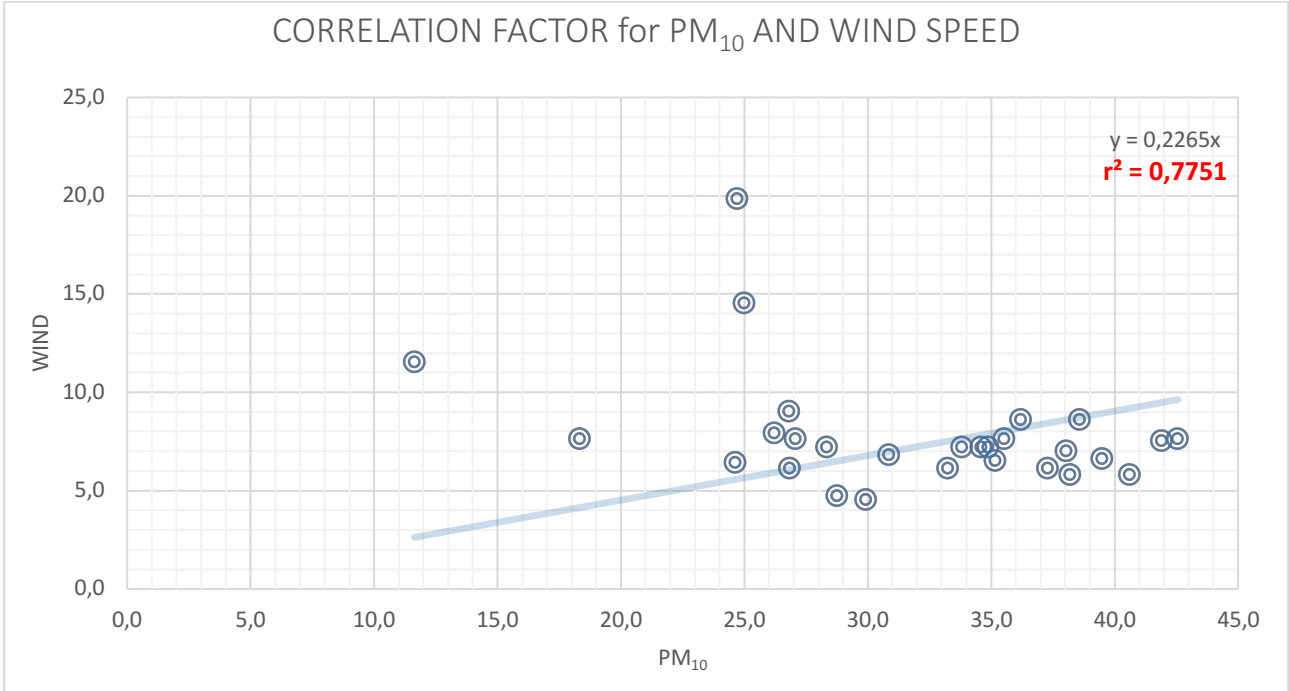
Source: Author

Graphic 49: Effect of wind and rain on the wash-out of PM₁₀ concentration at KIKA Complex during January 2023



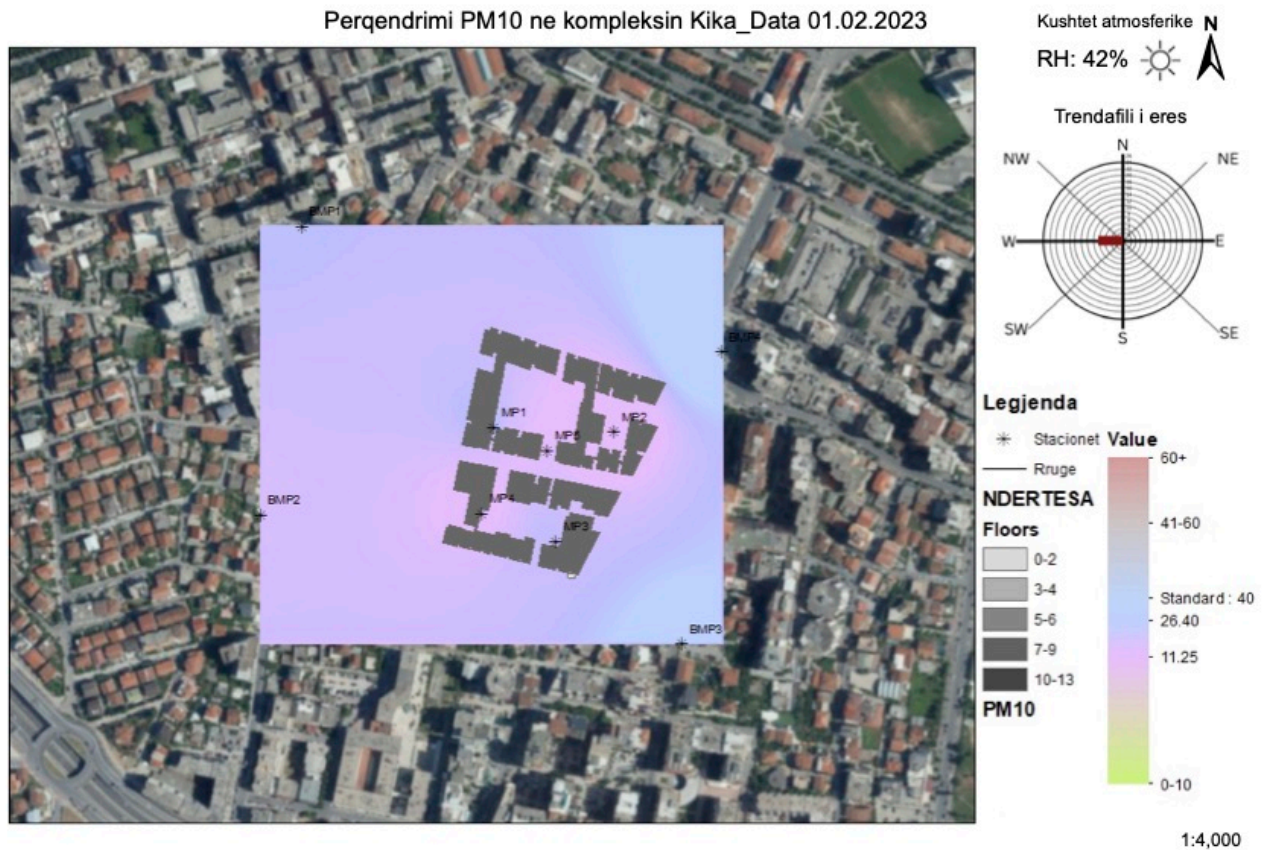
Source: Author

Graphic 50: Correlation factor between concentration of PM₁₀ and Wind speed during February at KIKA Complex



Source: Author

Figure 82: Sample from the dispersal of PM₁₀ sequence at KIKA Complex (01.02.2023)



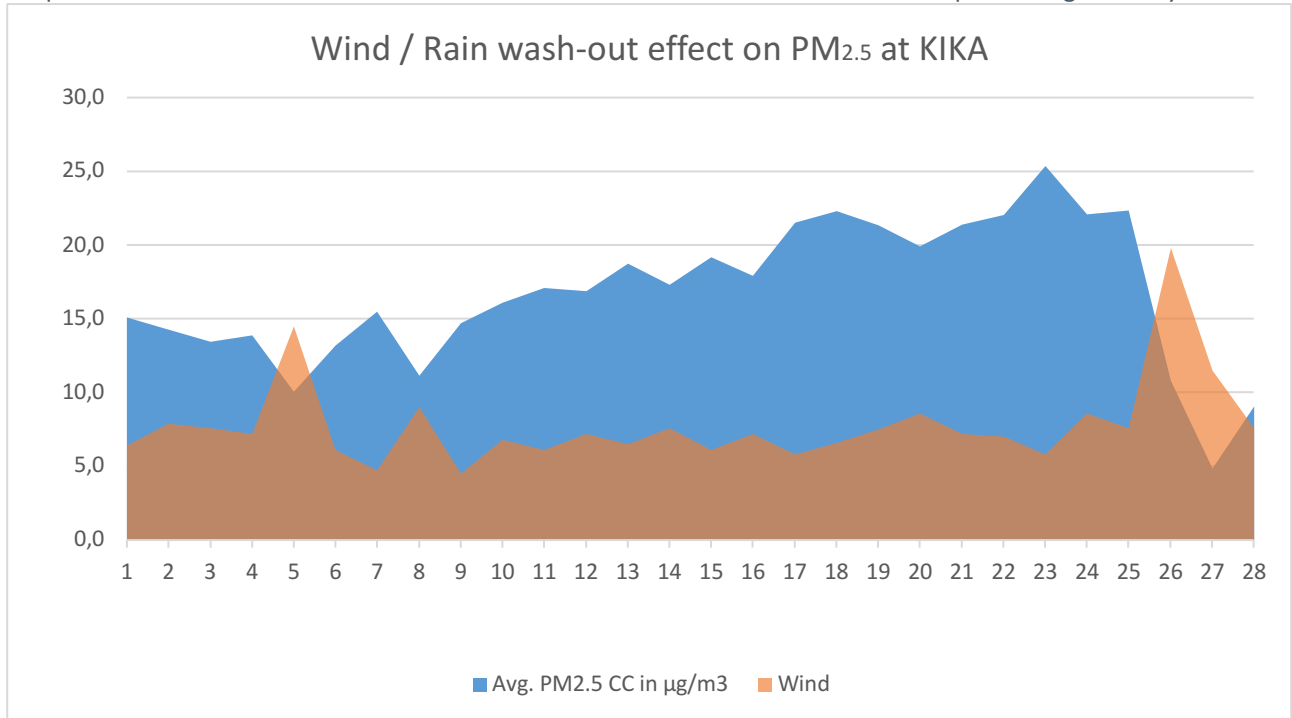
Source: Author

Table 46: PM_{2.5} concentrations and meteorological observations during January 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM2.5 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length	Daytime
1	16,4	14,2	16,8	13,7	14,4	17,40	18,10	18,80	22,30	15,1	6,4	W	42%	Sunny	2hrs	13:30 - 16:00
2	17,1	12,7	16,4	12,4	12,7	18,20	18,50	19,50	22,20	14,3	7,9	NW	58%	Cloudy	2hrs	13:30 - 16:00
3	16,8	11,5	16,1	11,4	11,4	18,40	16,80	19,30	21,40	13,4	7,6	NW	74%	Cloudy	2hrs	13:30 - 16:00
4	17,2	11,8	16,5	11,7	12,1	17,50	17,50	18,20	22,00	13,9	7,2	E	68%	Cloudy	2hrs	13:30 - 16:00
5	14,2	8,7	11,7	7,5	8,2	13,40	15,20	14,50	18,00	10,1	14,5	N	34%	Sunny	2hrs	13:30 - 16:00
6	16,3	11,1	14,6	12,1	11,8	15,50	16,80	18,50	19,70	13,2	6,1	N	28%	Sunny	2hrs	13:30 - 16:00
7	19,0	13,5	16,4	14,1	14,5	16,10	15,70	21,20	24,00	15,5	14,7	NE	29%	Sunny	2hrs	13:30 - 16:00
8	14,2	9,3	14,1	8,7	9,5	14,70	15,00	18,30	21,20	11,2	9,0	E	28%	Sunny	2hrs	13:30 - 16:00
9	18,3	12,4	17,2	12,1	13,5	19,20	18,50	22,40	22,50	14,7	14,5	E	29%	Cloudy	2hrs	13:30 - 16:00
10	20,2	14,0	17,8	13,5	14,9	20,58	19,90	22,80	24,80	16,1	6,8	NW	38%	Cloudy	2hrs	13:30 - 16:00
11	21,3	15,2	18,4	14,6	16,0	21,60	20,80	23,00	25,10	17,1	6,1	W	55%	Sunny	2hrs	13:30 - 16:00
12	22,5	13,6	19,1	13,5	15,6	21,30	20,50	21,80	24,30	16,9	7,2	NW	45%	Sunny	2hrs	13:30 - 16:00
13	24,2	15,1	22,7	15,5	16,3	23,20	22,40	24,00	26,10	18,8	6,5	NW	43%	Sunny	2hrs	13:30 - 16:00
14	24,0	14,3	22,3	12,2	13,8	21,80	20,30	22,60	23,90	17,3	7,6	NW	46%	Sunny	2hrs	13:30 - 16:00
15	25,6	15,7	23,8	14,7	16,1	24,00	21,50	24,50	25,70	19,2	6,1	W	38%	Sunny	2hrs	13:30 - 16:00
16	25,5	13,9	22,7	12,8	14,6	22,50	20,20	24,10	24,20	17,9	7,2	W	55%	Sunny	2hrs	13:30 - 16:00
17	28,4	17,2	25,7	17,5	18,7	26,10	22,80	26,50	27,70	21,5	5,8	W	59%	Sunny	2hrs	13:30 - 16:00
18	29,1	17,8	27,9	18,3	18,5	26,90	23,60	27,30	29,10	22,3	6,6	W	60%	Cloudy	2hrs	13:30 - 16:00
19	28,4	16,2	27,0	17,5	17,7	25,80	22,20	27,20	28,20	21,4	7,5	W	57%	Cloudy	2hrs	13:30 - 16:00
20	29,6	14,9	25,3	14,7	15,2	24,30	20,10	24,80	26,70	19,9	8,6	NW	59%	Cloudy	2hrs	13:30 - 16:00
21	31,4	15,8	27,2	16,1	16,5	25,80	21,60	25,10	28,20	21,4	7,2	W	52%	Sunny	2hrs	13:30 - 16:00
22	32,0	17,0	25,7	17,3	18,2	26,60	20,50	26,20	28,80	22,0	7,0	W	62%	Sunny	2hrs	13:30 - 16:00
23	36,2	21,1	26,9	20,4	22,2	28,10	26,30	28,90	33,00	25,4	5,8	W	64%	Cloudy	2hrs	13:30 - 16:00
24	30,7	18,7	24,8	17,5	18,8	26,50	25,50	27,50	30,50	22,1	8,6	W	55%	Sunny	2hrs	13:30 - 16:00
25	32,5	18,0	23,7	18,2	19,3	25,50	26,00	28,20	29,60	22,3	7,6	S	54%	Cloudy	2hrs	13:30 - 16:00
26	12,8	9,3	9,6	11,0	11,2	14,00	12,00	15,00	15,00	10,8	19,8	S	48%	Light Rain	2hrs	13:30 - 16:00
27	6,1	4,7	5,6	4,0	3,8	8,00	6,10	8,50	7,50	4,8	11,5	SE	70%	Rain	2hrs	13:30 - 16:00
28	9,5	7,1	11,5	8,4	8,8	12,20	10,30	13,00	16,50	9,1	7,6	SE	32%	Cloudy	2hrs	13:30 - 16:00
TOT	22,1	13,7	19,6	13,6	14,4	20,5	19,1	21,8	23,9	16,7	7,8					

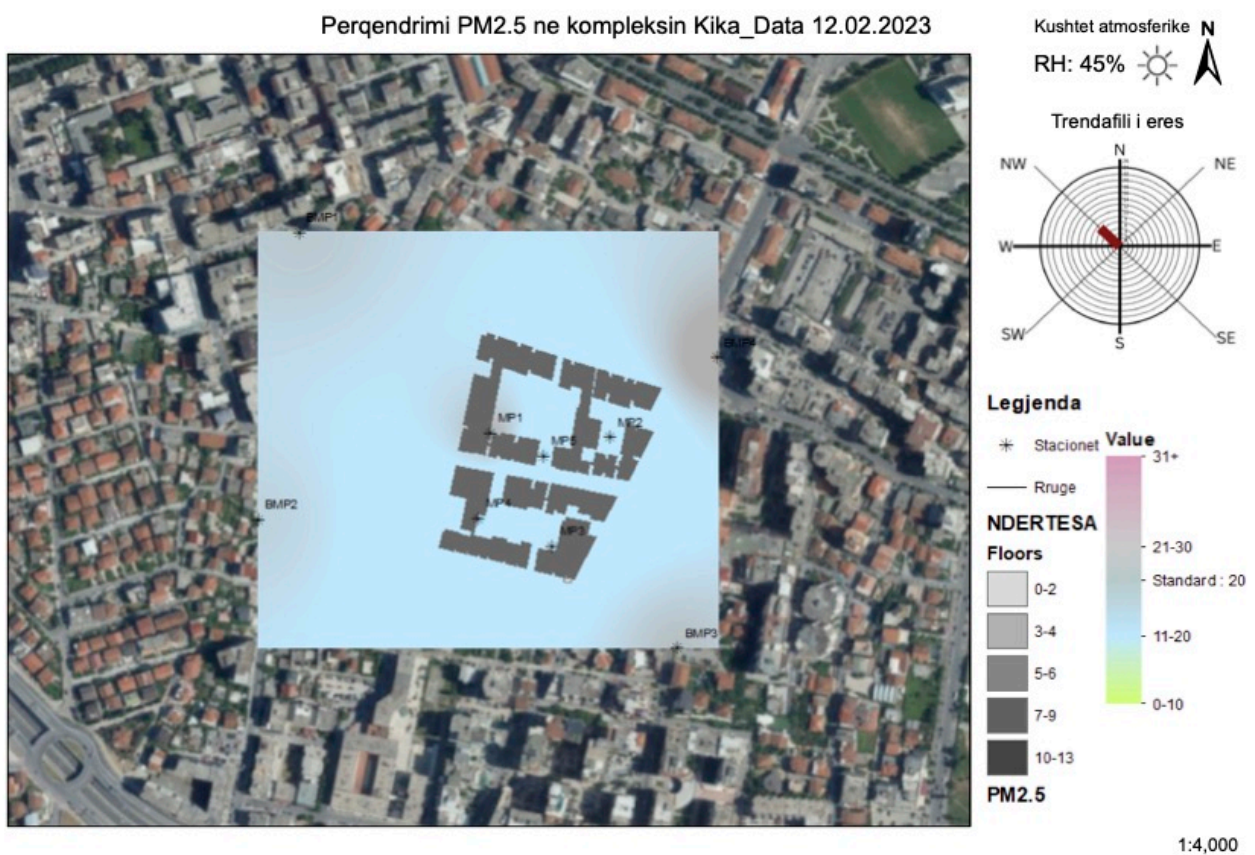
Source: Author

Graphic 51: Effect of wind and rain on the wash-out of PM_{2.5} concentration at KIKA Complex during February 2023



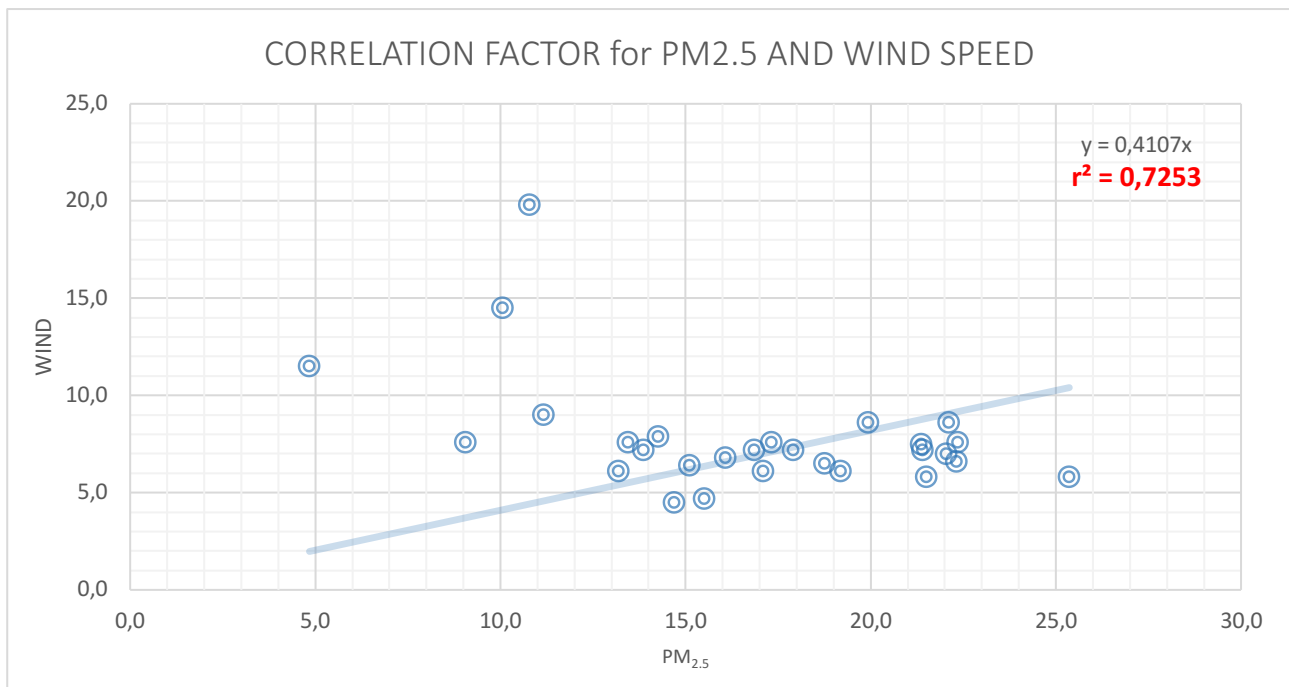
Source: Author

Figure 83: Sample from the dispersal of PM_{2.5} sequence at KIKA Complex (12.02.2023)



Source: Author

Graphic 52: Correlation factor between concentration of PM_{2.5} and Wind speed during January at KIKA Complex



Source: Author

February’s dry period and increasing concentration of pollutants in the city, proves and consolidates the argument that natural dispersal of air pollution within a closed block such as KIKA and earlier Magnet Complex is notably affected by the build form of this environment.

The overall result of the correlation between wind and air pollution concentration during February at KIKA Complex has an overall result of $r=0.76$, indicating a strong correlation between these variables.

Nevertheless, taking into consideration that the predominating wind directions are from West it appears that the assumptions on the creation of the vortex effect further consolidate the results of January.

Table 47: Number of days indicating the orientation of the wind during February at KIKA Complex

N	S	W	E	NW	NE	SE	SW
2	2	11	3	7	1	2	0
7%	7%	39%	11%	25%	4%	7%	0%

Source: Author

Concluding that the change on wind patterns during February, and the drought weather along all the month indicates MP.1, MP.3 to be considerably under the influence of Air Pollution Cavity Area given that the average concentration of all these three locations 15.6% higher during February than all other nearby monitoring points exposed.

KIKA _ MARCH 2023:

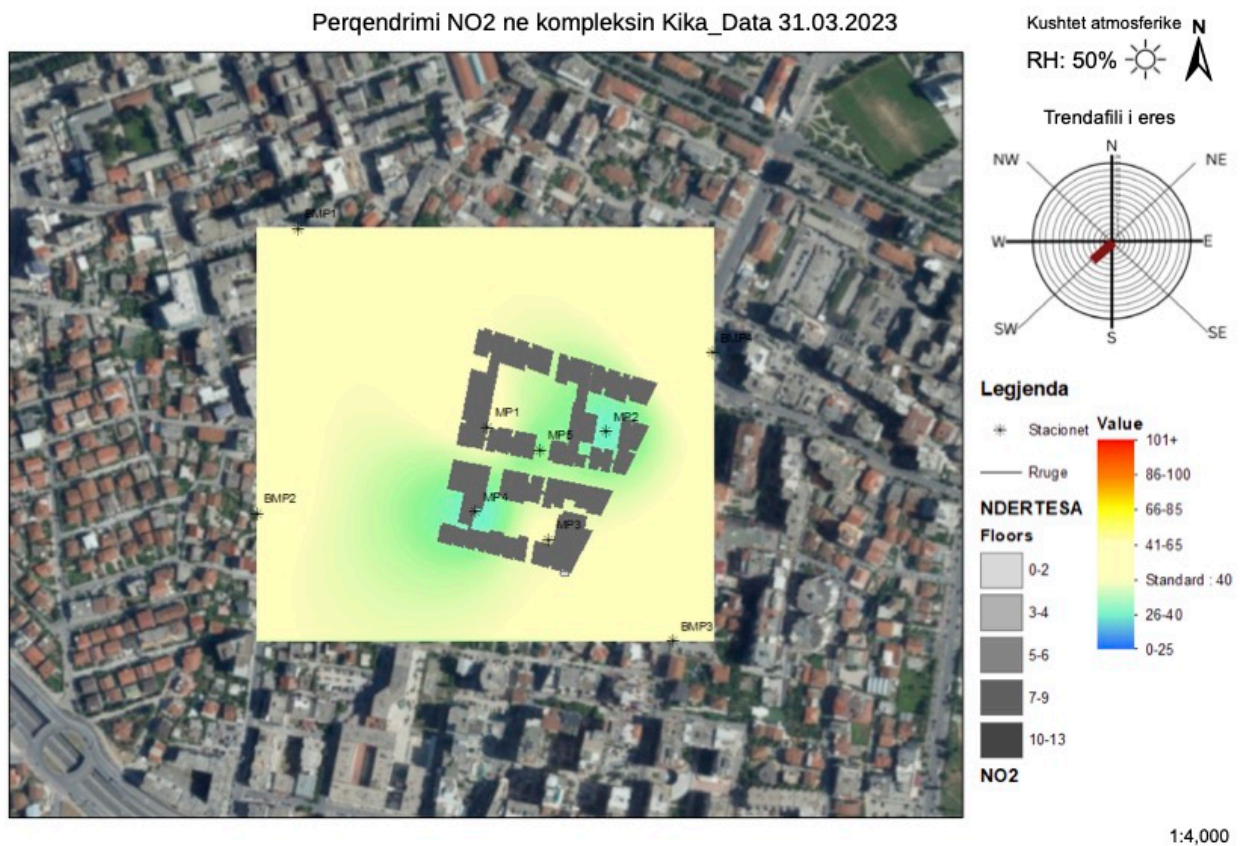
March at KIKA's started with 5 days in row of rain and winds blowing from West mostly. Such meteorological occurrence contributed to an overall reduction of all pollutant concentration at the area, this can be noticed also at the graphs indicating the wash-out effect on the monitored pollution, whereas concentrations were reduced even below the WHO standards during the first week. Offering thus the possibility for the research to obtain an occurrence where both scenarios when pollution accumulated from February was totally washed out and latter build up during the second part of the month. This situation presents a good potential to analyse the temporal perspective upon the creation of the pollution retention phenomena in such particular meteorological circumstances.

Table 48: Number of days with sun, cloud and rain during March at Magnet complex.

Rain	Cloud	Clear
10	7	14
32%	23%	45%

Source: Author

Figure 84: Sample from the dispersal of NO₂ sequence (31.3.2023)



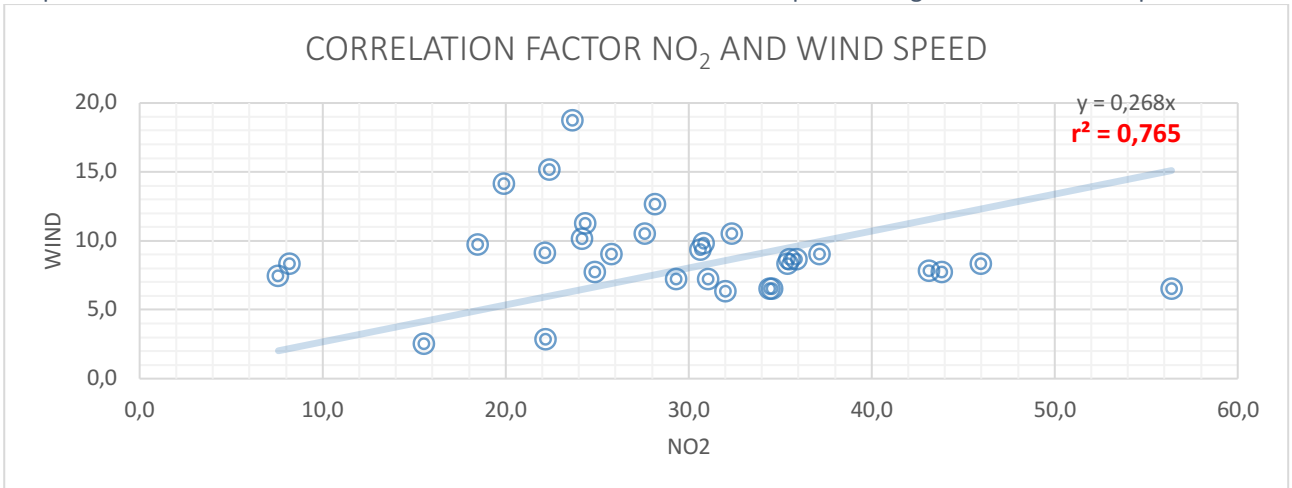
Source: Author

Table 49: NO₂ concentrations and meteorological observations during March 2023 /KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BM4	Avg. NO ₂ CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length	Daytime
1	35,2	37,1	30,2	27,3	25,5	32,10	31,50	38,50	37,40	31,1	7,2	SW	75%	Rainy	2hrs	13:30-16:00
2	32,0	33,0	35,2	31,0	30,7	36,80	34,80	35,70	36,50	32,4	10,5	SW	56%	Rainy	2hrs	13:30-16:00
3	21,7	22,5	22,0	21,5	23,2	25,60	22,10	22,80	26,30	22,2	2,8	S	68%	Rainy	2hrs	13:30-16:00
4	15,6	16,0	15,5	15,4	15,2	17,40	17,50	16,50	17,00	15,5	2,5	NW	66%	Rainy	2hrs	13:30-16:00
5	7,5	7,7	7,0	7,7	8,0	8,20	9,40	8,60	8,80	7,6	7,4	W	58%	Rainy	2hrs	13:30-16:00
6	22,6	19,8	21,3	17,5	18,4	26,40	25,10	31,20	33,10	19,9	14,1	SW	59%	Cloudy	2hrs	13:30-16:00
7	31,5	23,5	28,7	22,7	22,5	32,20	30,10	38,70	41,20	25,8	9,0	W	52%	Sunny	2hrs	13:30-16:00
8	39,4	27,2	33,4	26,8	27,4	32,80	35,10	43,50	48,20	30,8	9,8	SW	50%	Cloudy	2hrs	13:30-16:00
9	37,3	24,5	31,2	23,7	24,1	30,20	32,40	41,00	45,70	28,2	12,6	SW	60%	Cloudy	2hrs	13:30-16:00
10	22,5	21,4	22,6	22,5	23,0	19,80	18,50	21,20	22,30	22,4	15,1	S	72%	Rainy	2hrs	13:30-16:00
11	8,3	8,5	7,5	8,2	8,5	9,10	9,60	12,10	12,70	8,2	8,3	SW	69%	Rainy	2hrs	13:30-16:00
12	27,8	22,5	29,1	21,4	23,7	26,10	26,30	28,70	31,20	24,9	7,7	N	29%	Sunny	2hrs	13:30-16:00
13	36,5	28,7	37,2	28,5	29,2	33,20	33,20	37,50	41,70	32,0	6,3	W	31%	Sunny	2hrs	13:30-16:00
14	43,2	31,5	39,3	31,0	32,6	36,50	36,00	41,20	45,60	35,5	8,6	SW	30%	Cloudy	2hrs	13:30-16:00
15	22,4	21,5	22,2	23,1	21,5	23,20	22,20	26,10	25,40	22,1	9,1	S	82%	Rainy	2hrs	13:30-16:00
16	32,2	26,2	33,7	27,1	27,5	31,40	29,50	33,50	32,60	29,3	7,2	N	42%	Cloudy	2hrs	13:30-16:00
17	39,7	31,7	37,8	32,4	31,2	36,50	37,50	42,40	47,60	34,6	6,5	W	45%	Sunny	2hrs	13:30-16:00
18	42,3	30,5	42,5	30,2	31,5	38,50	38,30	46,50	51,90	35,4	8,3	W	46%	Sunny	2hrs	13:30-16:00
19	46,1	31,1	43,7	31,2	33,7	40,20	39,70	51,20	56,40	37,2	9,0	W	55%	Sunny	2hrs	13:30-16:00
20	51,5	38,7	52,8	37,6	38,5	47,30	46,30	58,00	63,10	43,8	7,7	W	58%	Sunny	2hrs	13:30-16:00
21	21,0	17,5	22,0	16,4	15,5	19,80	17,50	21,50	22,30	18,5	9,7	NW	94%	Rainy	2hrs	13:30-16:00
22	27,8	22,6	26,3	21,7	23,4	25,60	23,50	27,40	31,20	24,4	11,2	W	48%	Sunny	2hrs	13:30-16:00
23	34,2	29,8	35,2	27,5	26,5	30,10	30,50	35,60	42,70	30,6	9,3	NW	43%	Sunny	2hrs	13:30-16:00
24	41,7	32,3	39,8	33,0	32,7	35,30	34,80	41,80	50,20	35,9	8,6	W	48%	Sunny	2hrs	13:30-16:00
25	53,3	42,2	43,7	41,6	44,0	44,00	44,80	51,80	60,10	46,0	8,3	W	55%	Sunny	2hrs	13:30-16:00
26	60,6	53,1	62,7	50,5	55,0	56,50	62,40	73,20	77,80	56,4	6,5	W	56%	Sunny	2hrs	13:30-16:00
27	24,0	25,0	24,4	23,5	24,1	24,30	22,50	22,00	24,10	24,2	10,1	SE	89%	Rainy	2hrs	13:30-16:00
28	26,2	22,4	25,7	21,2	22,8	32,20	28,70	33,40	39,60	23,7	18,7	NW	31%	Cloudy	2hrs	13:30-16:00
29	32,7	23,5	31,1	25,2	25,6	36,20	33,80	37,40	43,50	27,6	10,5	NW	37%	Cloudy	2hrs	13:30-16:00
30	44,8	31,2	38,9	27,8	29,5	43,20	40,80	46,80	51,20	34,4	6,5	W	48%	Sunny	2hrs	13:30-16:00
31	52	38	47	37	42	52,00	49,60	57,90	62,30	43,1	7,8	SW	50%	Sunny	2hrs	13:30-16:00
TOT	33,8	26,7	32,4	26,2	27,0	31,7	31,3	36,7	40,3	29,2	9,2					

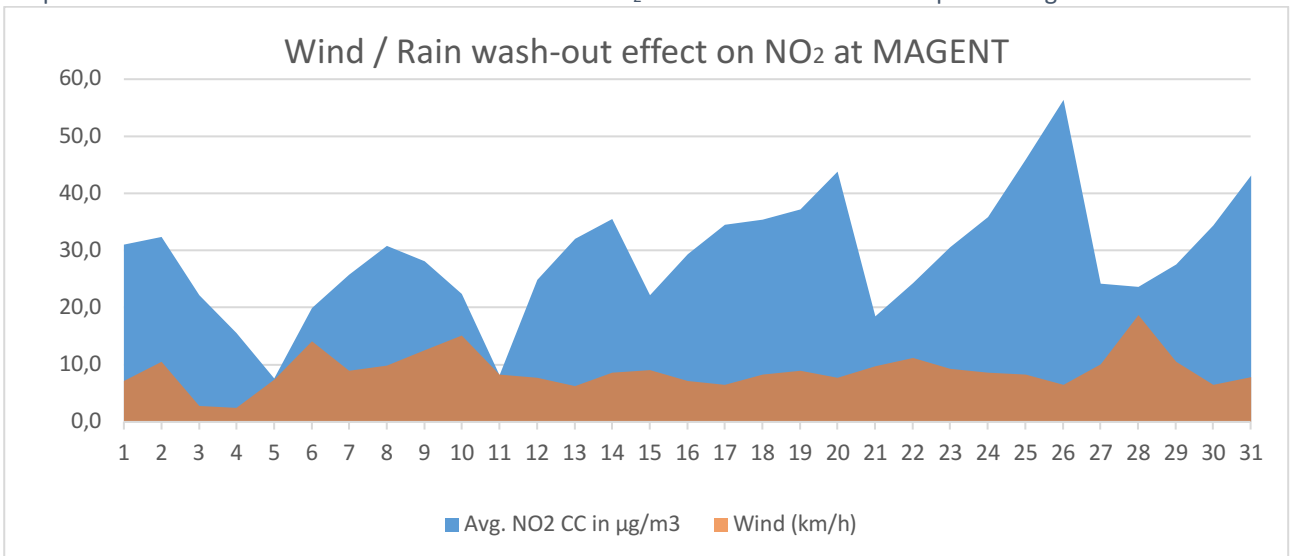
Source: Author

Graphic 53: Correlation factor between concentration of NO₂ and Wind speed during March at KIKA Complex.



Source: Author

Graphic 54: Effect of wind and rain on the wash-out of NO₂ concentration at KIKA complex during March 2023.



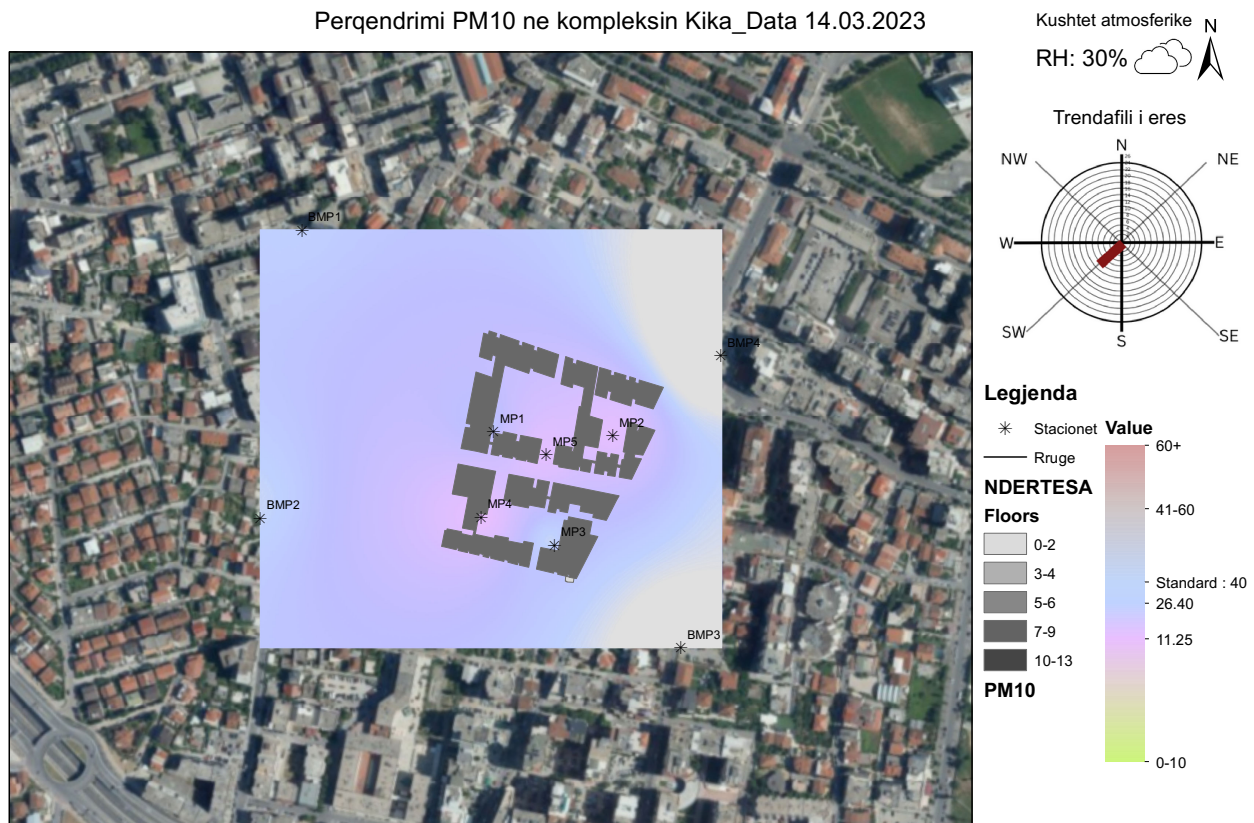
Source: Author

Table 50: PM₁₀ concentrations and meteorological observations during March 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length	Daytime
1	15,8	14,2	13,8	16,1	15,4	17,1	17,0	17,5	18,4	15,1	7,2	W	75%	Rainy	2hrs	10.20 - 12.45
2	8,8	9,0	8,5	7,4	8,1	11,2	10,0	12,1	13,4	8,4	10,5	SW	56%	Rainy	2hrs	10.20 - 12.45
3	4,8	2,6	3,7	2,2	3,0	8,4	8,0	8,7	11,2	3,3	2,8	S	68%	Rainy	2hrs	10.20 - 12.45
4	2,1	2,0	2,2	1,7	2,2	3,0	3,2	4,5	5,6	2,0	2,5	NW	66%	Rainy	2hrs	10.20 - 12.45
5	1,0	0,0	1,0	2,0	1,0	3,0	2,0	3,0	5,0	1,0	7,4	W	58%	Rainy	2hrs	10.20 - 12.45
6	12,7	7,5	12,8	6,8	6,5	17,5	15,0	18,2	19,4	9,3	14,1	SW	59%	Cloudy	2hrs	10.20 - 12.45
7	15,2	8,6	16,4	9,2	8,3	21,5	21,0	23,2	25,7	11,5	9,0	W	52%	Sunny	2hrs	10.20 - 12.45
8	18,3	10,4	17,5	10,5	11,2	22,8	23,5	27,5	26,8	13,6	9,8	SW	50%	Cloudy	2hrs	10.20 - 12.45
9	17,2	9,9	18,2	11,2	13,5	19,5	18,3	31,2	33,5	14,0	12,8	SW	60%	Cloudy	2hrs	10.20 - 12.45
10	9,2	8,8	8,1	10,0	9,5	13,2	14,5	17,2	15,6	9,1	15,1	S	72%	Rainy	2hrs	10.20 - 12.45
11	5,0	6,4	5,2	5,5	6,1	9,7	10,5	10,2	11,4	5,6	8,3	SW	69%	Rainy	2hrs	10.20 - 12.45
12	14,2	11,5	15,4	12,5	10,8	16,5	16,8	21,2	25,3	12,9	7,7	N	29%	Sunny	2hrs	10.20 - 12.45
13	18,1	15,1	20,8	16,5	15,8	22,2	22,5	27,8	35,3	17,3	6,3	W	31%	Sunny	2hrs	10.20 - 12.45
14	23,6	17,2	25,4	16,7	17,4	25,2	26,1	32,7	41,5	20,1	8,6	SW	30%	Cloudy	2hrs	10.20 - 12.45
15	12,6	12,3	12,4	13,5	12,7	15,0	15,2	15,8	15,4	12,7	9,1	S	82%	Rainy	2hrs	10.20 - 12.45
16	17,5	14,1	18,3	13,7	13,9	21,2	22,2	25,6	26,8	15,5	7,2	N	42%	Cloudy	2hrs	10.20 - 12.45
17	23,5	18,7	25,2	17,0	18,5	25,6	24,1	32,5	37,5	20,6	6,5	W	45%	Sunny	2hrs	10.20 - 12.45
18	27,3	17,5	26,2	16,5	15,8	25,1	25,2	30,5	35,8	20,7	8,3	W	46%	Sunny	2hrs	10.20 - 12.45
19	30,2	18,1	27,9	15,4	17,2	23,2	23,2	29,8	32,8	21,8	9,0	W	55%	Sunny	2hrs	10.20 - 12.45
20	34,6	23,5	35,1	24,2	24,8	26,4	25,1	33,5	41,3	28,4	7,7	W	58%	Sunny	2hrs	10.20 - 12.45
21	11,2	10,5	8,7	11,0	10,2	13,2	10,0	12,5	14,5	10,3	9,7	NW	94%	Rainy	2hrs	10.20 - 12.45
22	15,9	12,5	14,4	14,2	15,2	18,5	20,0	21,3	22,5	14,4	11,2	W	48%	Sunny	2hrs	10.20 - 12.45
23	21,3	14,7	18,7	12,5	13,8	24,2	22,5	27,3	31,2	16,2	9,3	NW	43%	Sunny	2hrs	10.20 - 12.45
24	27,5	19,2	23,8	18,5	19,9	27,8	28,7	33,5	39,0	21,8	8,6	W	48%	Sunny	2hrs	10.20 - 12.45
25	32,2	22,1	29,8	21,7	22,0	31,5	32,6	40,8	46,2	25,6	8,3	W	55%	Sunny	2hrs	10.20 - 12.45
26	38,5	26,8	34,2	25,5	26,8	36,2	35,5	45,6	53,5	30,4	6,5	W	56%	Sunny	2hrs	10.20 - 12.45
27	11,0	9,7	9,2	8,5	10,2	12,5	12,2	15,1	17,0	9,7	10,1	SE	89%	Rainy	2hrs	10.20 - 12.45
28	12,3	12,5	12,0	12,3	14,2	15,8	19,8	17,6	18,5	12,7	18,7	NW	31%	Cloudy	2hrs	10.20 - 12.45
29	17,5	16,1	18,8	14,7	15,5	17,3	16,4	22,4	26,0	16,5	10,5	NW	37%	Cloudy	2hrs	10.20 - 12.45
30	23,5	18,5	25,2	17,3	17,9	23,5	22,7	29,5	33,1	20,5	6,5	W	48%	Sunny	2hrs	10.20 - 12.45
31	25,6	21,2	27,3	20,2	21,9	25,1	25,0	31,5	33,7	23,2	7,8	SW	50%	Sunny	2hrs	10.20 - 12.45
TOT	17,7	13,3	17,3	13,1	13,5	19,1	19,0	23,2	26,2	15,0	8,9					

Source: Author

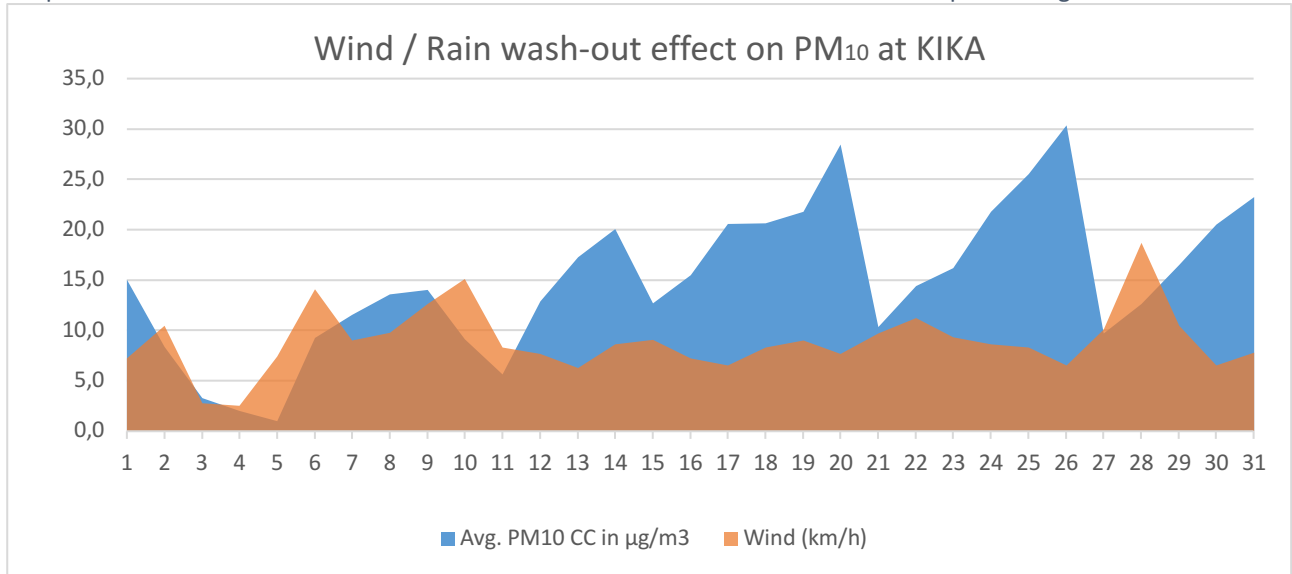
Figure 85: Sample from the dispersal of PM₁₀ sequence (14.3.2023)



1:4,000

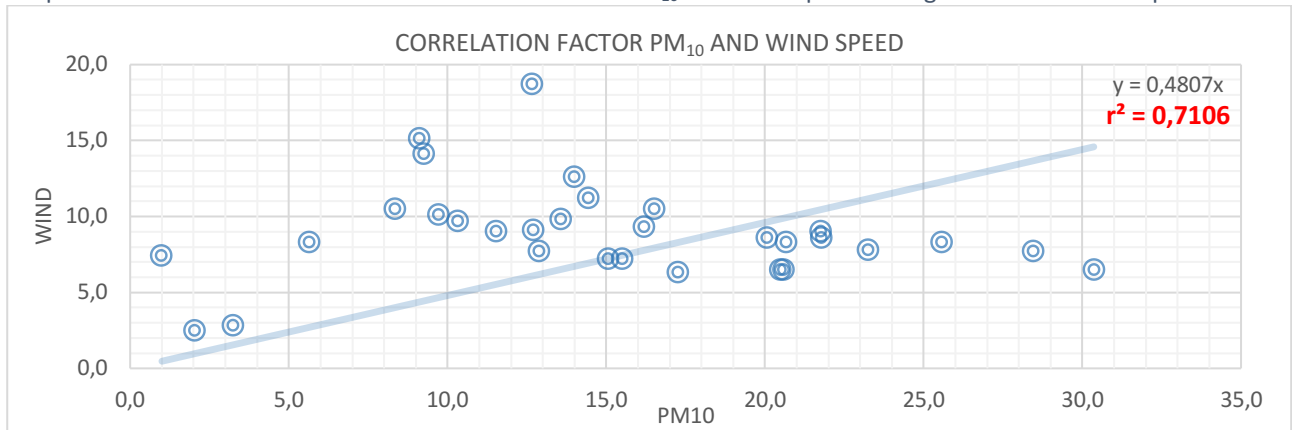
Source: Author

Graphic 55: Effect of wind and rain on the wash-out of PM₁₀ concentration at KIKA complex during March 2023.



Source: Author

Graphic 56: Correlation factor between concentration of PM₁₀ and Wind speed during March at KIKA Complex.



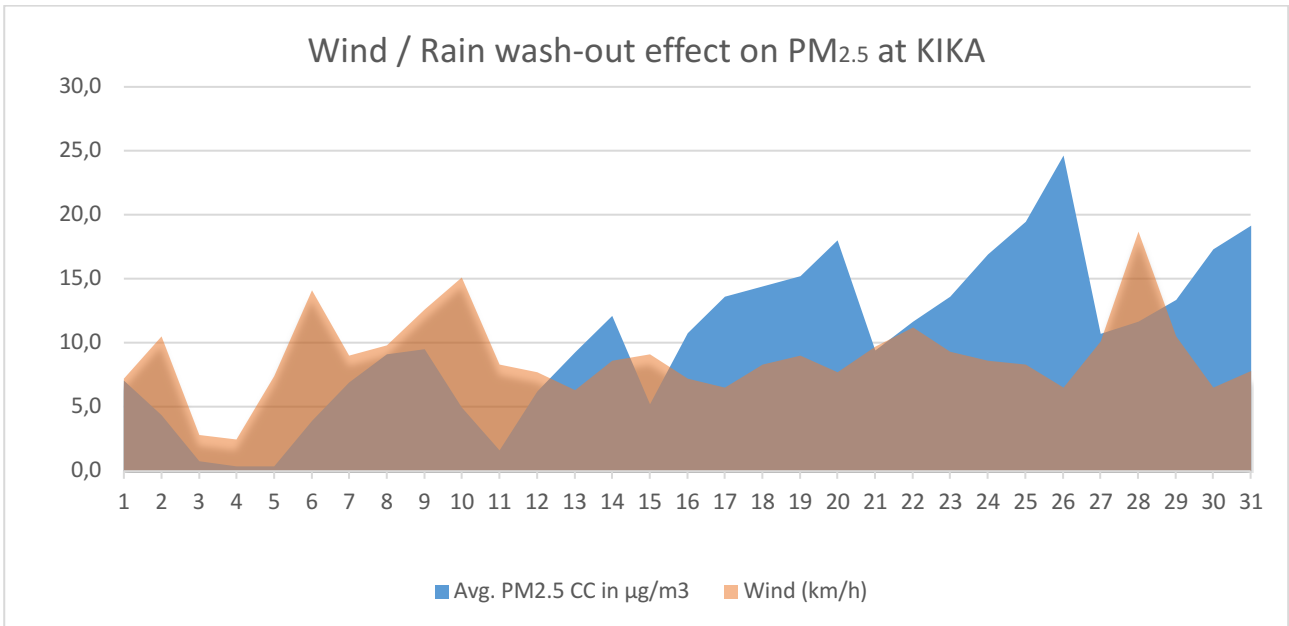
Source: Author

Table 51: PM_{2,5} concentrations and meteorological observations during March 2023 / KIKA Complex.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM2.5 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length	Daytime
1	7,4	6,8	6,5	6,6	8,1	10,20	10,00	12,00	12,80	7,1	7,2	W	75%	Rainy	2hrs	10.20 - 12.45
2	5,2	3,8	4,5	2,8	5,5	6,2	6,0	7,4	8,0	4,4	10,5	SW	56%	Rainy	2hrs	10.20 - 12.45
3	2,0	1,0	0,0	0,0	1,0	3,0	2,0	3,0	3,0	0,8	2,8	S	68%	Rainy	2hrs	10.20 - 12.45
4	1,0	0,0	1,0	0,0	0,0	1,0	1,0	2,0	1,0	0,4	2,5	NW	66%	Rainy	2hrs	10.20 - 12.45
5	0,0	0,0	1,0	0,0	1,0	0,0	0,0	0,0	1,0	0,4	7,4	W	58%	Rainy	2hrs	10.20 - 12.45
6	5,2	3,4	5,5	2,5	2,9	6,2	6,5	6,5	8,1	3,9	14,1	SW	59%	Cloudy	2hrs	10.20 - 12.45
7	9,3	5,1	10,2	4,6	5,3	11,1	12,5	10,5	14,1	6,9	9,0	W	52%	Sunny	2hrs	10.20 - 12.45
8	12,2	7,6	12,5	6,8	6,5	13,4	15,1	14,5	16,8	9,1	9,8	SW	50%	Cloudy	2hrs	10.20 - 12.45
9	14,2	6,5	13,1	6,6	7,3	14,5	14,1	16,2	18,7	9,5	12,8	SW	60%	Cloudy	2hrs	10.20 - 12.45
10	7,2	3,3	7,8	3,5	3,1	8,0	8,4	8,9	9,2	5,0	15,1	S	72%	Rainy	2hrs	10.20 - 12.45
11	2,6	1,1	2,0	0,0	2,5	3,3	3,5	3,1	5,6	1,6	8,3	SW	69%	Rainy	2hrs	10.20 - 12.45
12	7,9	4,2	8,3	5,1	5,6	11,2	11,7	12,5	14,9	6,2	7,7	N	29%	Sunny	2hrs	10.20 - 12.45
13	11,4	6,8	12,7	7,2	8,3	14,5	15,2	18,4	21,2	9,3	6,3	W	31%	Sunny	2hrs	10.20 - 12.45
14	15,6	8,9	15,2	11,2	9,7	16,8	15,5	21,3	24,6	12,1	8,6	SW	30%	Cloudy	2hrs	10.20 - 12.45
15	5,7	5,2	5,1	5,0	5,0	7,6	8,5	9,0	8,5	5,2	9,1	S	82%	Rainy	2hrs	10.20 - 12.45
16	13,4	8,6	14,6	8,5	8,8	15,4	15,0	17,2	18,7	10,8	7,2	N	42%	Cloudy	2hrs	10.20 - 12.45
17	17,2	10,3	18,6	10,5	11,4	19,2	16,7	19,1	22,4	13,6	6,5	W	45%	Sunny	2hrs	10.20 - 12.45
18	20,1	11,5	19,4	10,3	10,8	18,5	17,8	21,5	24,5	14,4	8,3	W	46%	Sunny	2hrs	10.20 - 12.45
19	22,6	9,7	21,6	10,9	11,4	19,1	18,7	21,1	26,7	15,2	9,0	W	55%	Sunny	2hrs	10.20 - 12.45
20	28,7	11,9	23,4	13,4	12,7	24,8	23,1	27,6	32,6	18,0	7,7	W	58%	Sunny	2hrs	10.20 - 12.45
21	13,1	7,6	12,4	6,3	7,8	11,5	12,0	11,4	11,9	9,4	9,7	NW	94%	Rainy	2hrs	10.20 - 12.45
22	16,5	8,7	13,5	9,7	10,0	14,6	14,8	16,7	19,7	11,7	11,2	W	48%	Sunny	2hrs	10.20 - 12.45
23	18,7	10,4	17,6	10,3	11,1	17,2	16,4	20,3	24,1	13,6	9,3	NW	43%	Sunny	2hrs	10.20 - 12.45
24	21,2	13,4	22,7	13,5	13,8	22,5	25,0	26,2	28,6	16,9	8,6	W	48%	Sunny	2hrs	10.20 - 12.45
25	24,9	15,7	25,1	16,0	15,7	25,8	24,3	29,8	32,3	19,5	8,3	W	55%	Sunny	2hrs	10.20 - 12.45
26	29,1	21,2	27,5	22,0	23,4	29,0	31,2	33,8	37,3	24,6	6,5	W	56%	Sunny	2hrs	10.20 - 12.45
27	12,4	10,7	8,9	10,5	11,2	12,6	11,1	11,5	14,5	10,7	10,1	SE	89%	Rainy	2hrs	10.20 - 12.45
28	15,4	9,6	11,8	9,7	11,8	14,5	14,1	16,7	18,2	11,7	18,7	NW	31%	Cloudy	2hrs	10.20 - 12.45
29	17,8	10,3	14,9	11,6	12,3	16,7	15,8	21,4	26,8	13,4	10,5	NW	37%	Cloudy	2hrs	10.20 - 12.45
30	22,7	14,5	19,1	14,0	16,2	23,0	22,1	28,0	34,1	17,3	6,5	W	48%	Sunny	2hrs	10.20 - 12.45
31	24,2	16,7	21,8	15,8	17,3	24,0	22,5	27,1	36,1	19,2	7,8	SW	50%	Sunny	2hrs	10.20 - 12.45
TOT	13,7	8,2	12,8	8,2	9,0	14,0	13,9	16,0	18,6	10,4	8,9					

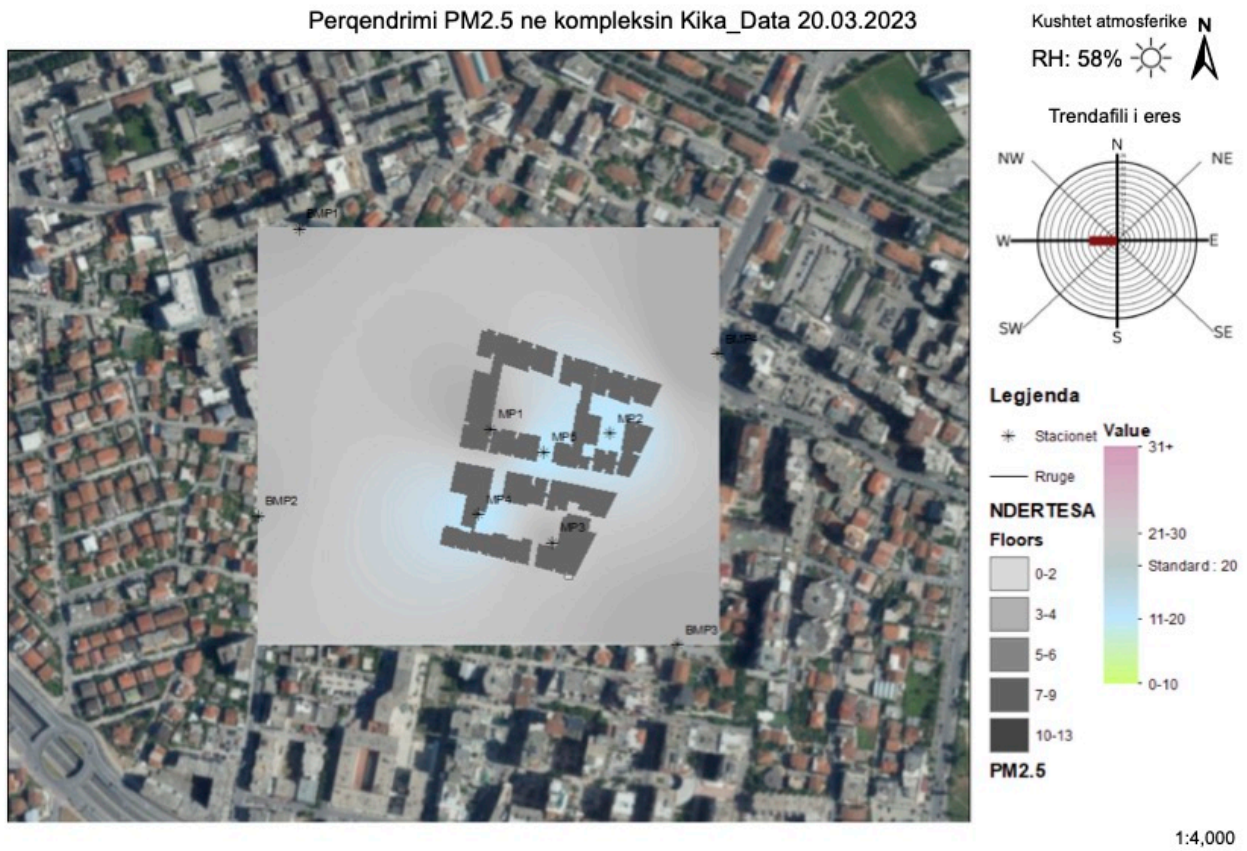
Source: Author

Graphic 57: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Magnet complex during March 2023



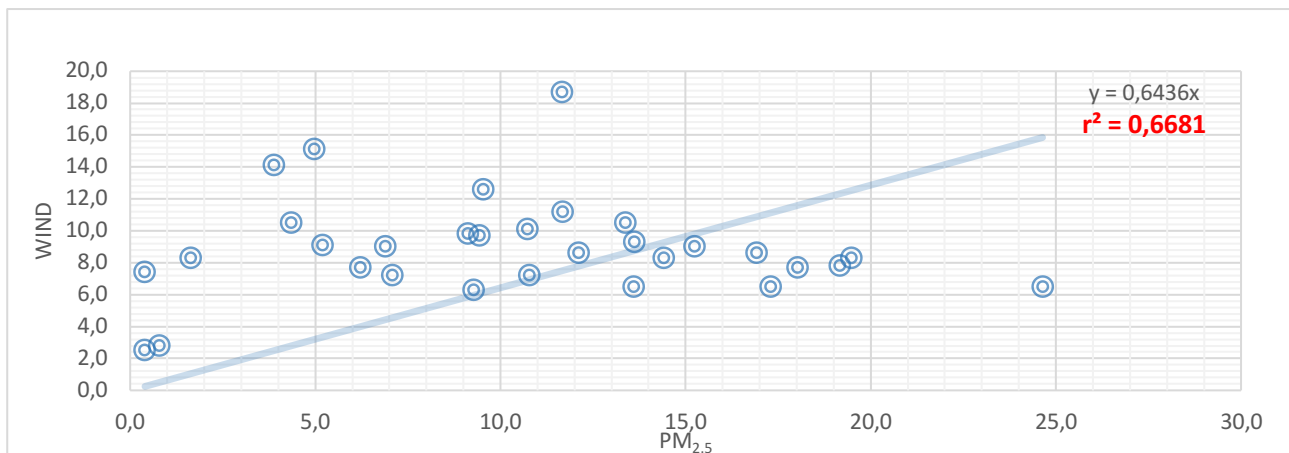
Source: Author

Figure 86: Sample from the dispersal of PM_{2.5} sequence (20.3.2023)



Source: Author

Graphic 58: Correlation factor between concentration of PM_{2.5} and Wind speed during March at KIKA Complex.



Source: Author

During March, the KIKA Complex was subject to rainfall for 32% of the monitored duration, a significant factor that could potentially influence air pollution patterns. In contrast to other monitored sites where the correlation between wind speed and the dispersal of air pollutants showed a moderate relationship, the KIKA Complex presented an exception. Even when including data from rainy days, the correlation coefficient (r) between wind speed and pollutant concentration at KIKA averaged to 0.714 suggesting a strong, consistent influence of wind on pollutant dispersion at this site, notwithstanding the precipitation that typically reduces pollution levels by washing pollutants out of the air.

Two primary factors appear to underlie this strong correlation, despite the mitigating effects of meteorological conditions. Firstly, the KIKA Complex's terrain elevation is higher relative to other monitoring locations, which may enhance wind's role in pollutant dispersion over the influence of rain. The elevated position likely augments wind flow and its capacity to disperse air pollutants effectively. Secondly, the architectural design and urban form of the KIKA Complex contribute significantly to this phenomenon. The complex features a unique layout with closed corners along its perimeter and several tunnels that serve both as access points at ground level and ventilation channels at higher floors. This design not only facilitates enhanced wind flow throughout the complex, thereby aiding in the natural ventilation and dispersal of pollutants but also exposes the interior parts of the complex to emissions from surrounding areas. The distinct urban form of KIKA, with its strategic openings and closed perimeters, effectively channels wind, making it a significant factor in pollutant dispersion.

Furthermore, meteorological data supports these findings, indicating that the KIKA Complex experiences higher average wind speeds, reaching 8.5 km/h from January to March, compared to a maximum of 6 km/h recorded in the other three areas. These conditions render the KIKA Complex as the site with the lowest pollution concentration during March, a stark contrast to its status among the most polluted sites under dry weather conditions. This analysis underscores the critical influence of urban form and elevation on the natural dispersion of air pollutants, highlighting the necessity of considering these factors in urban planning and design to mitigate air pollution effectively. The case of the KIKA Complex offers valuable insights into how architectural and environmental planning can be leveraged to improve air quality, even under varying weather conditions.

However, taking into consideration that the predominating wind directions are from West during March, it appears that the impact from the vortex effect to pollution retention in the monitored stations preserves the same pattern as in February.

Table 52: Number of days indicating the orientation of the wind during March at KIKA Complex

N	S	W	E	NW	NE	SE	SW
2	3	13	0	5	0	1	7
6%	10%	42%	0%	16%	0%	3%	23%

Source: Author

The conclusion that prevailing westerly wind patterns, coupled with the dry conditions observed during the latter half of the month, have a significant impact on MP.1 and MP.3, positioning them squarely within the influence of Air Pollution Cavity Areas, is notable. This phenomenon's formation requires merely 24 hours following any rain-induced washout effect, given the wind's dual role not only in ventilating the area but also in transporting pollution from surrounding or distant western sectors of the city.

The month of March recorded the lowest pollutant levels compared to January and February, a trend that can also be partly ascribed to the rain's washout effect, which effectively reduced the overall pollution concentration within the area. This observation underlines the complex interplay between meteorological conditions and urban pollution dynamics. While precipitation acts as a natural cleansing mechanism, reducing airborne pollutant levels, the subsequent dry periods coupled with specific wind patterns can quickly revert these areas to states of high pollution concentration, underscoring the transient and dynamic nature of urban air quality.

ISH-EKSPOZITA.

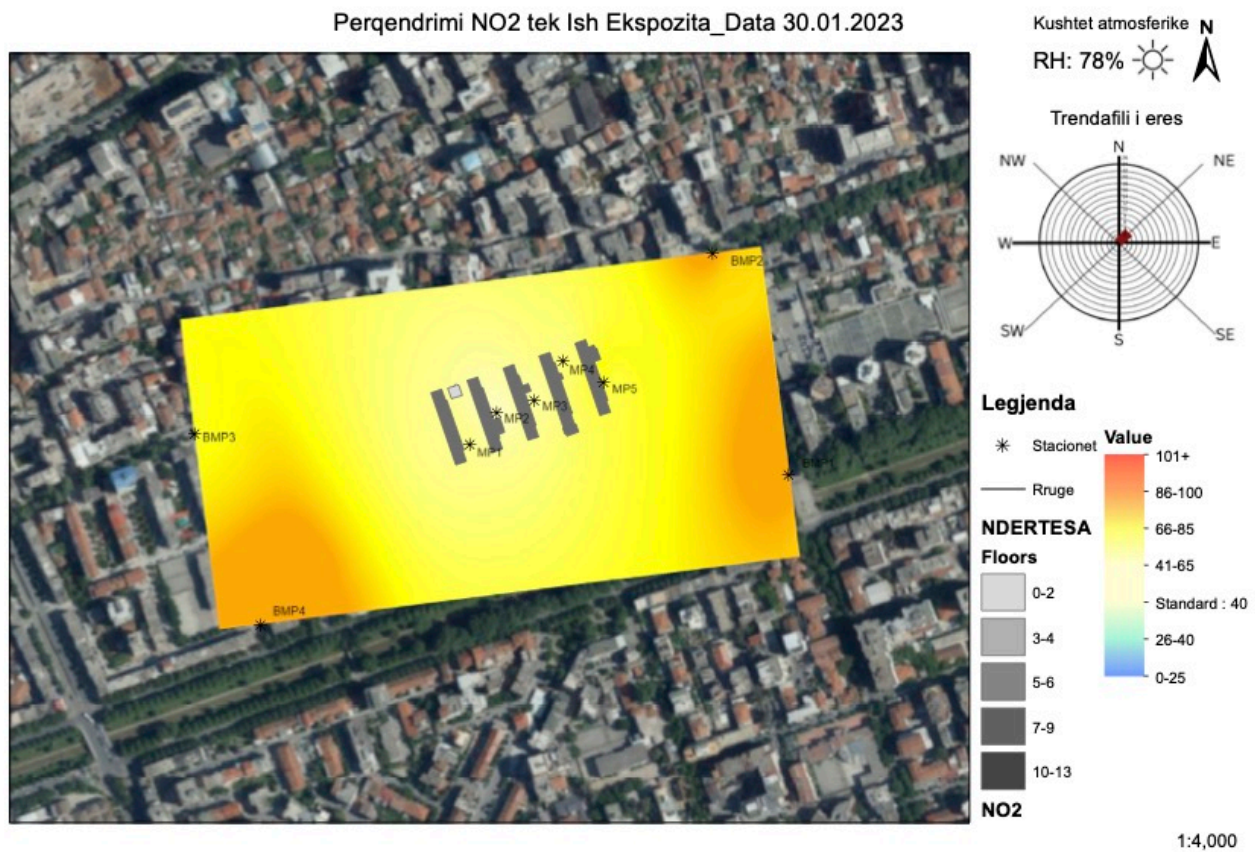
This particular study area, distinguished by the fact that among all the monitored location which are quite new complexes, Ish-Ekspozita was constructed over 55 years ago, features an urban form composed of linear and parallel residential buildings ranging from five to six stories, oriented from the Northwest. Such an arrangement is ideally suited for the natural dispersion of air pollutants and facilitates natural ventilation, leveraging the most prevalent wind directions in Tirana. Like all the other monitored sites, the same methodology was applied by selecting 5 Monitoring Points. Whereas, none of these points were anticipated to experience the vortex effect, which can retain pollutants for extended periods. This expectation stems from the strategic placement of monitoring points away from intersections, where the unique urban morphology of this area fosters wind corridors, enhancing air flow and pollutant dispersion.

Additionally, four buffer monitoring points were strategically placed near each crossroad to capture accurate pollution data being emitted from nearby areas, providing a comprehensive understanding of the local air quality. It's important to note that the site, formerly known as Ish-Ekspozita, has become one of Tirana's largest construction zones. The ongoing construction activities and the frequent movement of heavy-duty vehicles contribute to a noticeable increase in pollutant concentrations in this area, diverging from the pollution averages recorded in 2018-2019.

This scenario underscores the dynamic nature of urban environments and the impact of urban development and construction on air quality. It highlights the need for ongoing monitoring and adaptive planning strategies to mitigate the adverse effects of such developments on the urban atmosphere, ensuring that the benefits of natural pollutant dispersal mechanisms are not overshadowed by anthropogenic pollution sources.

The comprehensive monitoring effort encompassed a variety of elements, including urban form, pollution concentrations, wind direction and speed, meteorological conditions, and relative humidity. These components were systematically depicted through daily maps, offering a visual representation of the data collected. This mapping process was uniformly applied to three key pollutants: Nitrogen Dioxide (NO₂), Particulate Matter 2.5 (PM_{2.5}), and Particulate Matter 10 (PM₁₀), resulting in a total of 270 maps (90 for each pollutant). These maps were generated from data extracted from 90 site monitoring sheets, facilitating a detailed visualization of pollution dispersion within the study area.

Figure 87: Pollution concentration map (1 sample out of 270 maps prepared for Ish-Ekspozita Area)



Source: Author

Subsequently, these maps were sequenced by pollutant type, revealing areas potentially affected by Air Pollution Cavity Areas where the urban form significantly influences the natural dispersal of pollutants. The specific daily time-line for monitoring activities at the Ish-Ekspozita Complex ranged from 17:00 to 19:45, ensuring a comprehensive coverage of at least 25 minutes at each monitoring point within the complex. This focused effort aimed to identify specific areas where pollutants might accumulate, known as air pollution cavity areas. Additionally, each of the buffer monitoring points received between 7 to 10 minutes of observation, enabling a broader understanding of the surrounding air quality and the effects of urban form on pollution dispersion.

This methodical approach underscores the significance of temporal and spatial analysis in understanding urban air quality. By concentrating observations during these specific hours, the study captures pollution dynamics at times of potentially high variability, offering insights into how different urban forms and environmental conditions interact to affect air quality. This detailed mapping and sequencing methodology provides a solid foundation for identifying and addressing areas within urban environments where pollutant dispersion is hindered, thereby contributing valuable knowledge for urban planning and public health initiatives.

EKSPOZITA _ JANUARY 2023:

January witnessed notably high levels of pollution concentration, a direct aftermath of the substantial emissions carried over from the end of 2022. This situation was exacerbated by the fireworks displays marking the New Year's Eve celebrations, coupled with a prolonged period of dry weather and negligible wind activity persisting until mid-January. The absence of significant rainfall during this initial half of the month meant that there was no substantial wash-out effect to mitigate the pollution levels. Consequently, the minimal wind present during this period (aside of 9th January) was insufficient to facilitate the dispersal of pollutants across the complex and beyond into the broader cityscape.

Interestingly, the Ish-Ekspozita complex, known for its wind tunnels created by the strategic orientation of its buildings from the Northwest, would typically benefit from the prevailing wind patterns coming from the Northwest and Southeast. These wind conduits are designed to enhance natural ventilation and pollutant dispersion. However, in the unique meteorological conditions of early January, these normally advantageous wind patterns did not significantly contribute to alleviating the pollution accumulation. This anomaly highlights the complex interplay between urban design, weather conditions, and air quality. Despite the architectural intentions to harness natural wind patterns for pollution mitigation, the specific meteorological circumstances of early January thwarted these efforts, underscoring the challenge of predicting and managing air quality in urban environments with variable weather conditions.

One final note that should be underlined is that 2 of the 5 monitoring points were strategically positioned adjacent to the only two urban modifications within the study area. The first is located next to the Marilyn Monroe café, and the second is situated by an extension to an existing residential unit. Both modifications are ground-level structures, each extending to a height of approximately 2.5 to 3 meters.

This deliberate choice of monitoring locations by the researcher was aimed at examining whether such low-rise urban modifications could potentially induce the vortex effect and contribute to the formation of air pollution cavity areas.

This approach underscores a nuanced investigation into the microscale impacts of urban form changes on air quality. By focusing on these specific modifications, the study seeks to understand how even small-scale architectural or urban developments at ground level can influence the movement and concentration of air pollutants.

The hypothesis being tested is whether these modifications, due to their modest height and positioning, disrupt the airflow in such a way that it could lead to localized increases in pollution levels, essentially creating pockets where pollutants can accumulate due to altered wind patterns. This aspect of the research provides valuable insights into the intricacies of urban air flow dynamics and the potential for seemingly minor modifications to have a significant impact on local air quality. Understanding these dynamics is crucial for urban planning and development strategies aiming to mitigate pollution and enhance the health and well-being of urban populations.

Table 53: Number of days with sun, cloud and rain during January at Ekspozita complex.

Rain	Cloud	Clear
9	7	15
29%	23%	48%

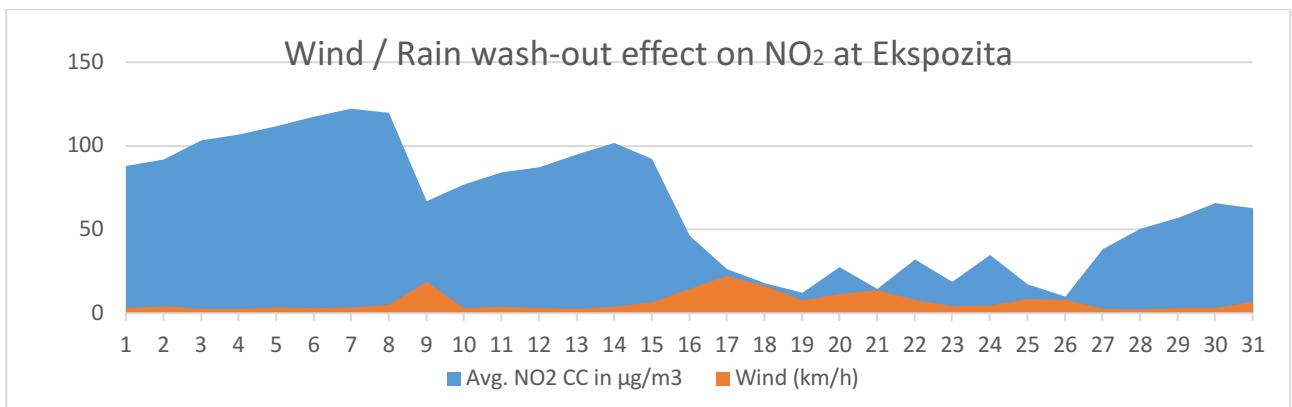
Source: Author

Table 54: NO₂ concentrations and meteorological observations during January 2023 / Ish-Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. NO2 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	87	89	91	88	85	112	110	108	110	88	2,9	E	61%	Clear	2hrs 17.00-19.40
2	92	91	94	92	90	109	108	102	105	92	4,2	E	58%	Clear	2hrs 17.00-19.40
3	103	101	107	104	102	114	117	109	112	103	2,7	E	74%	Clear	2hrs 17.00-19.40
4	105	104	110	108	106	118	121	115	118	107	2,5	E	75%	Cloudy	2hrs 17.00-19.40
5	109	110	116	113	110	123	122	118	126	112	3,6	E	86%	Cloudy	2hrs 17.00-19.40
6	115	115	124	116	117	127	126	121	130	117	2,9	E	71%	Clear	2hrs 17.00-19.40
7	119	121	132	119	120	130	131	127	132	122	3,3	E	69%	Clear	2hrs 17.00-19.40
8	117	115	127	120	119	129	130	124	133	120	5,0	E	83%	Clear	2hrs 17.00-19.40
9	68	66	67	65	69	76	74	68	72	67	18,7	SE	86%	Rainy	2hrs 17.00-19.40
10	79	75	77	76	78	83	82	75	88	77	3,2	E	91%	Cloudy	2hrs 17.00-19.40
11	83	81	89	86	82	89	86	83	92	84	3,9	E	77%	Cloudy	2hrs 17.00-19.40
12	86	86	92	84	89	96	95	89	99	87	3,2	E	47%	Clear	2hrs 17.00-19.40
13	91	90	99	93	102	107	104	100	111	95	2,5	E	82%	Clear	2hrs 17.00-19.40
14	95	97	106	99	111	110	107	102	115	102	3,9	E	77%	Clear	2hrs 17.00-19.40
15	87	91	96	90	97	111	104	100	113	92	6,5	E	71%	Clear	2hrs 17.00-19.40
16	48	46	44	41	53	53	47	46	58	46	14,5	SE	81%	Rainy	2hrs 17.00-19.40
17	29	22	27	23	31	31	30	24	35	26	22,3	SE	83%	Rainy	2hrs 17.00-19.40
18	17	17	16	17	23	24	25	21	28	18	16,5	SE	70%	Rainy	2hrs 17.00-19.40
19	13	11	9	11	17	22	20	24	22	12	7,7	SE	90%	Rainy	2hrs 17.00-19.40
20	26	28	22	27	35	39	41	34	45	28	11,5	E	77%	Cloudy	2hrs 17.00-19.40
21	14	14	14	13	18	25	23	25	29	15	13,7	SE	77%	Rainy	2hrs 17.00-19.40
22	28	32	30	33	38	42	40	36	43	32	7,9	E	64%	Cloudy	2hrs 17.00-19.40
23	17	16	17	18	25	23	22	17	23	19	4,3	E	91%	Rainy	2hrs 17.00-19.40
24	32	34	33	35	41	48	47	38	49	35	4,7	NE	80%	Clear	2hrs 17.00-19.40
25	18	15	17	12	24	21	19	15	24	17	8,6	E	71%	Rainy	2hrs 17.00-19.40
26	7	11	10	5	16	16	13	11	18	10	8,2	E	77%	Rainy	2hrs 17.00-19.40
27	35	38	42	37	40	48	51	40	53	38	2,5	E	81%	Cloudy	2hrs 17.00-19.40
28	46	49	53	46	58	66	68	56	72	50	2,4	E	73%	Clear	2hrs 17.00-19.40
29	52	57	60	55	61	73	73	61	80	57	3,2	E	68%	Clear	2hrs 17.00-19.40
30	65	62	64	66	72	86	83	72	93	66	2,9	NE	78%	Clear	2hrs 17.00-19.40
31	59	58	61	58	78	81	79	66	85	63	6,8	N	56%	Clear	2hrs 17.00-19.40
TOT	62,6	62,6	66,0	62,9	68,0	75,2	74,1	68,6	77,8	64,4	6,7				

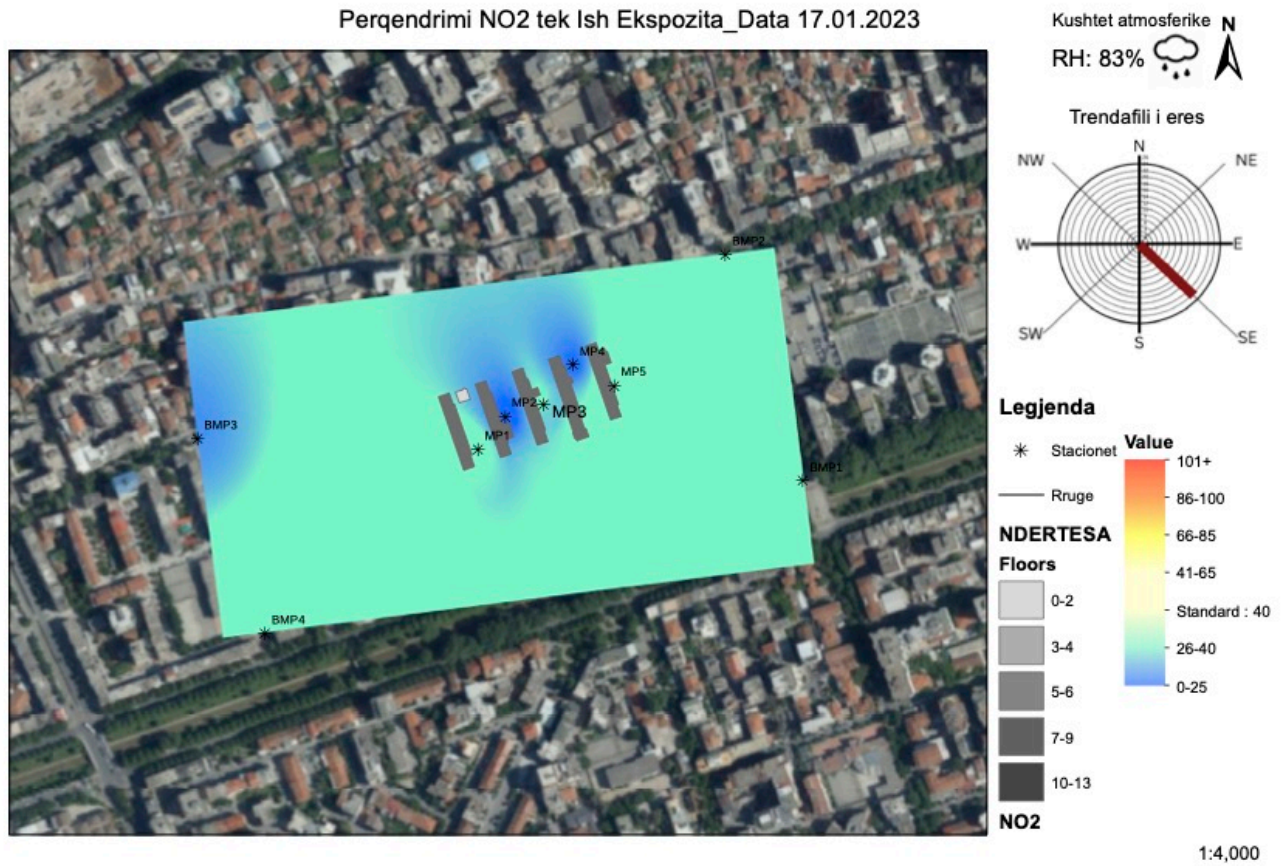
Source: Author

Graphic 59: Effect of wind and rain on the wash-out of NO₂ concentration at Ekspozita during January 2023.



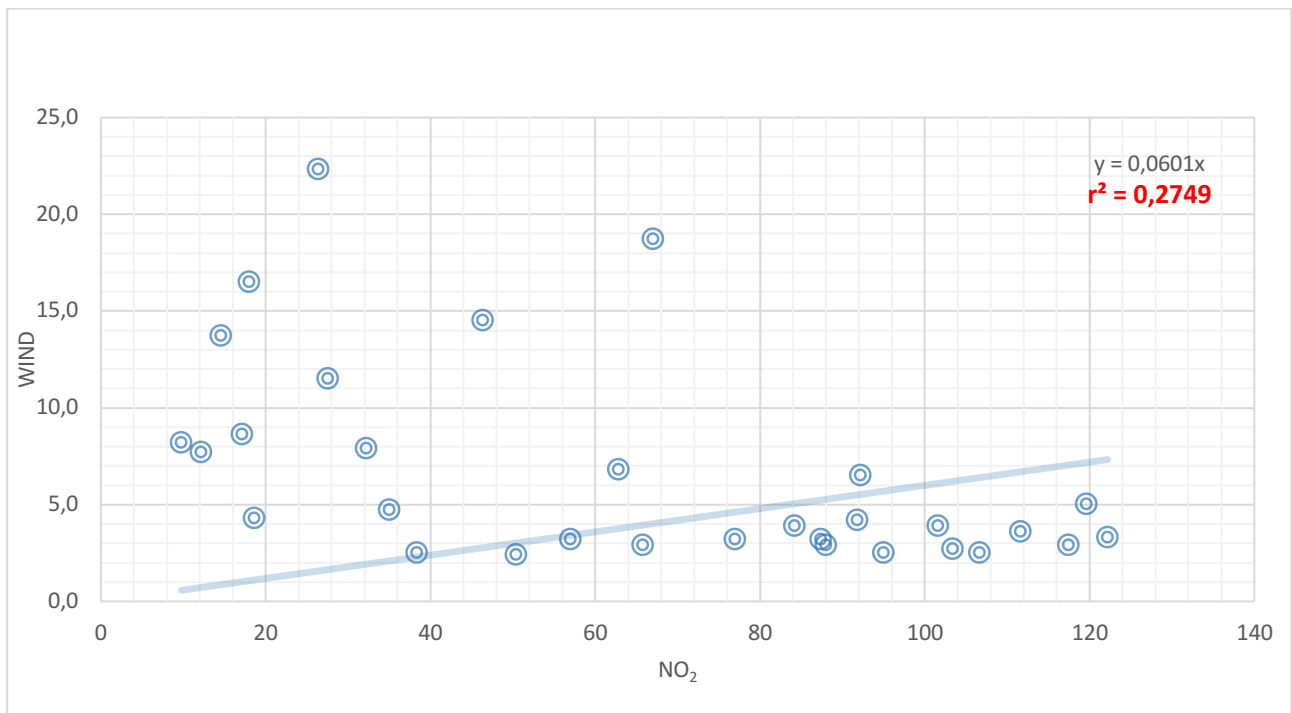
Source: Author

Figure 88: Sample from the dispersal of NO₂ sequence at Ish-Espozita (17.01.2023)



Source: Author

Graphic 60: Correlation factor between concentration of NO₂ and Wind speed during January at Ekspozita.



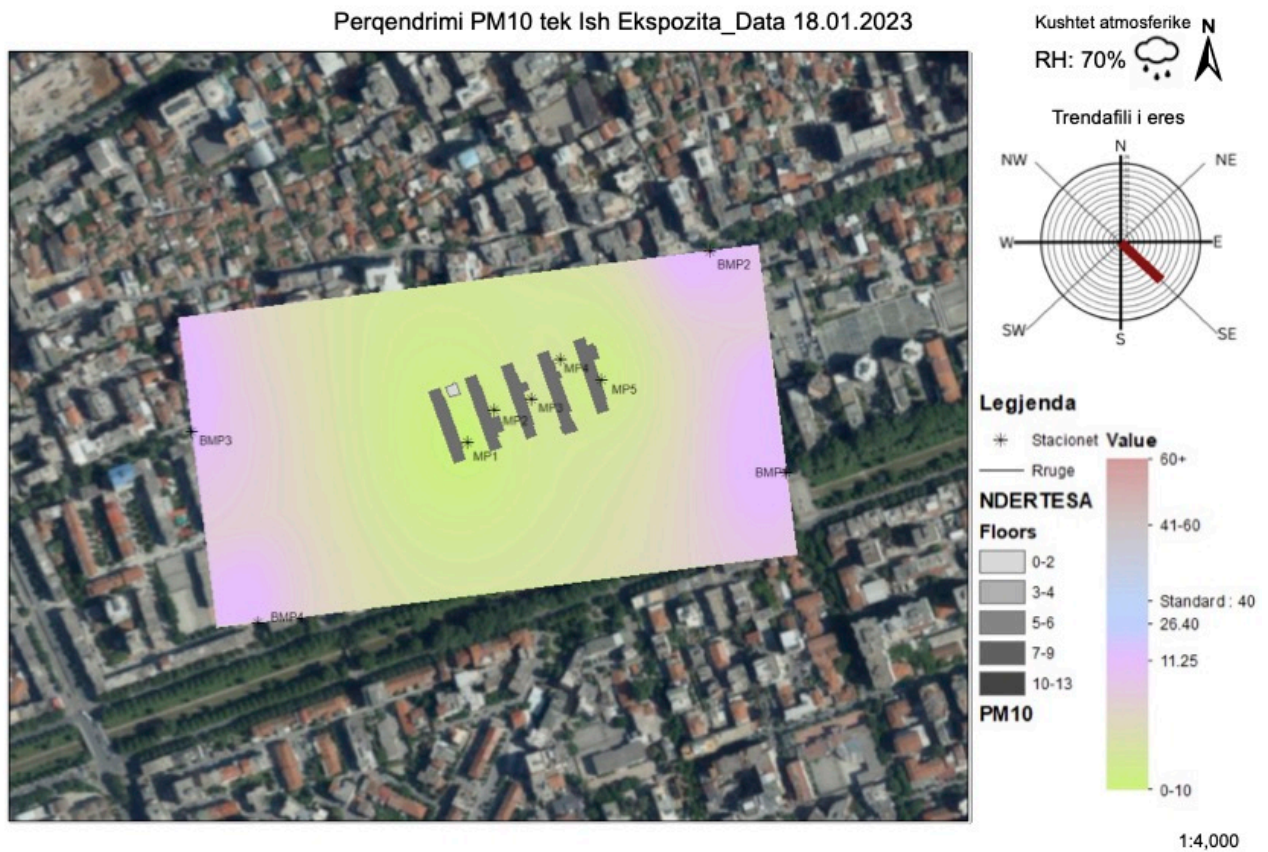
Source: Author

Table 55: PM₁₀ concentrations and meteorological observations during January 2023 / Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	16	15	14	15	19	21	22	17	23	16	2,9	E	61%	Clear	2hrs 17.00-19.40
2	15	15	16	13	18	22	24	21	24	15	4,2	E	58%	Clear	2hrs 17.00-19.40
3	17	15	17	15	19	23	25	20	27	17	2,7	E	74%	Clear	2hrs 17.00-19.40
4	18	17	19	20	22	27	28	22	27	19	2,5	E	75%	Cloudy	2hrs 17.00-19.40
5	17	18	21	22	22	26	28	24	26	20	3,6	E	86%	Cloudy	2hrs 17.00-19.40
6	20	23	24	27	26	30	32	27	33	24	2,9	E	71%	Clear	2hrs 17.00-19.40
7	20	22	21	20	26	29	27	24	27	22	3,3	E	69%	Clear	2hrs 17.00-19.40
8	17	16	18	15	22	25	28	22	29	18	5,0	E	83%	Clear	2hrs 17.00-19.40
9	7	7	5	8	9	11	15	10	14	7	18,7	SE	86%	Rainy	2hrs 17.00-19.40
10	14	15	15	13	17	20	22	18	25	15	3,2	E	91%	Cloudy	2hrs 17.00-19.40
11	16	17	19	15	19	23	24	21	29	17	3,9	E	77%	Cloudy	2hrs 17.00-19.40
12	20	19	22	20	25	30	31	26	33	21	3,2	E	47%	Clear	2hrs 17.00-19.40
13	26	24	28	25	32	37	36	32	40	27	2,5	E	82%	Clear	2hrs 17.00-19.40
14	27	27	26	28	29	35	34	33	36	27	3,9	E	77%	Clear	2hrs 17.00-19.40
15	24	23	25	23	24	31	29	27	32	24	6,5	E	71%	Clear	2hrs 17.00-19.40
16	14	12	15	14	16	22	20	18	20	14	14,5	SE	81%	Rainy	2hrs 17.00-19.40
17	8	7	8	8	9	14	12	10	15	8	22,3	SE	83%	Rainy	2hrs 17.00-19.40
18	3	4	5	5	4	12	13	12	10	4	16,5	SE	70%	Rainy	2hrs 17.00-19.40
19	1	2	2	3	2	7	8	5	9	2	17,7	SE	90%	Rainy	2hrs 17.00-19.40
20	9	10	12	15	17	18	14	11	18	13	11,5	E	77%	Cloudy	2hrs 17.00-19.40
21	3	2	7	6	8	10	9	6	11	5	13,7	SE	77%	Rainy	2hrs 17.00-19.40
22	6	9	11	10	11	15	17	12	18	9	17,9	E	64%	Cloudy	2hrs 17.00-19.40
23	8	10	12	10	16	16	15	10	15	11	4,3	E	91%	Rainy	2hrs 17.00-19.40
24	14	15	17	13	19	21	25	22	25	16	4,7	NE	80%	Clear	2hrs 17.00-19.40
25	7	4	7	6	9	17	15	11	18	7	8,6	E	71%	Rainy	2hrs 17.00-19.40
26	5	2	6	8	10	14	12	8	10	6	8,2	E	77%	Rainy	2hrs 17.00-19.40
27	16	15	19	18	21	25	23	16	21	18	2,5	E	81%	Cloudy	2hrs 17.00-19.40
28	19	17	21	19	25	32	30	24	29	20	2,4	E	73%	Clear	2hrs 17.00-19.40
29	16	15	17	16	19	29	31	18	28	17	3,2	E	68%	Clear	2hrs 17.00-19.40
30	23	23	26	25	25	34	32	33	37	24	2,9	NE	78%	Clear	2hrs 17.00-19.40
31	18	17	19	14	21	32	31	24	30	18	6,8	N	56%	Clear	2hrs 17.00-19.40
TOT	14,3	14,1	15,9	15,1	18,1	22,8	23,0	18,8	23,8	15,5	6,7				

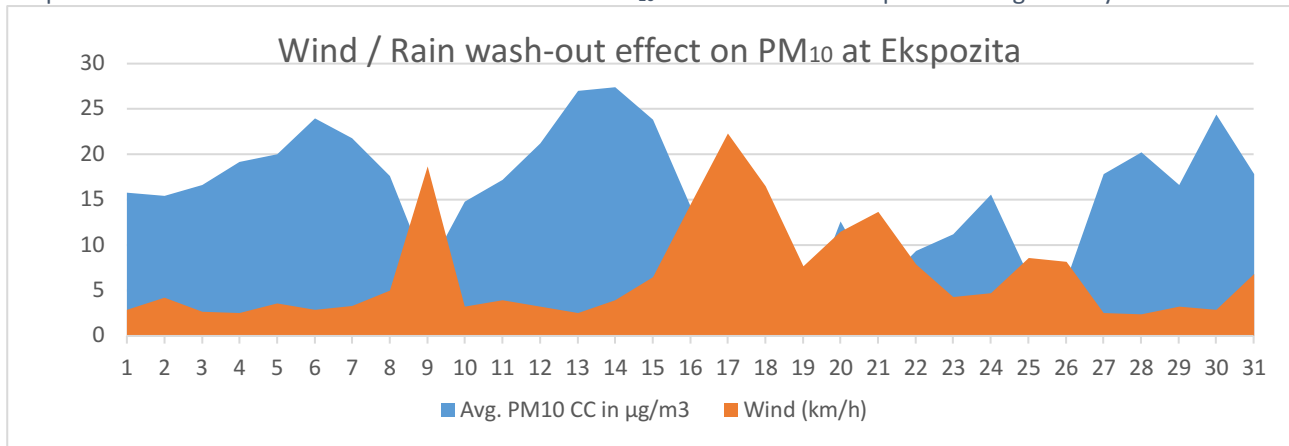
Source: Author

Figure 89: Sample from the dispersal of PM₁₀ sequence at Ekspozita (18.01.2023)



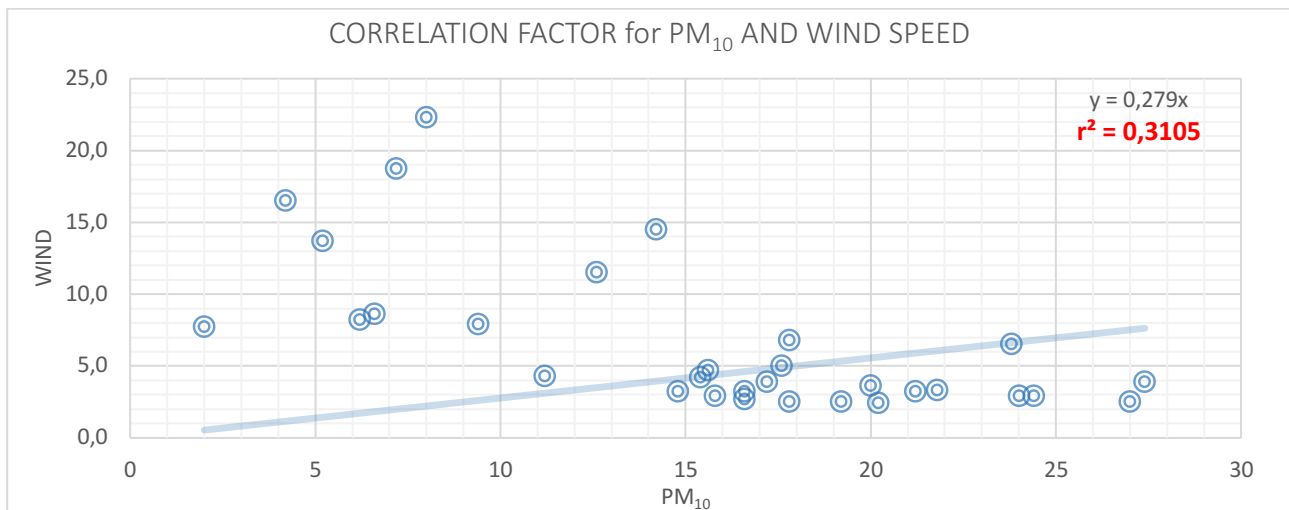
Source: Author

Graphic 61: Effect of wind and rain on the wash-out of PM₁₀ concentration at Ekspozita during January 2023



Source: Author

Graphic 62: Correlation factor between concentration of PM₁₀ and Wind speed during January at Ekspozita.



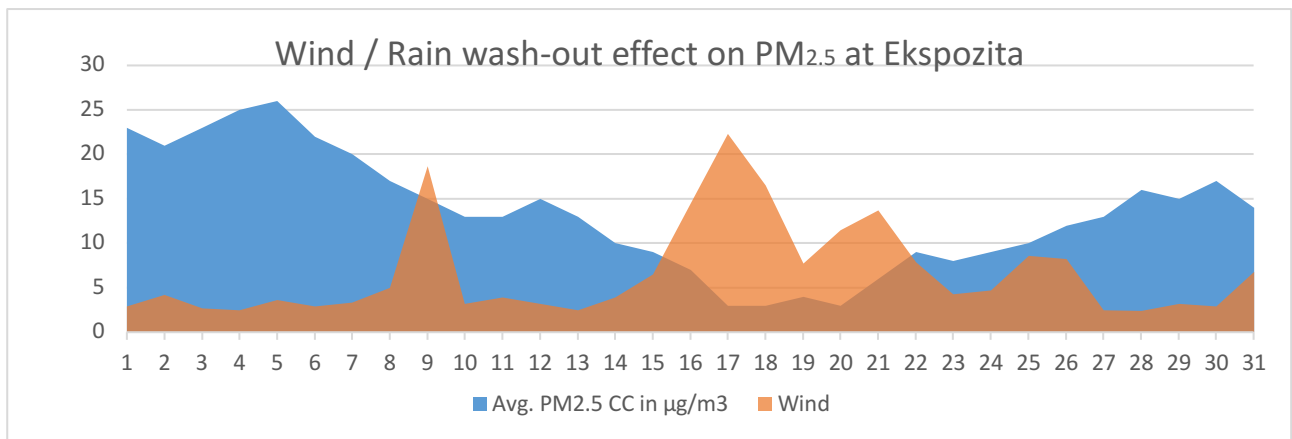
Source: Author

Table 56: PM_{2.5} concentrations and meteorological observations during January 2023 / Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM2.5 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	9,9	9,5	10,1	8,3	10,4	11,6	11,1	10,6	12,3	9,6	2,9	E	61%	Clear	2hrs 17.00-19.40
2	10,2	10,4	10,7	10,5	11,8	13,5	13,6	12,2	14,8	10,7	4,2	E	58%	Clear	2hrs 17.00-19.40
3	11,9	12,5	13,4	11,3	13,9	15,5	12,6	13,5	14,8	12,6	2,7	E	74%	Clear	2hrs 17.00-19.40
4	13,3	13,0	14,2	12,6	14,8	17,7	16,8	14,5	16,6	13,6	2,5	E	75%	Cloudy	2hrs 17.00-19.40
5	15,1	14,9	17,3	13,8	17,8	23,4	20,8	18,7	22,2	15,8	3,6	E	86%	Cloudy	2hrs 17.00-19.40
6	15,8	15,6	18,2	14,7	19,3	24,6	23,4	20,3	24,7	16,7	2,9	E	71%	Clear	2hrs 17.00-19.40
7	15,0	15,2	17,7	14,3	19,5	25,6	24,1	22,8	25,4	16,3	3,3	E	69%	Clear	2hrs 17.00-19.40
8	12,7	12,3	13,5	11,8	14,7	22,5	23,4	19,6	24,1	13,0	5,0	E	83%	Clear	2hrs 17.00-19.40
9	5,8	4,6	6,2	4,3	6,8	13,2	12,4	10,3	14,0	5,5	18,7	SE	86%	Rainy	2hrs 17.00-19.40
10	8,3	9,2	9,5	9,1	10,0	18,5	18,0	15,5	18,1	9,2	3,2	E	91%	Cloudy	2hrs 17.00-19.40
11	9,0	8,6	10,3	8,9	10,9	22,4	24,2	19,6	23,5	9,5	3,9	E	77%	Cloudy	2hrs 17.00-19.40
12	9,7	10,2	12,4	10,1	13,4	24,8	24,1	19,3	25,9	11,2	3,2	E	47%	Clear	2hrs 17.00-19.40
13	11,6	11,3	13,8	12,4	14,6	27,2	25,7	21,3	28,8	12,7	2,5	E	82%	Clear	2hrs 17.00-19.40
14	12,3	12,2	14,4	13,5	15,7	28,6	27,4	19,5	26,3	13,6	3,9	E	77%	Clear	2hrs 17.00-19.40
15	11,2	11,1	12,5	10,7	13,3	24,6	24,2	19,4	24,6	11,8	6,5	E	71%	Clear	2hrs 17.00-19.40
16	5,4	5,1	4,9	5,2	5,8	13,6	16,1	12,5	13,9	5,3	14,5	SE	81%	Rainy	2hrs 17.00-19.40
17	4,2	4,6	3,8	4,1	4,1	8,6	9,1	8,1	8,7	4,2	22,3	SE	83%	Rainy	2hrs 17.00-19.40
18	3,1	3,1	3,1	3,1	3,1	5,6	4,7	4,1	6,3	3,1	16,5	SE	70%	Rainy	2hrs 17.00-19.40
19	2,1	2,1	2,1	2,1	4,1	4,1	3,1	2,1	5,1	2,5	7,7	SE	90%	Rainy	2hrs 17.00-19.40
20	6,1	5,7	5,6	5,4	5,6	11,1	10,6	11,3	13,5	5,7	11,5	E	77%	Cloudy	2hrs 17.00-19.40
21	4,1	5,1	5,1	4,1	5,1	6,2	6,6	6,5	8,1	4,7	13,7	SE	77%	Rainy	2hrs 17.00-19.40
22	5,3	4,9	5,6	5,9	7,0	13,4	11,8	10,2	15,6	5,7	7,9	E	64%	Cloudy	2hrs 17.00-19.40
23	4,1	4,6	4,0	4,5	5,2	8,9	8,6	9,3	10,8	4,5	4,3	E	91%	Rainy	2hrs 17.00-19.40
24	7,3	7,6	8,4	6,8	9,4	14,5	16,2	12,8	18,0	7,9	4,7	NE	80%	Clear	2hrs 17.00-19.40
25	5,2	5,6	5,3	5,6	6,3	10,2	9,7	7,5	9,3	5,6	8,6	E	71%	Rainy	2hrs 17.00-19.40
26	4,6	4,2	4,5	4,6	5,5	7,6	7,3	6,1	6,4	4,7	8,2	E	77%	Rainy	2hrs 17.00-19.40
27	9,9	8,6	10,3	9,2	12,7	16,4	17,1	14,5	15,6	10,1	2,5	E	81%	Cloudy	2hrs 17.00-19.40
28	13,3	12,8	14,6	12,9	14,6	19,5	19,6	14,4	18,8	13,6	2,4	E	73%	Clear	2hrs 17.00-19.40
29	12,6	11,4	13,5	11,7	15,5	20,6	19,3	12,2	17,9	12,9	3,2	E	68%	Clear	2hrs 17.00-19.40
30	16,3	15,4	17,6	16,8	19,9	24,2	25,5	17,7	23,4	17,2	2,9	NE	78%	Clear	2hrs 17.00-19.40
31	14,5	13,6	14,8	14,0	18,9	23,8	24,2	15,3	24,6	15,2	6,8	N	56%	Clear	2hrs 17.00-19.40
TOT	9,4	9,2	10,2	9,1	11,3	16,8	16,5	13,6	17,2	9,8	6,7				

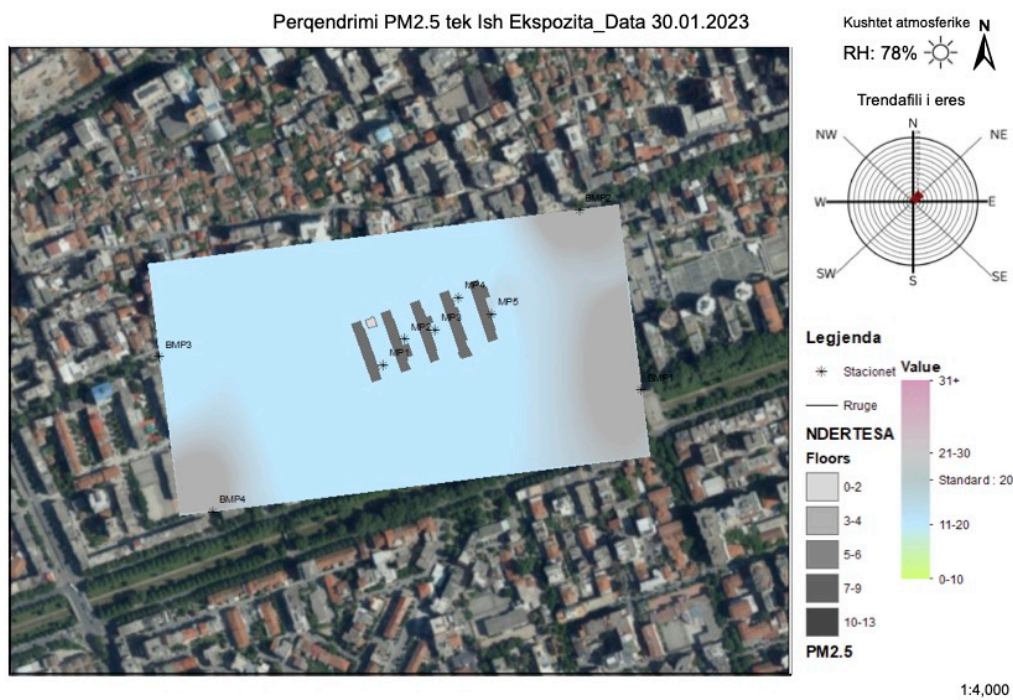
Source: Author

Graphic 63: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Ekspozita during January 2023



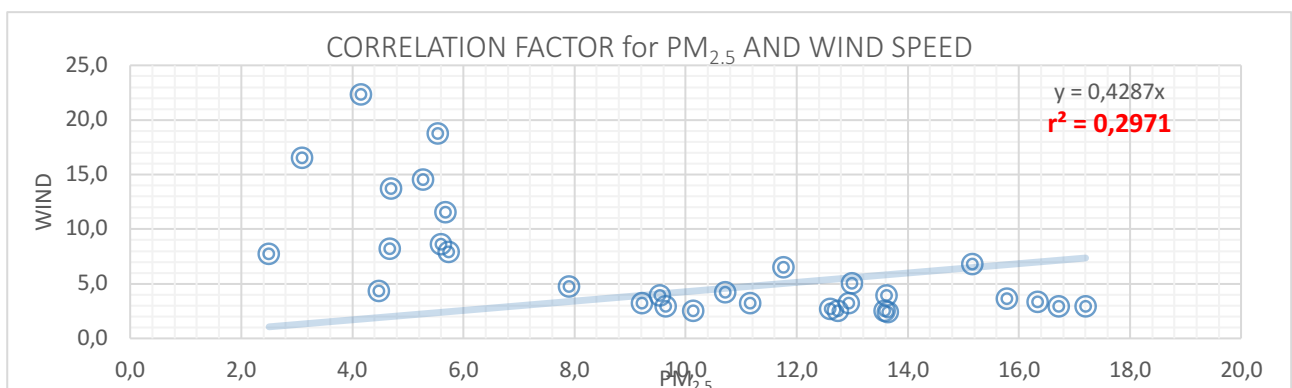
Source: Author

Figure 90: Sample from the dispersal of PM_{2.5} sequence at Ekspozita (30.01.2023)



Source: Author

Graphic 64: Correlation factor between concentration of PM_{2.5} and Wind speed during January at Ekspozita Complex.



Source: Author

The meteorological patterns observed during January were marked by a sequence of nine consecutive days characterized by rainfall and storms. As a result, the correlation coefficient (r) measuring the impact of wind speed on the natural dispersion of air pollution within the Ekspozita Complex was calculated to be 0.3. This value indicates a moderate correlation between wind speed and pollutant dispersion. However, when the analysis is refined to exclude the data collected during the nine days of rain, the correlation coefficient rises to 0.56. This adjusted figure suggests a stronger correlation, emphasizing the significant role of wind in dispersing pollutants under dry weather conditions.

It's important to note that the prevailing wind directions in the area are from the Northwest, and the architectural layout of the Ekspozita Complex, with its extensive wind tunnels, is designed to facilitate air flow. Despite this, the findings do not suggest that these features lead to the creation of vortex effects that might trap pollutants. Instead, the elevated levels of pollutants observed at Monitoring Points 3 and 5 can be attributed to their proximity to a construction site adjacent to the monitoring area. This association highlights the influence of local activities and the urban environment on air quality, underscoring the complexity of factors that contribute to pollution levels in urban settings.

Furthermore, even the urban modifications within the study area that are ground-level structures, each extending to a height of approximately 2.5 to 3 meters did not generate any indication that there was a vortex effect and contribute to the formation of air pollution cavity areas. This conclusion is rather preliminary given the meteorological patterns during January.

Table 57: Number of days indicating the orientation of the wind during January at Ekspozita.

N	S	W	E	NW	NE	SE	SW
1	0	0	22	0	2	6	0
3%	0%	0%	71%	0%	6%	19%	0%

Source: Author

Coming to the conclusion that the urban form of Ekspozita eases even the vortex effect and Air Pollution Cavity Area created by the occurrence of Eastern winds (which during January account for 71% of the total wind direction patterns during January).

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Finally, also to Ish-Ekspozita, February offered the most favorable conditions for monitoring within the scope of this study. The month was characterized by predominantly clear weather, with light rain only recorded on the 26th and 27th. Consequently, a significant 93% of the monitoring data from this period demonstrates a direct correlation between wind activity and the dispersion of air pollutants within the Ish-Ekspozita study area. This high percentage of correlation underscores the effectiveness of wind in mitigating air pollution levels, serving as a natural ventilation mechanism within this particular urban block.

This observation not only highlights the pivotal role of wind in air quality management but also prompts a deeper analysis into the architectural and urban planning aspects of the Ish-Ekspozita urban form. Specifically, it raises questions about how the design and orientation of buildings within the complex facilitate or hinder the natural flow of air and, by extension, the dispersal of pollutants. The favorable monitoring results from February provide a unique opportunity to evaluate the efficiency of natural ventilation strategies employed in the complex and their impact on enhancing urban air quality.

Table 58: Number of days with sun, cloud and rain during February at Ekspozita complex.

Sun	Cloudy	Rain
18	8	2
64%	29%	7%

Source: Author

In contrast to January, the wind direction monitoring conducted in February revealed a more evenly distributed range of prevailing directions, with east winds most frequently dominating the observed patterns during the monitoring timeframe from 17:00 to 20:00. This variability underscores the influence of larger-scale climatic patterns affecting Tirana and the Western Plain of Albania, which can lead to shifts in wind direction.

This observation highlights the dynamic nature of wind behavior and its critical role in air pollution dispersion within urban environments. The variability in wind direction, particularly the predominance of east winds during the evening hours, suggests that urban planning and pollution management strategies need to be adaptable to these changing environmental conditions. The fluctuating wind directions observed in February, differing significantly from the patterns noted in January, indicate that wind's effectiveness in dispersing pollutants can vary substantially over time, influenced by broader meteorological trends.

Table 59: Number of days indicating the orientation of the wind during February at Ekspozita.

N	S	W	E	NW	NE	SE	SW
5	1	0	13	0	6	3	0
18%	4%	0%	46%	0%	21%	11%	0%

Source: Author

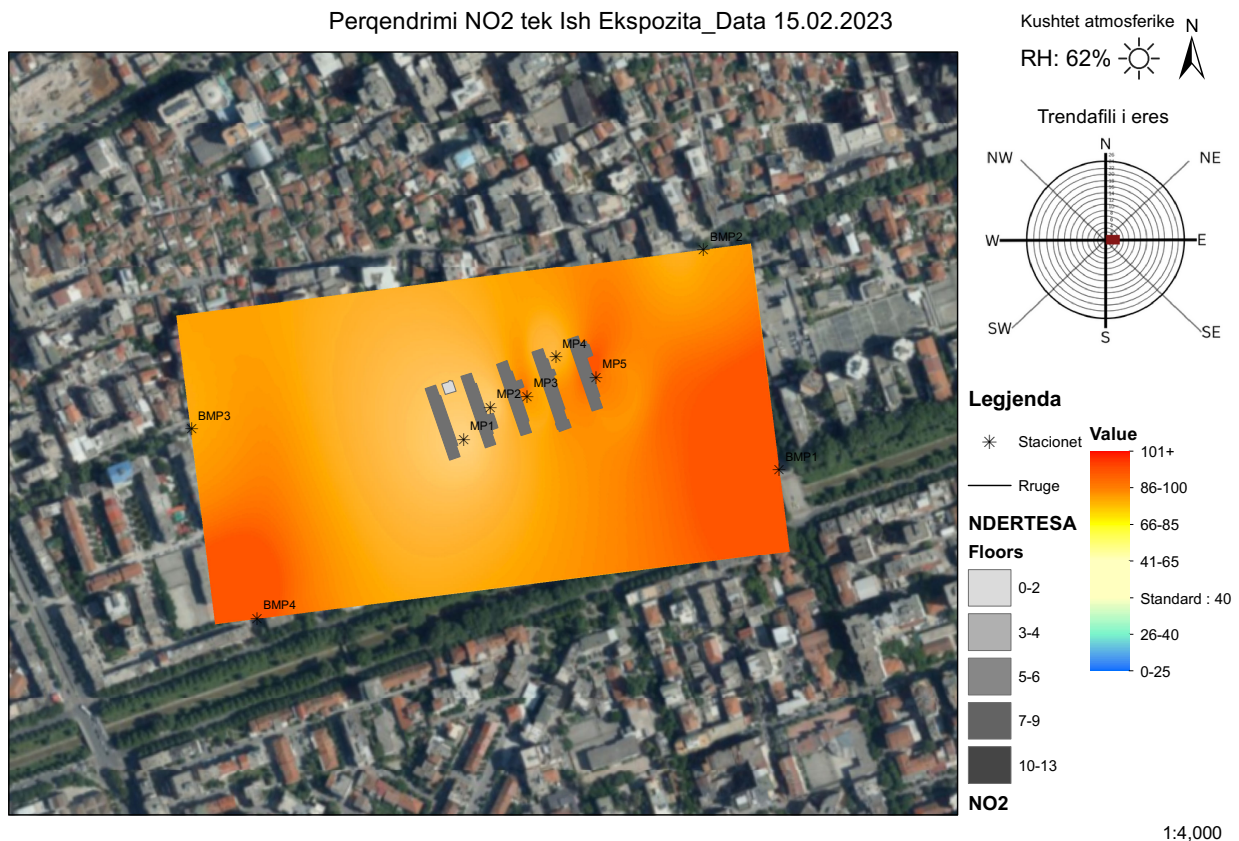
Table 60: NO₂ concentrations and meteorological observations during February 2023 / Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. NO ₂ CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	51	49	53	51	55	62	60	53	66	51,8	4,4	E	65%	Clear	2hrs 17.00-19.40
2	55	56	59	57	61	71	67	58	74	57,6	1,7	N	82%	Cloudy	2hrs 17.00-19.40
3	57	59	62	58	64	73	75	61	77	60,0	3,6	E	65%	Cloudy	2hrs 17.00-19.40
4	54	56	59	55	59	68	65	57	69	56,6	10,2	N	85%	Cloudy	2hrs 17.00-19.40
5	57	58	64	56	63	70	70	60	71	59,6	6,5	N	55%	Clear	2hrs 17.00-19.40
6	61	60	66	61	67	72	69	64	70	63,0	5,0	NE	47%	Clear	2hrs 17.00-19.40
7	62	60	67	60	69	74	72	65	71	63,6	8,3	NE	40%	Clear	2hrs 17.00-19.40
8	60	61	65	58	68	75	73	62	76	62,4	9,7	E	35%	Clear	2hrs 17.00-19.40
9	63	65	70	66	71	77	77	67	81	67,0	5,1	E	47%	Cloudy	2hrs 17.00-19.40
10	66	68	73	69	75	80	79	70	80	70,2	4,2	E	63%	Clear	2hrs 17.00-19.40
11	68	71	75	68	78	82	79	75	80	72,0	5,8	NE	66%	Clear	2hrs 17.00-19.40
12	67	70	73	66	75	83	79	74	85	70,2	7,9	E	58%	Clear	2hrs 17.00-19.40
13	72	74	77	72	81	89	82	75	84	75,2	8,1	N	73%	Clear	2hrs 17.00-19.40
14	77	76	83	78	86	92	88	82	90	80,0	14,3	E	77%	Clear	2hrs 17.00-19.40
15	84	85	92	88	95	100	89	89	97	88,8	2,9	E	62%	Clear	2hrs 17.00-19.40
16	88	89	96	91	100	107	92	93	100	92,8	4,0	E	81%	Clear	2hrs 17.00-19.40
17	91	90	99	92	104	108	91	95	105	95,2	5,3	NE	88%	Clear	2hrs 17.00-19.40
18	99	100	105	98	112	117	100	103	118	102,8	2,5	E	83%	Cloudy	2hrs 17.00-19.40
19	102	101	110	99	117	126	119	106	125	105,8	5,0	E	90%	Cloudy	2hrs 17.00-19.40
20	107	105	113	105	124	129	121	111	131	110,8	5,4	N	85%	Cloudy	2hrs 17.00-19.40
21	110	109	120	111	129	133	124	117	132	115,8	3,6	E	89%	Clear	2hrs 17.00-19.40
22	116	115	129	118	136	142	129	123	138	122,8	2,9	NE	87%	Clear	2hrs 17.00-19.40
23	119	120	132	120	141	148	137	127	144	126,4	14,7	NE	93%	Clear	2hrs 17.00-19.40
24	122	125	131	123	145	150	141	132	145	129,2	5,5	SE	82%	Clear	2hrs 17.00-19.40
25	116	116	124	117	133	141	135	128	133	121,2	13,3	SE	50%	Cloudy	2hrs 17.00-19.40
26	62	60	69	63	73	77	69	68	72	65,4	14,0	S	90%	Rain	2hrs 17.00-19.40
27	29	31	35	33	40	43	38	34	45	33,6	12,2	SE	74%	Rain	2hrs 17.00-19.40
28	38	37	42	40	47	55	51	49	58	40,8	9,1	E	59%	Clear	2hrs 17.00-19.40
TOT	76,9	77,4	83,7	77,6	88,1	94,4	88,3	82,1	93,5	80,7	6,2				

Source: Author

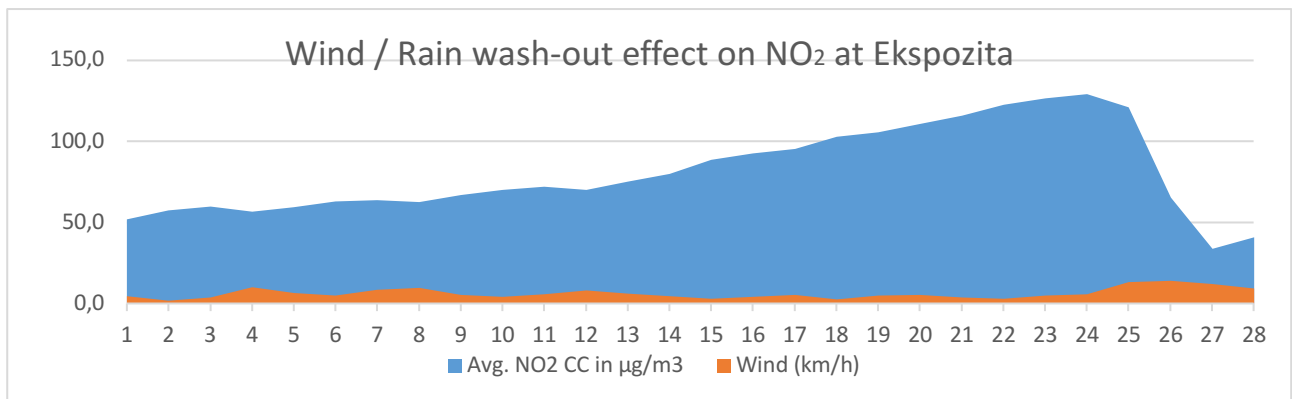
Figure 91: Sample from the dispersal of NO₂ sequence at Ekspozita (15.02.2023)

Perqendrimi NO₂ tek Ish Ekspozita_Data 15.02.2023



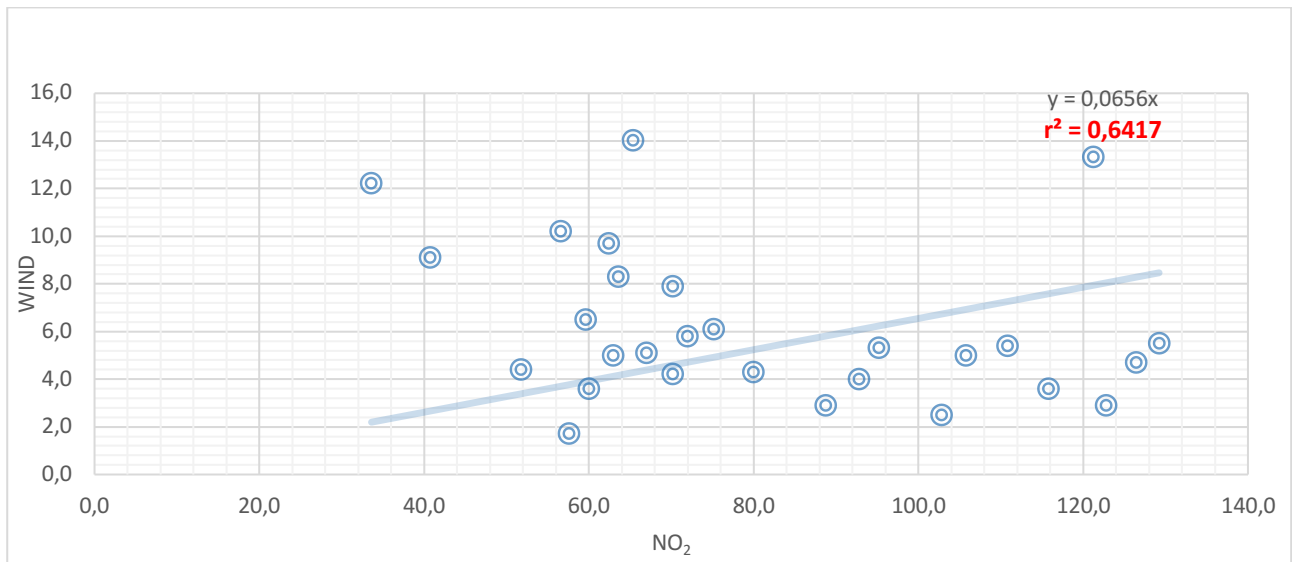
Source: Author

Graphic 65: Effect of wind and rain on the wash-out of NO₂ concentration at Ekspozita during February 2023.



Source: Author

Graphic 66: Correlation factor between concentration of NO₂ and Wind speed during January at Ekspozita.



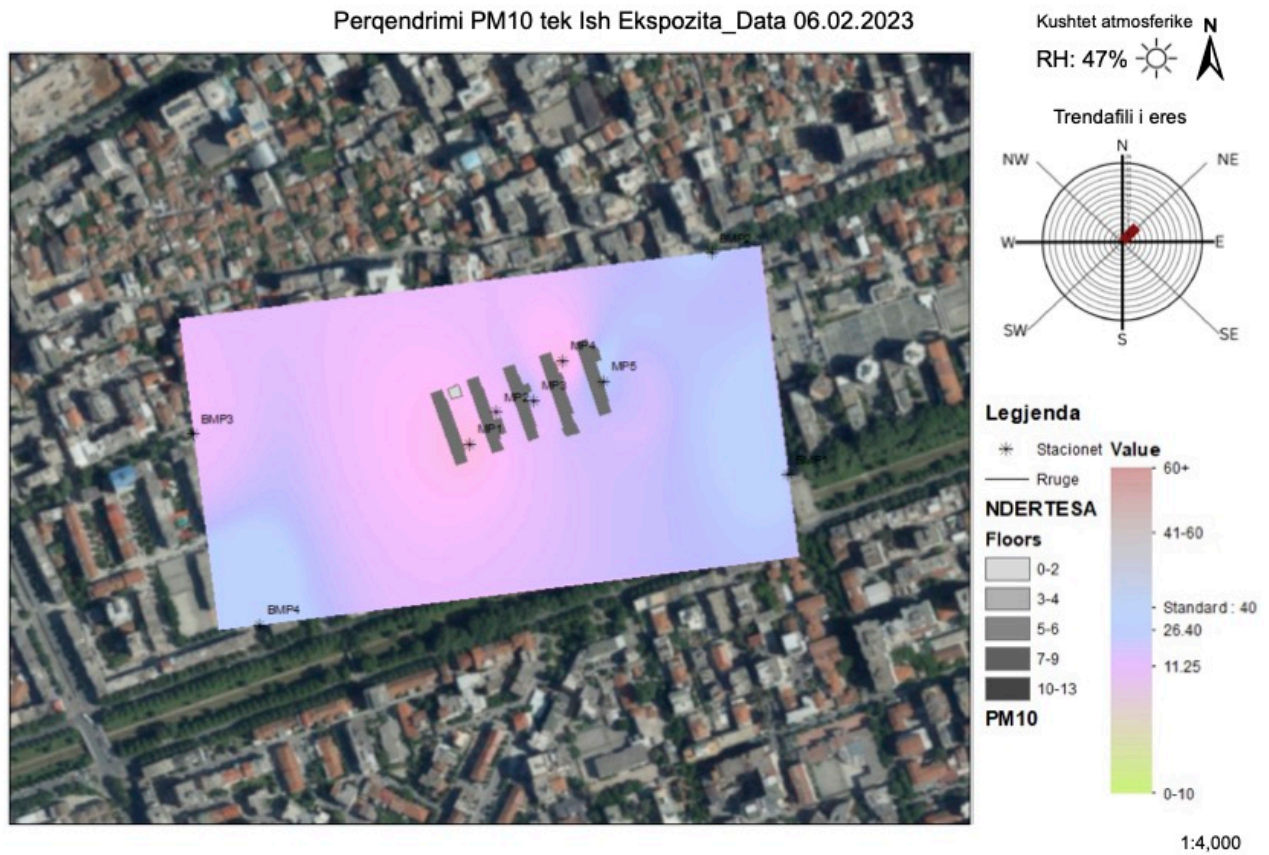
Source: Author

Table 61: PM₁₀ concentrations and meteorological observations during February 2023 / Ekspozita

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	16,0	15,0	18,0	16,0	19,0	22,0	20,0	16,0	21,0	16,8	4,4	E	65%	Clear	2hrs 17:00-19:40
2	18,0	17,0	20,0	18,0	23,0	24,0	21,0	20,0	25,0	19,2	1,7	N	82%	Cloudy	2hrs 17:00-19:40
3	19,0	19,0	21,0	19,0	24,0	26,0	24,0	21,0	26,0	20,4	3,6	E	65%	Cloudy	2hrs 17:00-19:40
4	15,0	17,0	19,0	16,0	24,0	23,0	26,0	19,0	25,0	18,2	10,2	N	85%	Cloudy	2hrs 17:00-19:40
5	18,0	19,0	22,0	18,0	25,0	27,0	25,0	21,0	28,0	20,4	6,5	N	55%	Clear	2hrs 17:00-19:40
6	18,0	21,0	24,0	19,0	27,0	26,0	25,0	21,0	29,0	21,8	5,0	NE	47%	Clear	2hrs 17:00-19:40
7	16,0	19,0	22,0	18,0	25,0	25,0	24,0	23,0	25,0	20,0	8,3	NE	40%	Clear	2hrs 17:00-19:40
8	17,0	17,0	21,0	19,0	24,0	26,0	23,0	24,0	28,0	19,6	9,7	E	35%	Clear	2hrs 17:00-19:40
9	19,0	18,0	23,0	21,0	26,0	28,0	27,0	26,0	31,0	21,4	5,1	E	47%	Cloudy	2hrs 17:00-19:40
10	22,0	24,0	27,0	23,0	30,0	32,0	30,0	27,0	30,0	25,2	4,2	E	63%	Clear	2hrs 17:00-19:40
11	23,0	23,0	29,0	21,0	32,0	33,0	31,0	26,0	34,0	25,6	5,8	NE	66%	Clear	2hrs 17:00-19:40
12	21,0	22,0	26,0	21,0	27,0	32,0	33,0	22,0	33,0	23,4	7,9	E	58%	Clear	2hrs 17:00-19:40
13	22,0	21,0	25,0	22,0	26,0	31,0	29,0	24,0	30,0	23,2	6,1	N	73%	Clear	2hrs 17:00-19:40
14	23,0	22,0	27,0	23,0	29,0	32,0	33,0	25,0	33,0	24,8	4,3	E	77%	Clear	2hrs 17:00-19:40
15	25,0	26,0	28,0	26,0	33,0	36,0	32,0	29,0	34,0	27,6	2,9	E	62%	Clear	2hrs 17:00-19:40
16	27,0	28,0	31,0	26,0	35,0	37,0	33,0	30,0	39,0	29,4	4,0	E	81%	Clear	2hrs 17:00-19:40
17	28,0	28,0	32,0	29,0	36,0	36,0	34,0	31,0	39,0	30,6	5,3	NE	88%	Clear	2hrs 17:00-19:40
18	33,0	32,0	35,0	31,0	40,0	40,0	38,0	36,0	43,0	34,2	2,5	E	83%	Cloudy	2hrs 17:00-19:40
19	34,0	35,0	38,0	33,0	43,0	42,0	41,0	39,0	45,0	36,6	5,0	E	90%	Cloudy	2hrs 17:00-19:40
20	35,0	34,0	38,0	34,0	46,0	47,0	44,0	41,0	46,0	37,4	5,4	N	85%	Cloudy	2hrs 17:00-19:40
21	36,0	37,0	41,0	36,0	50,0	50,0	47,0	42,0	49,0	40,0	3,6	E	89%	Clear	2hrs 17:00-19:40
22	39,0	40,0	44,0	39,0	54,0	52,0	50,0	43,0	55,0	43,2	2,9	NE	87%	Clear	2hrs 17:00-19:40
23	38,0	41,0	45,0	40,0	57,0	56,0	52,0	46,0	53,0	44,2	4,7	NE	93%	Clear	2hrs 17:00-19:40
24	37,0	39,0	43,0	38,0	56,0	57,0	50,0	45,0	55,0	42,6	5,5	SE	82%	Clear	2hrs 17:00-19:40
25	35,0	36,0	40,0	34,0	47,0	49,0	45,0	38,0	47,0	38,4	13,3	SE	50%	Cloudy	2hrs 17:00-19:40
26	11,0	10,0	9,0	12,0	15,0	16,0	13,0	11,0	17,0	11,4	14,0	S	90%	Rain	2hrs 17:00-19:40
27	2,0	2,0	3,0	4,0	6,0	11,0	8,0	4,0	9,0	3,4	12,2	SE	74%	Rain	2hrs 17:00-19:40
28	9,0	10,0	13,0	9,0	13,0	18,0	17,0	14,0	18,0	10,8	9,1	E	59%	Clear	2hrs 17:00-19:40
TOT	23,4	24,0	27,3	23,8	31,9	33,4	31,3	27,3	33,8	26,1	6,2				

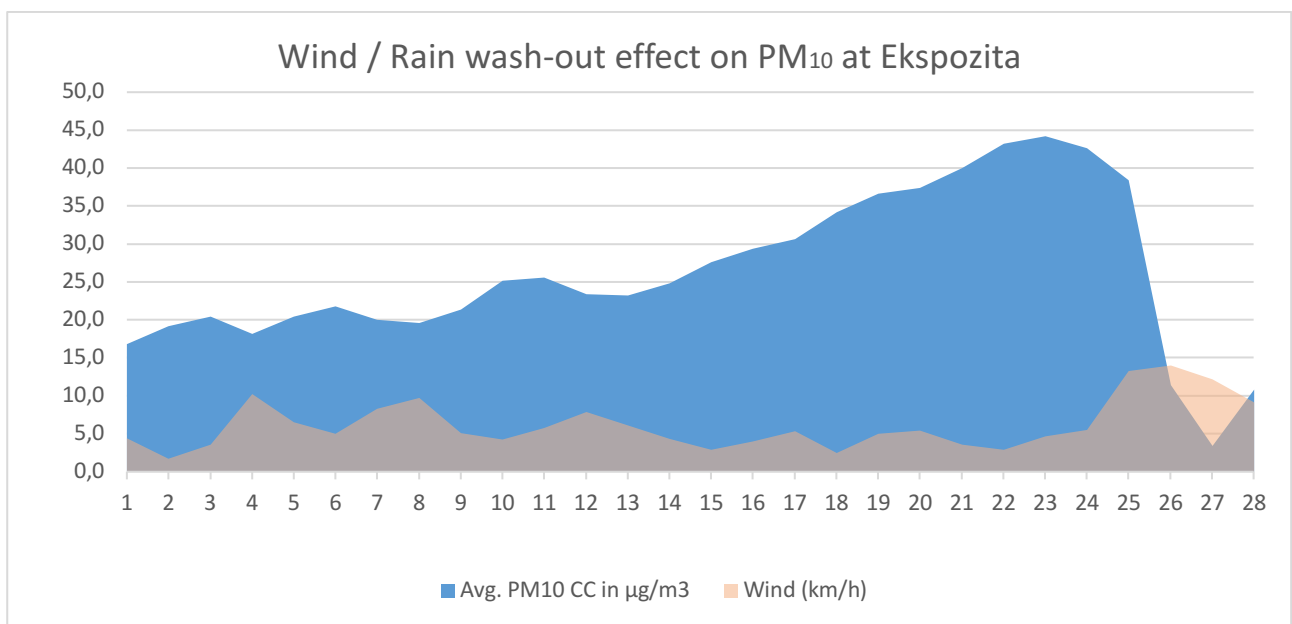
Source: Author

Figure 92: Sample from the dispersal of PM₁₀ sequence at Ekspozita (06.02.2023)



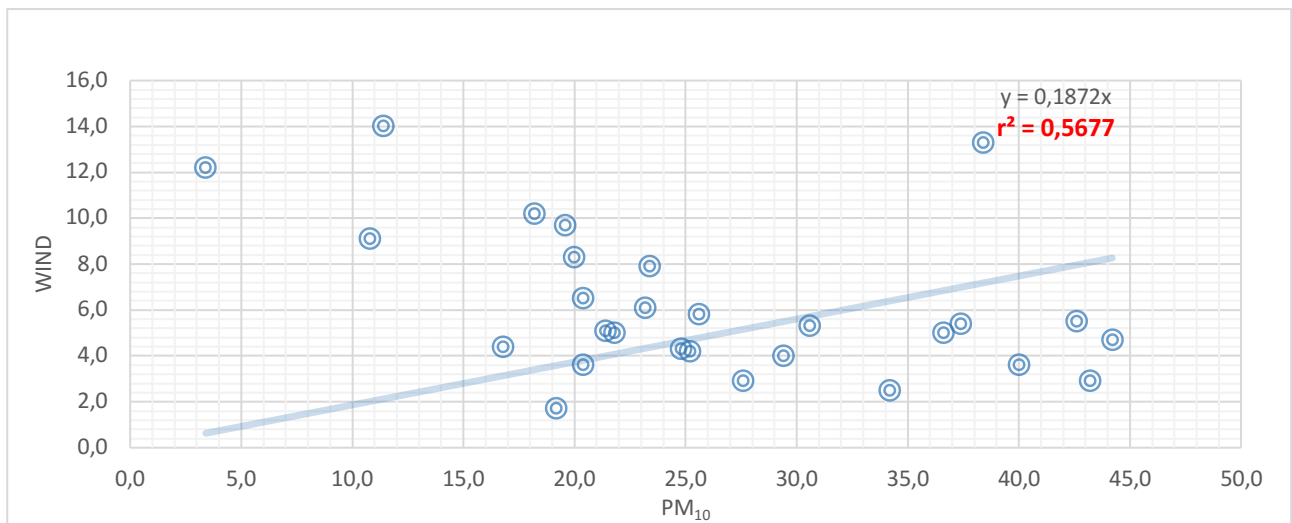
Source: Author

Graphic 67: Effect of wind and rain on the wash-out of PM₁₀ concentration at Ekspozita during February 2023.



Source: Author

Graphic 68: Correlation factor between concentration of PM₁₀ and Wind speed during February at Ekspozita.



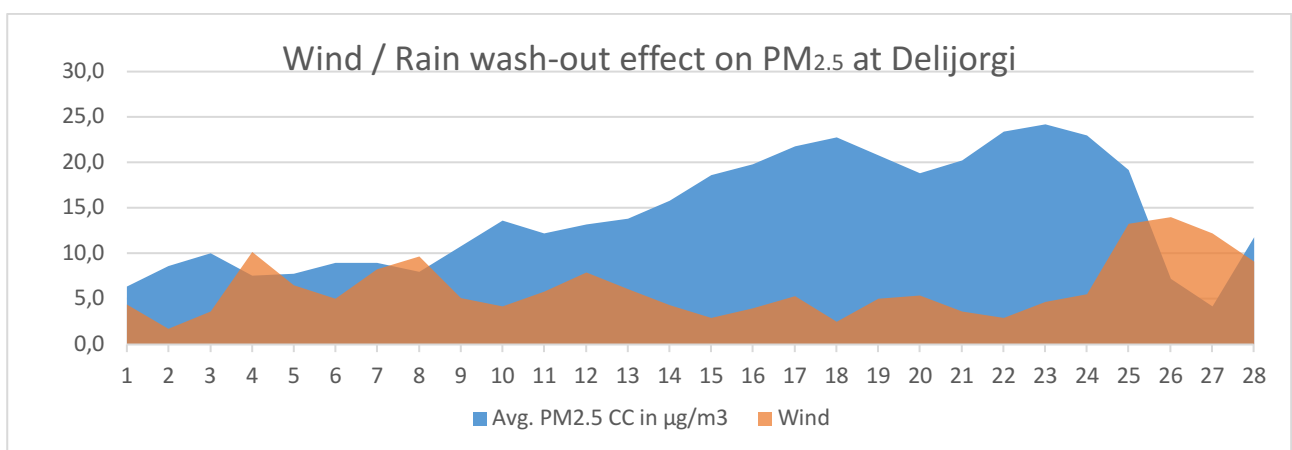
Source: Author

Table 62: PM_{2.5} concentrations and meteorological observations during February 2023 / Ekspozita

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. PM2.5 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	5,0	6,0	7,0	6,0	8,0	12,00	12,00	10,00	14,00	6,4	4,4	E	65%	Clear	2hrs 17.00-19.40
2	8,0	8,0	9,0	8,0	10,0	16,00	14,00	11,00	15,00	8,6	1,7	N	82%	Cloudy	2hrs 17.00-19.40
3	8,0	10,0	11,0	9,0	12,0	18,00	15,00	13,00	21,00	10,0	3,6	E	65%	Cloudy	2hrs 17.00-19.40
4	7,0	6,0	8,0	8,0	9,0	14,00	13,00	12,00	17,00	7,6	10,2	N	85%	Cloudy	2hrs 17.00-19.40
5	7,0	7,0	8,0	7,0	10,0	14,00	15,00	12,00	18,00	7,8	6,5	N	55%	Clear	2hrs 17.00-19.40
6	8,0	8,0	10,0	8,0	11,0	15,00	13,00	10,00	17,00	9,0	5,0	NE	47%	Clear	2hrs 17.00-19.40
7	7,0	9,0	11,0	8,0	10,0	16,00	13,00	11,00	15,00	9,0	8,3	NE	40%	Clear	2hrs 17.00-19.40
8	7,0	6,0	8,0	8,0	11,0	18,00	15,00	14,00	16,00	8,0	9,7	E	35%	Clear	2hrs 17.00-19.40
9	10,0	9,0	12,0	10,0	13,0	19,00	17,00	15,00	20,00	10,8	5,1	E	47%	Cloudy	2hrs 17.00-19.40
10	12,0	12,0	15,0	13,0	16,0	21,00	22,00	17,00	22,00	13,6	4,2	E	63%	Clear	2hrs 17.00-19.40
11	11,0	10,0	13,0	12,0	15,0	21,00	17,00	15,00	19,00	12,2	5,8	NE	66%	Clear	2hrs 17.00-19.40
12	12,0	11,0	14,0	13,0	16,0	19,00	19,00	23,00	22,00	13,2	7,9	E	58%	Clear	2hrs 17.00-19.40
13	14,0	10,0	15,0	13,0	17,0	19,00	16,00	19,00	20,00	13,8	6,1	N	73%	Clear	2hrs 17.00-19.40
14	14,0	13,0	17,0	15,0	20,0	23,00	22,00	21,00	25,00	15,8	14,3	E	77%	Clear	2hrs 17.00-19.40
15	18,0	17,0	22,0	16,0	20,0	25,00	23,00	20,00	23,00	18,6	2,9	E	62%	Clear	2hrs 17.00-19.40
16	18,0	19,0	23,0	18,0	21,0	27,00	25,00	21,00	27,00	19,8	4,0	E	81%	Clear	2hrs 17.00-19.40
17	19,0	21,0	25,0	20,0	24,0	31,00	32,00	28,00	30,00	21,8	5,3	NE	88%	Clear	2hrs 17.00-19.40
18	20,0	20,0	26,0	21,0	27,0	30,00	33,00	26,00	35,00	22,8	2,5	E	83%	Cloudy	2hrs 17.00-19.40
19	19,0	17,0	23,0	20,0	25,0	29,00	27,00	25,00	33,00	20,8	5,0	E	90%	Cloudy	2hrs 17.00-19.40
20	17,0	15,0	21,0	18,0	23,0	31,00	25,00	24,00	29,00	18,8	5,4	N	85%	Cloudy	2hrs 17.00-19.40
21	18,0	19,0	22,0	17,0	25,0	33,00	28,00	29,00	35,00	20,2	3,6	E	89%	Clear	2hrs 17.00-19.40
22	21,0	21,0	25,0	22,0	28,0	36,00	32,00	32,00	37,00	23,4	2,9	NE	87%	Clear	2hrs 17.00-19.40
23	22,0	21,0	28,0	20,0	30,0	35,00	30,00	26,00	33,00	24,2	14,7	NE	93%	Clear	2hrs 17.00-19.40
24	22,0	20,0	24,0	21,0	28,0	34,00	33,00	29,00	39,00	23,0	5,5	SE	82%	Clear	2hrs 17.00-19.40
25	18,0	17,0	21,0	15,0	25,0	29,00	31,00	30,00	34,00	19,2	13,3	SE	50%	Cloudy	2hrs 17.00-19.40
26	7,0	5,0	8,0	5,0	11,0	11,00	13,00	8,00	13,00	7,2	14,0	S	90%	Rain	2hrs 17.00-19.40
27	2,0	4,0	4,0	4,0	7,0	9,00	8,00	10,00	8,00	4,2	12,2	SE	74%	Rain	2hrs 17.00-19.40
28	11,0	10,0	12,0	11,0	15,0	16,00	15,00	18,00	19,00	11,8	9,1	E	59%	Clear	2hrs 17.00-19.40
TOT	12,9	12,5	15,8	13,1	17,4	22,2	20,6	18,9	23,4	14,3	6,2				

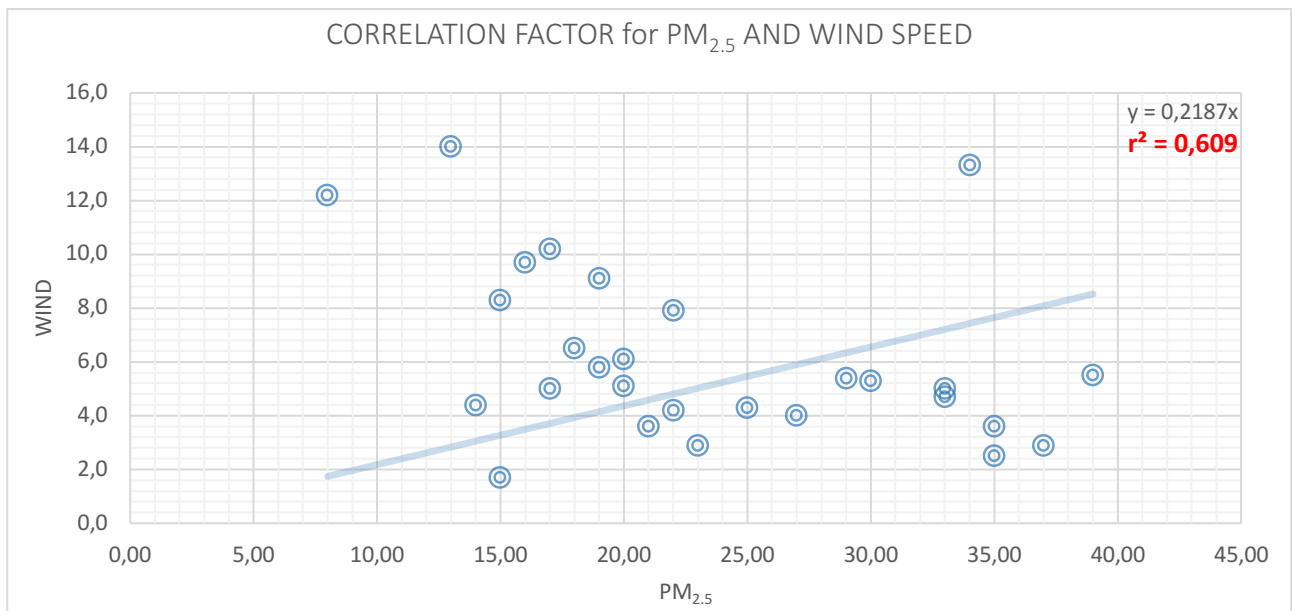
Source: Author

Graphic 69: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Ekspozita during February 2023.



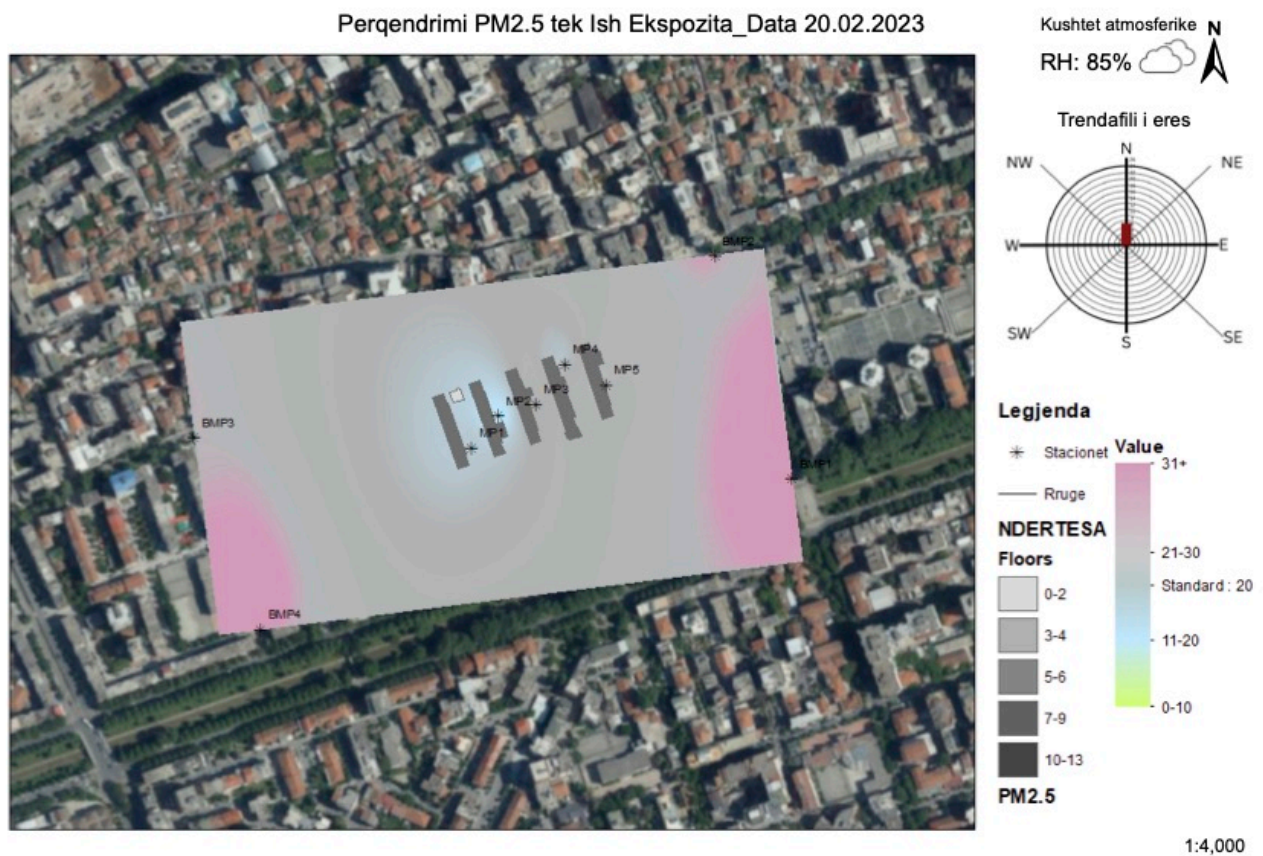
Source: Author

Graphic 70: Correlation factor between concentration of PM_{2.5} and Wind speed during February at Ekspozita



Source: Author

Figure 93: Sample from the dispersal of PM_{2.5} sequence at Ekspozita (20.02.2023)



Source: Author

Since in February, a notable 96% of the period was marked by dry conditions, leading to a significant finding: the correlation coefficient (r) measuring the impact of wind speed on air pollution

dispersion within the Ekspozita stood at 0.61. This figure robustly suggests a strong relationship between wind velocity and the natural scattering of pollutants in the area, underscoring the efficacy of wind in mitigating air quality issues under dry weather scenarios.

However, despite a more variable wind direction during February compared to January, there was no definitive evidence to suggest the formation of an Air Pollution Cavity Area within the Ekspozita complex attributable to its urban layout. This observation is critical, indicating that variations in wind patterns alone, even when coupled with prolonged dry spells, do not necessarily exacerbate pollution levels within an urban block.

However, Monitoring Points 2 and 3, which were deliberately located near the sole two urban modifications in the study area to evaluate their impact on creating minor vortexes and subsequent air pollution cavity areas, showed that only MP3 demonstrated such an effect. There was a modest 3% increase in pollution levels at MP3 compared to the overall area average, though it did not rank as the most polluted spot. This finding suggests that even small alterations, like ground-level extensions to existing buildings, can indeed play a role in the formation of Air Pollution Cavity Areas (APCA). The reason MP3 exhibited this effect, while MP2 did not, despite both being extensions, can be attributed to the nature of the modifications. The modification at MP2 is a lightweight structure serving as a coffee bar, featuring a retractable terrace and slender beams supporting removable glass walls, which likely had less impact on wind flow and pollutant distribution.

Further analysis reveals that elevated pollution readings at Monitoring Point 5 (MP5), compared to other monitoring points, may be closely associated with the fact that it is frequently used as a connection between Gjergj Fishta Blv. and Myslym Shyri.

EKSPOZITA _ MARCH 2023:

In March, there was a notable occurrence of intriguing meteorological patterns captured within a 12-hour time-lapse. For example, the morning monitoring sessions observed heavy rainfall, which later ceased. While previous locations experienced rainy conditions for 10 days, Ekspozita observed such conditions during the afternoon for only 4 days. Considering that the initial two weeks of the month were characterized by predominantly cloudy or rainy weather across the city, there was a discernible effect of pollution washout.

This phenomenon significantly reduced the levels of nitrogen oxides (NOx) and particulate matter (PM) to within the European Union's limits—a rarity for Tirana. Such reduction in pollutant concentrations across the area enabled the research to examine scenarios where pollution accumulated from February decreased considerably, followed by a subsequent build-up in the latter half of the month. Analyzing the temporal dynamics of pollution concentration build-up is essential for identifying the onset or initial phases of pollution retention phenomena under specific meteorological conditions. Moreover, the urban structure and location of Ekspozita rank it among the city's most naturally ventilated areas. Hence, the occurrence of Air Pollution Concentration Accumulation (APCA) is deemed highly improbable, except for the MP3 indicator, which previously indicated an increase by 3% in pollution concentration during February and a 4% increase in January, this in comparison to the study area overall average.

Table 63: Number of days with sun, cloud and rain during March at Ekspozita.

Rain	Cloud	Clear
4	10	17
13%	32%	55%

Source: Author

The wind patterns at this particular location exhibit a significant degree of variability and are substantially influenced by the urban form of Tirana at ground level. To the north of the study area, the residential buildings along Myslym Shyri street feature unique openings that facilitate the penetration of winds from the Northeast and Northwest into our study areas. To the south, the study area is bordered by three major arteries descending from Blloku, Komuna Parisit, and Tirana Re. Meanwhile, the East-to-West main corridor is interconnected with the Lana River, which acts as the primary wind canyon for Tirana.

While the urban form and positioning of Ekspozita buildings may be perceived as beneficial due to its natural ventilation capabilities and inherent pollution dispersion properties, it is also necessary to acknowledge that well-ventilated areas may be more susceptible to increased exposure due to emissions from surrounding regions being funneled into and out of the area.

Table 64: Number of days indicating the orientation of the wind during March at Ekspozita Complex

N	S	W	E	NW	NE	SE	SW
9	3	1	4	1	7	4	2
29%	10%	3%	13%	3%	23%	13%	6%

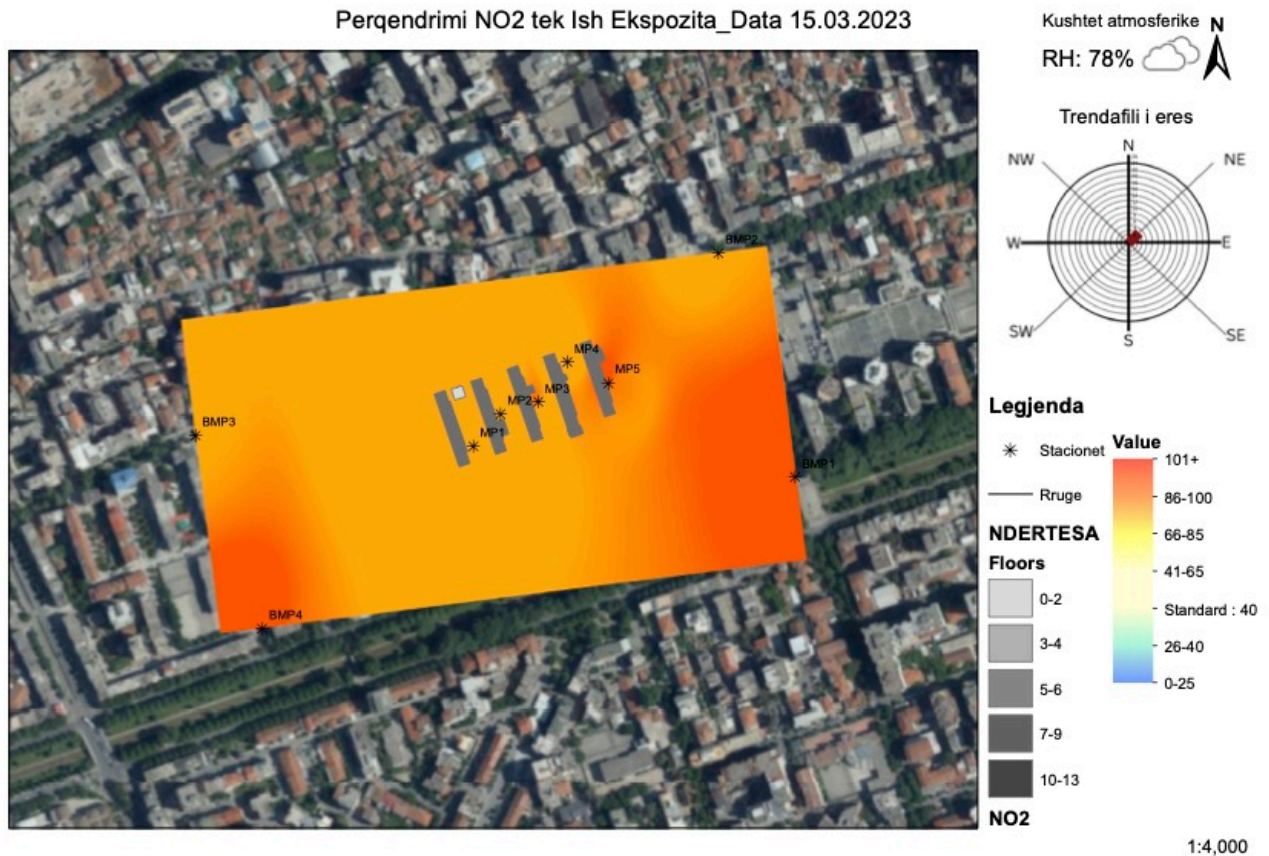
Source: Author

Table 65: NO₂ concentrations and meteorological observations during March 2023 / Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BM2	BMP3	BM4	Avg. NO ₂ CC in µg/m ³	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	24,0	26,0	27,0	25,0	26,0	32,00	29,00	27,00	31,00	25,6	8,5	E	91%	Rainy	2hrs 17.00-19.40
2	31,0	34,0	35,0	33,0	36,0	39,00	38,00	33,00	40,00	33,8	4,0	NE	84%	Cloudy	2hrs 17.00-19.40
3	35,0	35,0	38,0	36,0	39,0	42,00	41,00	40,00	45,00	36,6	3,6	E	88%	Cloudy	2hrs 17.00-19.40
4	37,0	37,0	39,0	38,0	42,0	44,00	41,00	38,00	46,00	38,6	4,5	NE	91%	Cloudy	2hrs 17.00-19.40
5	42,0	44,0	46,0	44,0	48,0	52,00	48,00	41,00	51,00	44,8	3,6	N	85%	Clear	2hrs 17.00-19.40
6	43,0	45,0	47,0	42,0	47,0	50,00	51,00	45,00	52,00	44,8	6,5	E	82%	Cloudy	2hrs 17.00-19.40
7	46,0	48,0	50,0	47,0	48,0	51,00	50,00	46,00	53,00	47,8	3,2	NE	83%	Clear	2hrs 17.00-19.40
8	47,0	48,0	50,0	48,0	51,0	54,00	52,00	48,00	53,00	48,8	5,0	SE	73%	Cloudy	2hrs 17.00-19.40
9	48,0	48,0	51,0	47,0	52,0	55,00	57,00	51,00	54,00	49,2	3,4	SE	77%	Cloudy	2hrs 17.00-19.40
10	25,0	28,0	24,0	26,0	29,0	31,00	28,00	27,00	29,00	26,4	16,2	S	91%	Rainy	2hrs 17.00-19.40
11	15,0	14,0	16,0	15,0	17,0	21,00	22,00	19,00	18,00	15,4	4,0	E	90%	Rainy	2hrs 17.00-19.40
12	23,0	22,0	24,0	25,0	22,0	26,00	23,00	20,00	25,00	23,2	6,1	N	49%	Clear	2hrs 17.00-19.40
13	27,0	28,0	29,0	27,0	28,0	32,00	30,00	27,00	34,00	27,8	2,9	NE	63%	Clear	2hrs 17.00-19.40
14	32,0	33,0	35,0	34,0	33,0	39,00	41,00	35,00	37,00	33,4	4,0	SE	59%	Cloudy	2hrs 17.00-19.40
15	40,0	42,0	44,0	40,0	46,0	48,00	50,00	46,00	53,00	42,4	2,5	NE	78%	Cloudy	2hrs 17.00-19.40
16	39,0	42,0	42,0	42,0	48,0	53,00	52,00	45,00	56,00	42,6	8,3	N	46%	Clear	2hrs 17.00-19.40
17	46,0	47,0	51,0	49,0	52,0	57,00	52,00	49,00	53,00	49,0	1,8	W	66%	Clear	2hrs 17.00-19.40
18	50,0	52,0	56,0	52,0	55,0	62,00	64,00	60,00	67,00	53,0	4,7	N	74%	Clear	2hrs 17.00-19.40
19	52,0	53,0	55,0	53,0	58,0	66,00	65,00	63,00	69,00	54,2	3,3	NE	84%	Clear	2hrs 17.00-19.40
20	54,0	54,0	58,0	55,0	60,0	74,00	72,00	69,00	75,00	56,2	2,1	N	89%	Cloudy	2hrs 17.00-19.40
21	38,0	35,0	40,0	36,0	41,0	47,00	48,00	41,00	46,00	38,0	2,9	N	91%	Cloudy	2hrs 17.00-19.40
22	40,0	42,0	44,0	42,0	43,0	55,00	51,00	48,00	53,00	42,2	0,7	SW	78%	Clear	2hrs 17.00-19.40
23	42,0	43,0	47,0	44,0	48,0	61,00	62,00	60,00	66,00	44,8	4,7	N	80%	Clear	2hrs 17.00-19.40
24	46,0	45,0	50,0	45,0	49,0	68,00	66,00	63,00	73,00	47,0	3,6	NE	77%	Clear	2hrs 17.00-19.40
25	48,0	49,0	52,0	48,0	55,0	69,00	68,00	66,00	72,00	50,4	4,3	SE	80%	Clear	2hrs 17.00-19.40
26	50,0	49,0	54,0	51,0	54,0	77,00	74,00	71,00	75,00	51,6	5,0	S	73%	Clear	2hrs 17.00-19.40
27	29,0	30,0	32,0	30,0	33,0	37,00	35,00	29,00	31,00	30,8	7,6	SW	91%	Rainy	2hrs 17.00-19.40
28	31,0	32,0	31,0	32,0	34,0	36,00	37,00	31,00	35,00	32,0	11,5	NW	32%	Clear	2hrs 17.00-19.40
29	38,0	37,0	41,0	39,0	44,0	52,00	50,00	48,00	55,00	39,8	3,6	S	44%	Clear	2hrs 17.00-19.40
30	38,0	38,0	43,0	40,0	46,0	57,00	54,00	51,00	59,00	41,0	4,2	N	76%	Clear	2hrs 17.00-19.40
31	39,0	38,0	45,0	42,0	45,0	62,00	66,00	57,00	68,00	41,8	6,3	N	77%	Clear	2hrs 17.00-19.40
TOT	39,5	40,1	42,7	40,5	43,9	51,3	50,3	46,2	52,1	40,4	5,0				

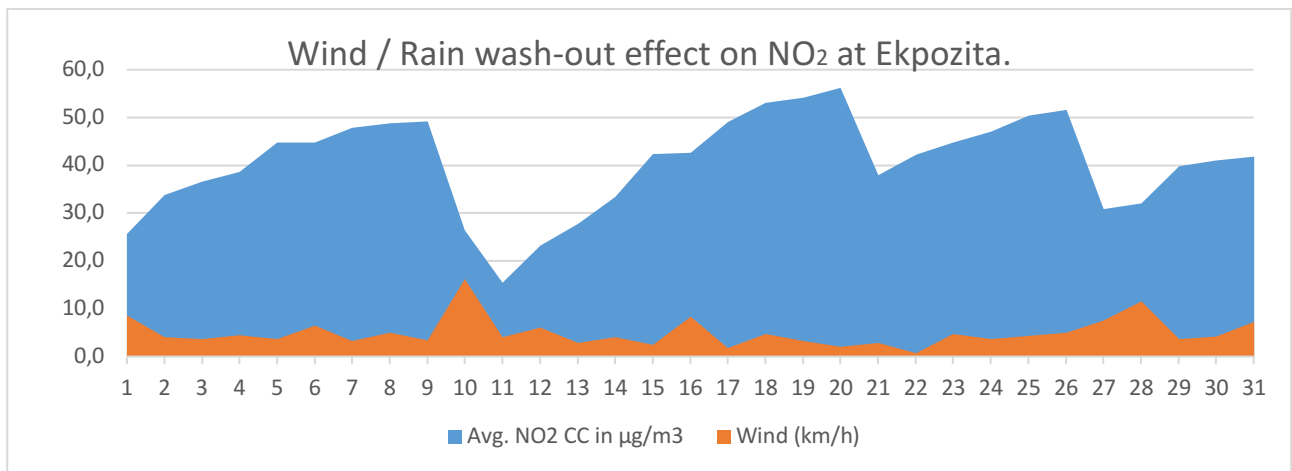
Source: Author

Figure 94: Sample from the dispersal of PM_{2.5} sequence at Ekspozita (15.03.2023)



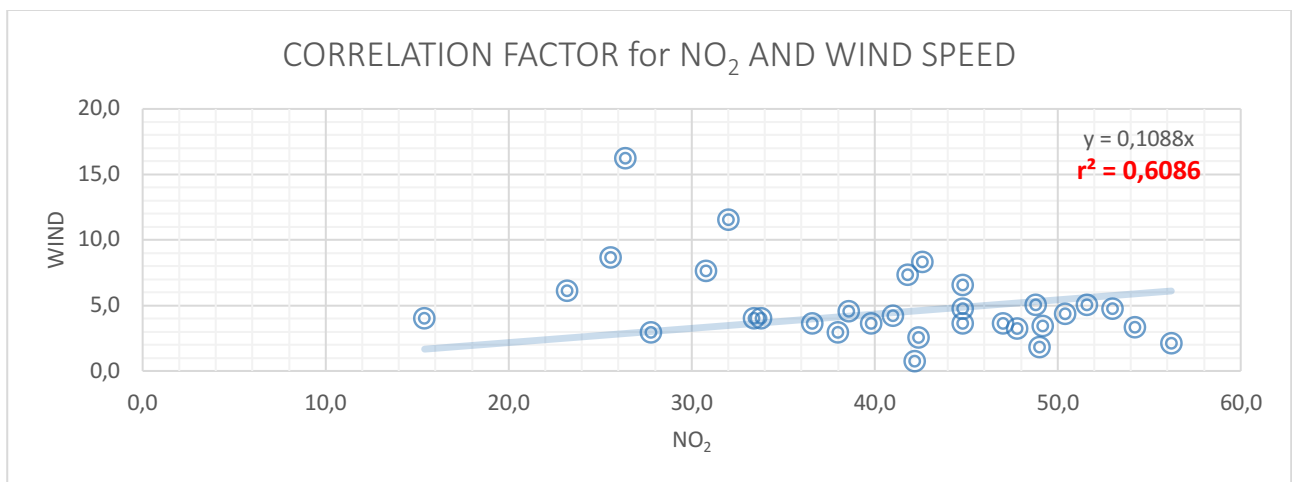
Source: Author

Graphic 71: Effect of wind and rain on the wash-out of NO₂ concentration at Ekspozita during March 2023.



Source: Author

Graphic 72: Correlation factor between concentration of NO₂ and Wind speed during March at Ekspozita.



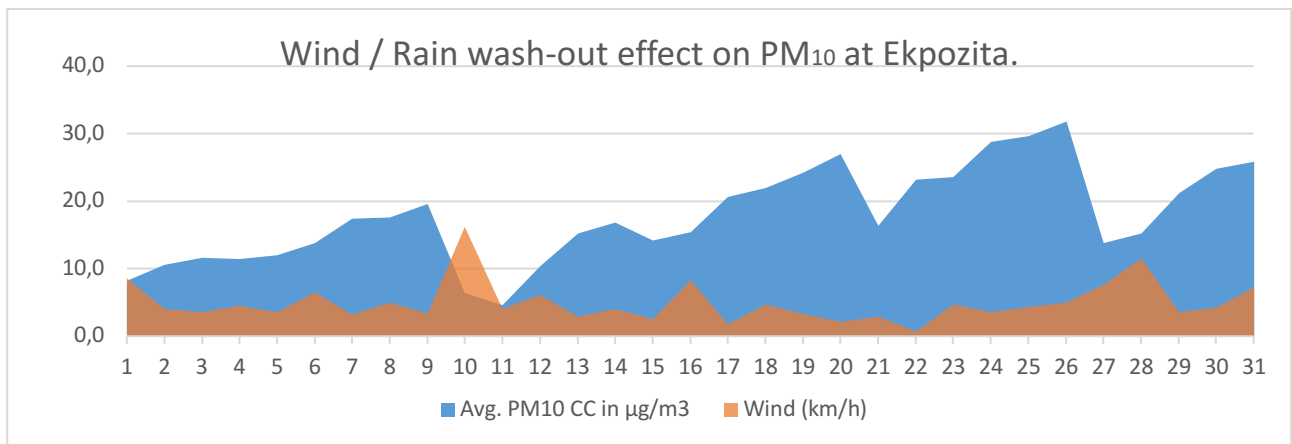
Source: Author

Table 66: PM₁₀ concentrations and meteorological observations during March 2023 / Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM10 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	7,0	8,0	9,0	7,0	10,0	12,0	11,0	10,0	11,0	8,2	8,6	E	91%	Rainy	2hrs 17.00-19.40
2	9,0	10,0	11,0	10,0	13,0	15,0	13,0	12,0	16,0	10,6	4,0	NE	84%	Cloudy	2hrs 17.00-19.40
3	10,0	10,0	12,0	11,0	15,0	14,0	12,0	14,0	15,0	11,6	3,6	E	88%	Cloudy	2hrs 17.00-19.40
4	11,0	9,0	12,0	10,0	15,0	16,0	10,0	13,0	18,0	11,4	4,5	NE	91%	Cloudy	2hrs 17.00-19.40
5	10,0	10,0	13,0	11,0	16,0	18,0	17,0	15,0	17,0	12,0	3,6	N	85%	Clear	2hrs 17.00-19.40
6	12,0	14,0	13,0	12,0	18,0	22,0	21,0	15,0	20,0	13,8	6,5	E	82%	Cloudy	2hrs 17.00-19.40
7	16,0	17,0	18,0	15,0	21,0	23,0	25,0	20,0	29,0	17,4	3,2	NE	83%	Clear	2hrs 17.00-19.40
8	15,0	16,0	19,0	16,0	22,0	27,0	26,0	19,0	27,0	17,6	5,0	SE	73%	Cloudy	2hrs 17.00-19.40
9	18,0	17,0	21,0	18,0	24,0	29,0	31,0	23,0	30,0	19,6	3,4	SE	77%	Cloudy	2hrs 17.00-19.40
10	7,0	6,0	5,0	6,0	8,0	14,0	16,0	15,0	16,0	6,4	16,2	S	91%	Rainy	2hrs 17.00-19.40
11	4,0	5,0	4,0	4,0	6,0	9,0	8,0	6,0	8,0	4,6	4,0	E	90%	Rainy	2hrs 17.00-19.40
12	9,0	10,0	12,0	10,0	11,0	16,0	15,0	16,0	18,0	10,4	6,1	N	49%	Clear	2hrs 17.00-19.40
13	13,0	15,0	16,0	15,0	17,0	25,0	22,0	22,0	27,0	15,2	2,9	NE	63%	Clear	2hrs 17.00-19.40
14	15,0	16,0	18,0	15,0	20,0	26,0	28,0	21,0	26,0	16,8	4,0	SE	59%	Cloudy	2hrs 17.00-19.40
15	12,0	15,0	15,0	14,0	15,0	25,0	24,0	19,0	27,0	14,2	2,5	NE	78%	Cloudy	2hrs 17.00-19.40
16	13,0	16,0	15,0	15,0	18,0	27,0	26,0	23,0	30,0	15,4	8,3	N	46%	Clear	2hrs 17.00-19.40
17	17,0	19,0	22,0	20,0	25,0	32,0	31,0	28,0	33,0	20,6	1,8	W	66%	Clear	2hrs 17.00-19.40
18	19,0	21,0	23,0	21,0	26,0	34,0	35,0	26,0	36,0	22,0	4,7	N	74%	Clear	2hrs 17.00-19.40
19	23,0	22,0	25,0	22,0	29,0	38,0	38,0	28,0	35,0	24,2	3,3	NE	84%	Clear	2hrs 17.00-19.40
20	26,0	25,0	29,0	24,0	31,0	40,0	42,0	31,0	38,0	27,0	2,1	N	89%	Cloudy	2hrs 17.00-19.40
21	16,0	14,0	19,0	15,0	18,0	24,0	26,0	24,0	25,0	16,4	2,9	N	91%	Cloudy	2hrs 17.00-19.40
22	20,0	22,0	25,0	23,0	26,0	29,0	31,0	30,0	34,0	23,2	0,7	SW	78%	Clear	2hrs 17.00-19.40
23	23,0	21,0	25,0	22,0	27,0	35,0	32,0	30,0	37,0	23,6	4,7	N	80%	Clear	2hrs 17.00-19.40
24	27,0	28,0	29,0	28,0	32,0	39,0	35,0	34,0	41,0	28,8	3,6	NE	77%	Clear	2hrs 17.00-19.40
25	27,0	27,0	30,0	29,0	35,0	43,0	38,0	37,0	46,0	29,6	4,3	SE	80%	Clear	2hrs 17.00-19.40
26	29,0	30,0	32,0	31,0	37,0	48,0	42,0	38,0	49,0	31,8	5,0	S	73%	Clear	2hrs 17.00-19.40
27	14,0	15,0	14,0	13,0	13,0	16,0	14,0	17,0	18,0	13,8	7,6	SW	91%	Rainy	2hrs 17.00-19.40
28	16,0	15,0	15,0	16,0	14,0	23,0	20,0	19,0	22,0	15,2	11,5	NW	32%	Clear	2hrs 17.00-19.40
29	21,0	20,0	22,0	21,0	22,0	24,0	22,0	22,0	26,0	21,2	3,6	S	44%	Clear	2hrs 17.00-19.40
30	23,0	25,0	25,0	24,0	27,0	31,0	28,0	25,0	36,0	24,8	4,2	N	76%	Clear	2hrs 17.00-19.40
31	24,0	24,0	26,0	26,0	29,0	33,0	32,0	29,0	39,0	25,8	7,3	N	77%	Clear	2hrs 17.00-19.40
TOT	16,3	16,8	18,5	16,9	20,6	26,0	24,9	22,0	27,4	17,8	5,0				

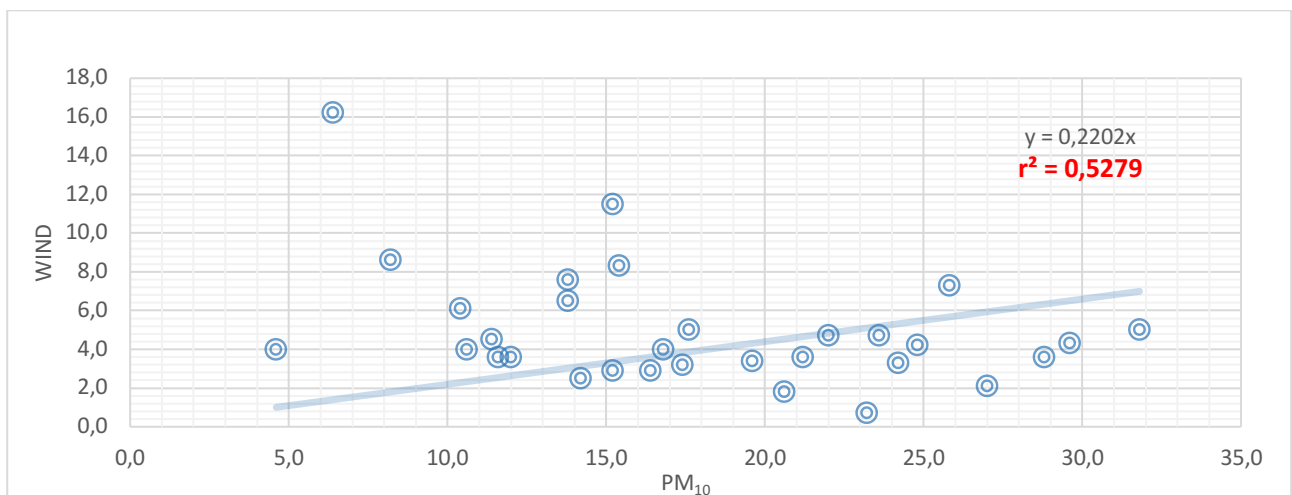
Source: Author

Graphic 73: Effect of wind and rain on the wash-out of PM₁₀ concentration at Ekspozita during March 2023.



Source: Author

Graphic 74: Correlation factor between concentration of PM₁₀ and Wind speed during March at Ekspozita.



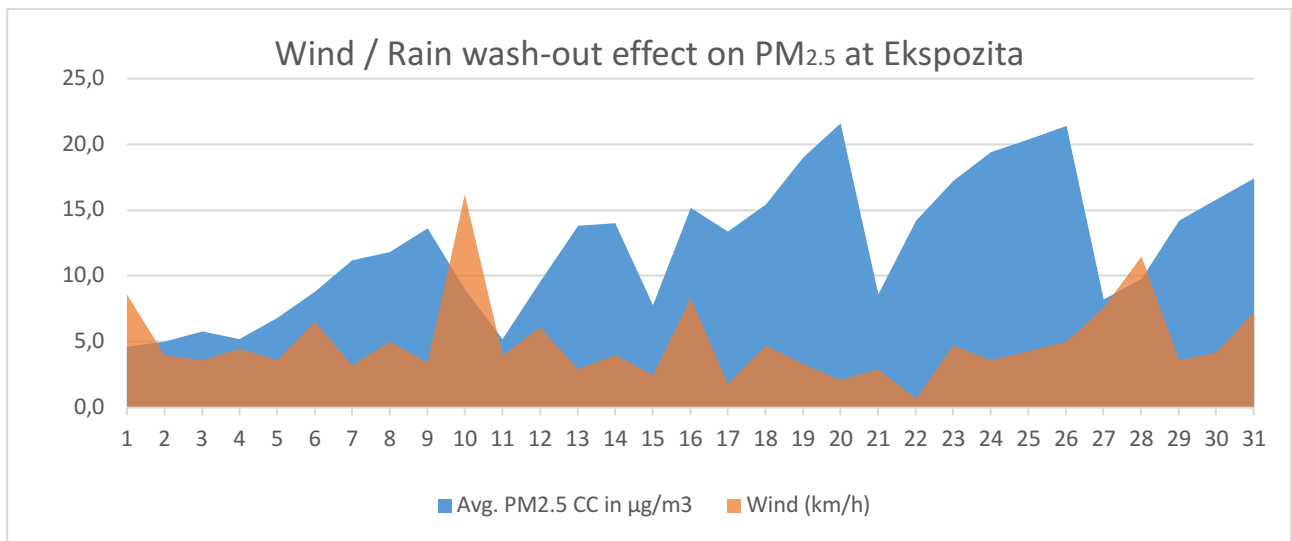
Source: Author

Table 67: PM_{2.5} concentrations and meteorological observations during March 2023 / Ekspozita.

Date	MP1	MP2	MP3	MP4	MP5	BMP1	BMP2	BMP3	BMP4	Avg. PM2.5 CC in µg/m3	Wind (km/h)	Direction	Humidity	Weather	Monitoring length
1	4,0	4,0	5,0	4,0	6,0		5,00	5,00		4,6	8,5	E	91%	Rainy	2hrs 10.20 -12.45
2	5,0	4,0	5,0	5,0	6,0		5,0	6,00		5,0	4,0	NE	84%	Cloudy	2hrs 10.20 -12.45
3	5,0	6,0	6,0	5,0	7,0		6,0	5,00		5,8	4,6	E	88%	Cloudy	2hrs 10.20 -12.45
4	5,0	5,0	5,0	5,0	6,0		5,0	6,00		5,2	4,5	NE	91%	Cloudy	2hrs 10.20 -12.45
5	6,0	7,0	7,0	6,0	8,0		7,0	7,00		6,8	3,6	N	85%	Clear	2hrs 10.20 -12.45
6	8,0	9,0	9,0	8,0	10,0		9,0	10,00		8,8	5,5	E	82%	Cloudy	2hrs 10.20 -12.45
7	10,0	10,0	12,0	10,0	14,0		11,0	12,00		11,2	3,2	NE	83%	Clear	2hrs 10.20 -12.45
8	11,0	10,0	12,0	11,0	15,0		12,0	14,00		11,8	5,0	SE	73%	Cloudy	2hrs 10.20 -12.45
9	12,0	11,0	15,0	12,0	18,0		14,0	15,00		13,6	3,4	SE	77%	Cloudy	2hrs 10.20 -12.45
10	8,0	6,0	10,0	9,0	12,0		9,0	8,00		9,0	16,2	S	91%	Rainy	2hrs 10.20 -12.45
11	3,0	5,0	6,0	5,0	7,0		5,0	6,00		5,2	4,0	E	90%	Rainy	2hrs 10.20 -12.45
12	9,0	8,0	10,0	9,0	12,0		10,0	8,00		9,6	6,1	N	49%	Clear	2hrs 10.20 -12.45
13	13,0	14,0	15,0	12,0	15,0		13,0	15,00		13,8	2,9	NE	63%	Clear	2hrs 10.20 -12.45
14	13,0	12,0	16,0	13,0	16,0		14,0	16,00		14,0	4,0	SE	59%	Cloudy	2hrs 10.20 -12.45
15	6,0	8,0	8,0	8,0	9,0		8,0	11,00		7,8	2,5	NE	78%	Cloudy	2hrs 10.20 -12.45
16	14,0	14,0	16,0	15,0	17,0		15,0	11,00		15,2	8,3	N	46%	Clear	2hrs 10.20 -12.45
17	12,0	13,0	15,0	12,0	15,0		13,0	15,00		13,4	1,8	W	66%	Clear	2hrs 10.20 -12.45
18	15,0	14,0	16,0	15,0	17,0		15,0	17,00		15,4	4,7	N	74%	Clear	2hrs 10.20 -12.45
19	17,0	18,0	19,0	19,0	22,0		19,0	20,00		19,0	3,3	NE	84%	Clear	2hrs 10.20 -12.45
20	20,0	20,0	22,0	21,0	25,0		22,0	23,00		21,6	2,1	N	89%	Cloudy	2hrs 10.20 -12.45
21	8,0	9,0	8,0	7,0	11,0		9,0	15,00		8,6	2,9	N	91%	Cloudy	2hrs 10.20 -12.45
22	12,0	14,0	15,0	14,0	16,0		14,0	20,00		14,2	0,7	SW	78%	Clear	2hrs 10.20 -12.45
23	15,0	17,0	18,0	17,0	19,0		17,0	22,00		17,2	4,7	N	80%	Clear	2hrs 10.20 -12.45
24	17,0	17,0	19,0	20,0	24,0		19,0	22,00		19,4	3,6	NE	77%	Clear	2hrs 10.20 -12.45
25	18,0	18,0	21,0	20,0	25,0		20,0	23,00		20,4	4,3	SE	80%	Clear	2hrs 10.20 -12.45
26	18,0	19,0	22,0	21,0	27,0		21,0	22,00		21,4	5,0	S	73%	Clear	2hrs 10.20 -12.45
27	8,0	7,0	9,0	7,0	10,0		8,0	6,00		8,2	7,6	SW	91%	Rainy	2hrs 10.20 -12.45
28	8,0	9,0	11,0	8,0	13,0		10,0	9,00		9,8	11,5	NW	32%	Clear	2hrs 10.20 -12.45
29	12,0	14,0	15,0	13,0	17,0		13,0	13,00		14,2	3,6	S	44%	Clear	2hrs 10.20 -12.45
30	14,0	14,0	17,0	15,0	19,0		15,0	14,00		15,8	4,2	N	76%	Clear	2hrs 10.20 -12.45
31	15,0	16,0	19,0	15,0	22,0		17,0	15,00		17,4	7,3	N	77%	Clear	2hrs 10.20 -12.45
TOT	11,0	11,4	13,0	11,6	14,8	#DIV/0!	12,3	13,3	#DIV/0!	12,4	5,0				

Source: Author

Graphic 75: Effect of wind and rain on the wash-out of PM_{2.5} concentration at Ekspozita during March 2023.



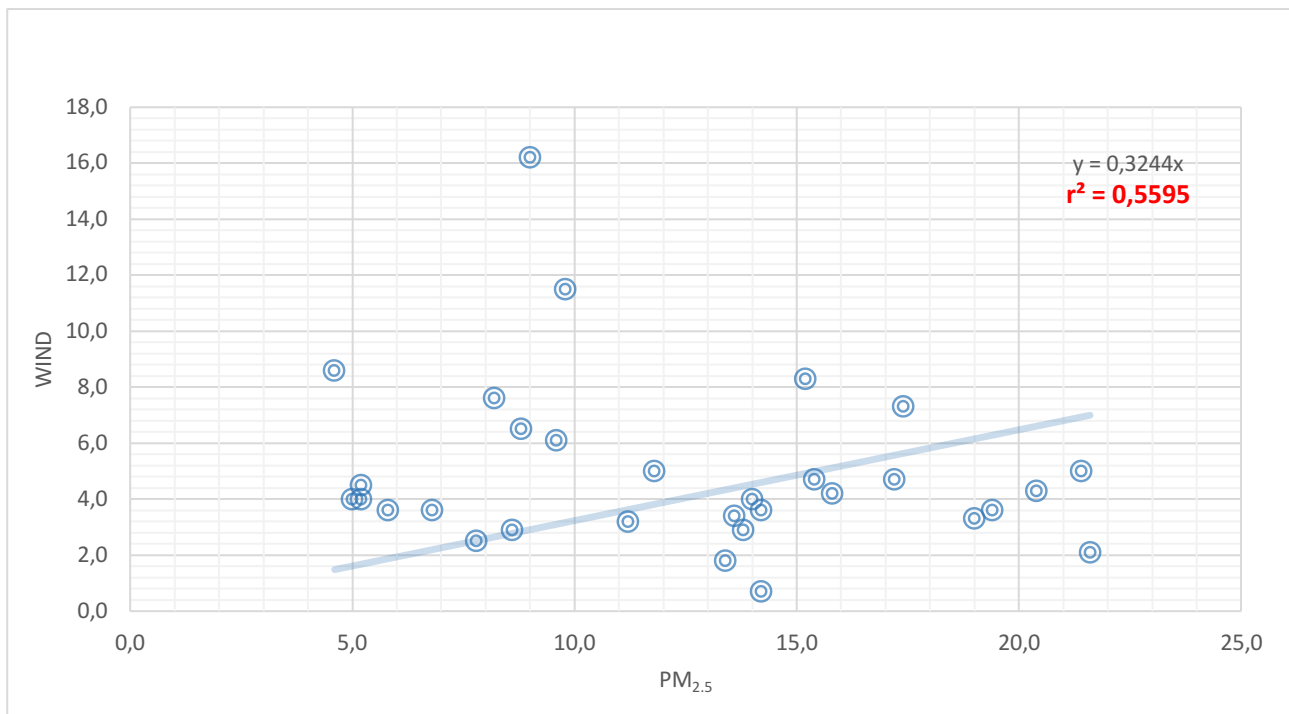
Source: Author

Figure 95: Sample from the dispersal of PM_{2.5} sequence at Ekspozita (19.03.2023)



Source: Author

Graphic 76: Correlation factor between concentration of PM_{2.5} and Wind speed during March at Ekspozita.



Source: Author

The meteorological conditions observed during the morning sessions in March were characterized by instability and frequent rainfall in the initial two weeks. However, the latter half of the month exhibited more stable weather, revealing a correlation coefficient ($r=0.57$) that signifies a moderate relationship between wind speed and the natural dispersion of air pollutants within the Ekspozita area. Excluding the days affected by rainfall from the analysis, the correlation between wind speed and pollution concentration in the area strengthens to $r=0.71$.

Moreover, the variability in wind directions noted in March, which differed slightly from those in January and also from February, does not strongly suggest the formation of an Air Pollution Cavity Area in Ekspozita due to its urban configuration. This is except for the MP3 measurements, which indicate that even minor, yet consolidated, ground-level structures extending from existing buildings can cause a localized retention of pollutants, increasing pollution levels by 3-5% above the area's average.

Thus, despite the variations in wind directions during February and March, coupled with March's nuanced weather patterns and February's extreme dry conditions, there was no discernible contribution to an artificial increase in pollution levels within the block. The elevated readings from MP5, relative to other monitoring points, could be associated with its proximity to the most heavily trafficked road. This analysis leads to the conclusion that Ekspozita's urban layout, with parallel

dwellings facilitating wind tunnels from the Northwest to the Southeast, optimally supports natural ventilation and pollution dispersal, though this finding is specific to Tirana's micro-climatic conditions.

In summary, March witnessed the least impact on pollution levels compared to January and February at Ekspozita. This reduction is directly linked to the rain-induced washout effect, which decreased overall pollution concentrations in the area and throughout the city or region.

4.10. Final Discussion

The 18th century marked a zenith in the intellectual exploration of meteorology, a period characterized by significant advancements that laid the foundation for modern climatological understanding. Gabriel Fahrenheit's invention of the mercury thermometer provided highly reliable temperature measurements, while Anders Celsius introduced a novel temperature scale that further refined thermal measurement practices. Concurrently, Daniel Bernoulli's publication of "Hydrodynamica" in 1738 introduced the inaugural model of the kinetic theory of gases, heralding a new era in the understanding of atmospheric sciences.

In a notable progression of empirical studies, Alexander Wilson and Thomas Melville embarked on the inaugural meteorological monitoring in 1748, signifying the commencement of systematic climate observation. The emergence of such data proved to be invaluable across critical sectors of the era, notably trade and agriculture, marking the beginning of meteorology's integral role in societal and economic frameworks.

Since these seminal developments, the field of meteorology and the broader study of climate have evolved to become core components of scientific inquiry, characterized by remarkable advancements in both theory and application. In the contemporary landscape, climatology has attained unprecedented levels of sophistication and predictability, leveraging advanced technological methodologies to further our comprehension of atmospheric phenomena.

the field of modern meteorology emerged, buoyed by an enhanced comprehension of gaseous behaviors and their responses to varying thermal conditions. The publication of the inaugural global temperature map by Alexander von Humboldt in 1817 marked a pivotal moment, offering the

scientific community an early overview of global climatic patterns. This period also witnessed the proliferation of meteorological monitoring equipment globally, significantly enriching meteorological data archives. The advent of the telegraph in the early nineteenth century represented a watershed moment for meteorology, facilitating the swift transmission of weather observations and effectively laying the foundation for systematic weather forecasting. Francis Galton's publication of the first weather map in "The Times" newspaper in 1861 epitomized a substantial leap towards contemporary weather prediction methodologies.

The establishment of several key observatories and meteorological organizations, including the Paris Observatory in 1854, New York's Meteorological Observatory in 1869, the UK's Met Office in 1854, and the International Meteorological Organization in Vienna in 1873, underscored the increasing importance of climate to economic research and development. These efforts were characterized by a focus on technological innovations and global collaboration.

Advancements continued into the twentieth century with the introduction of radiosondes and weather balloons in the 1920s, providing critical data on upper-atmosphere conditions. The development of computer-based models for weather prediction marked a significant breakthrough in the latter half of the century, exemplified by Jule Charney and John von Neumann's pioneering work with ENIAC, the first general-purpose digital computer. The era of satellite meteorology commenced with the launch of TIROS-1 in 1960, heralding a new phase in meteorological observation by offering unparalleled perspectives of weather systems from space. The formation of the World Meteorological Organization (WMO) in 1950 further facilitated global collaboration in meteorological research and forecasting.

In the 21st century, climate monitoring has become one of the most meticulously scrutinized sectors globally. This historical trajectory culminates in the contemporary scientific consensus that anthropogenic factors are not only altering micro-climatic conditions and the broader global climate but are also precipitating the emergence of a new climatic era at an unprecedented rate. Enhanced computational capabilities have fostered the development of sophisticated climate models that integrate oceanic, atmospheric, and terrestrial processes, thereby improving the precision of climate change impact predictions.

The widespread adoption of the internet and mobile technology has catalyzed a surge in citizen science initiatives and the application of big data in climatology, augmenting real-time data collection and public engagement in climate science. Furthermore, advances in remote sensing,

drone technology, and the deployment of autonomous observation stations are offering novel insights into areas previously beyond reach, enriching our understanding of the Earth's climatic systems.

Despite the wealth of knowledge available, the majority of urban developments fail to integrate this wisdom in the planning and expansion of urban areas. The pursuit of economic gain often takes precedence over considerations of environmental sustainability and climate resilience. Contemporary urban environments are typically equipped to manage only minor climate variations, while they remain vulnerable to extreme climate events. T

his situation underscores the urgent need for a fundamental reevaluation of planning theories and urban design principles, aiming to foster a shift towards urban futures that are both climate-resilient and environmentally neutral. Such futures should not only support economic prosperity but also offer a sustainable and healthful living environment for their inhabitants. This research delves into a specific concern, acknowledging that wind plays a pivotal role in the dispersion of air pollutants at ground level. It posits that a comprehensive understanding of the interplay between urban form, its aerodynamics, and prevailing winds is essential.

Such an understanding is crucial for optimizing the natural dispersion of air pollutants in urban settings, thereby aligning urban development strategies with environmental health and sustainability objectives.

Every element introduced into the urban landscape modifies the behavior of wind due to the resistance and friction presented by solid objects to the airflow. Buildings, in particular, can significantly alter the urban microclimate. Urban environments, exemplified by densely built cities such as Tirana, typically experience turbulent airflow. This turbulence results from the built environment's disruption of natural wind patterns, which originate from various directions. The phenomenon is further influenced by the Bernoulli principle, which postulates a decrease in pressure accompanying an increase in fluid velocity.

An illustrative example of the Bernoulli effect is observed in the design of airplane wings, where air moving over the top surface experiences reduced pressure and increased velocity, while the oppositedol occurs beneath the wing. This differential pressure contributes to the lift force essential for aircraft flight. Providing the first conclusion that form (in the above case the aerodynamics) actually matters and is pivotal to obtaining the desired result such as decrease friction or dispersal of pressure to lift planes or keep race cars at ground.

Thus, alterations in air pressure and airflow velocity, particularly pronounced at higher wind velocities, engender turbulence with consequent effects including:

- Chaotic mixing flows, where air particles embark on erratic, swirling trajectories.
- The emergence of eddies and vortexes of diverse magnitudes.

From a more nuanced urban perspective, the Venturi Effect warrants attention. Initially observed by Giovanni Battista Venturi, this phenomenon elucidates how the velocity of a fluid escalates as it traverses through constricted sections along its path, thereby precipitating a reduction in pressure. The Venturi Effect plays a crucial role in ventilation systems, both artificial and natural, by enhancing air circulation through strategically designed pathways that alternately narrow and widen, thus efficiently directing airflow to targeted areas.

Moreover, the vortex effect, manifesting behind obstructions once airflow is bifurcated by a structure, naturally gives rise to vortex shapes. This process leads to the formation of so-called cavity zones where wind speed diminishes and pressure increases, prolonging the persistence of urban air pollutants (Blocken, 2004)

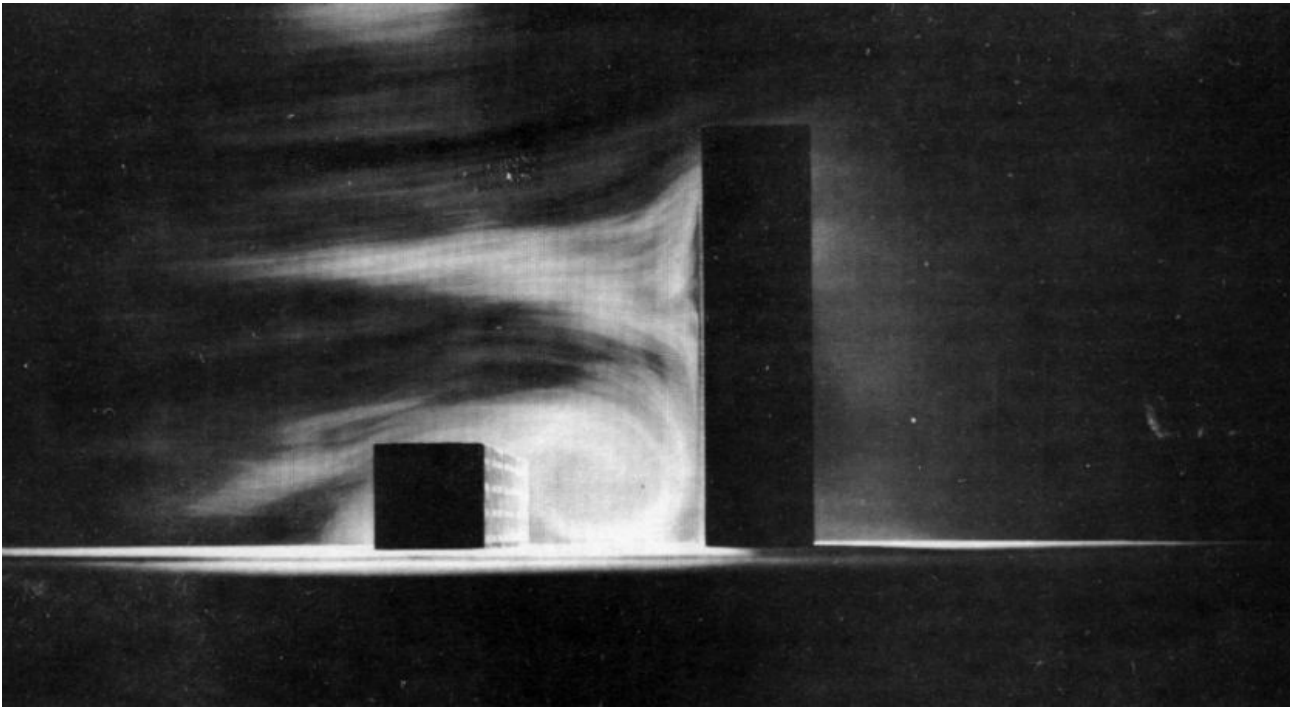
Considering the above-mentioned principles, when wind encounters a building, it generates areas of low pressure along the sides parallel to the wind direction and on the leeward side as well.

However, analyzing wind and airflow in urban settings, particularly at ground level, presents significant challenges. Historically, insights into urban ventilation relied predominantly on scaled models, which were subsequently examined using smoke or powder to assess the effects of urban wind tunnels. Presently, Computational Fluid Dynamics (CFD) enables designers to predict the impacts of their designs with considerable accuracy. Nonetheless, CFD has largely corroborated previous empirical observations.

For example, positioning a lower building in front of a taller one generates significant turbulence between the two structures when the wind direction is from the lower to the higher building.

The best conditions for a natural air flow pattern are created when the outlet opening is higher and wider than the inlet. The building orientation should be oriented to maximize surface exposure to prevailing winds.

Figure 96: Smoke visualization illustrating wind vortex flow between a high and low block.



Source: Ten Hagen & Stam bv. Copyright BRE

The primary objective of this research was to quantify the impact of "Cavity Areas" on pollution retention within urban environments, distinctly omitting the utilization of Computational Fluid Dynamics (CFD) simulation. This deliberate research focus diverges from the investigation of previously mentioned effects, concentrating instead on the formation of vortices in specific urban configurations and their consequent role in air pollution retention. This methodological choice is attributed to the inherent variability in mathematical models employed by CFD simulations. Specifically, Reynolds Averaged Simulation (RAS) and Large Eddy Simulations (LES) employ distinct approaches, yielding divergent outcomes regarding the magnitude of vortex formation in urban contexts (Reynolds, 1895). Such discrepancies underscore the rationale for the research's emphasis on direct quantification of pollution retention in "Cavity Areas," thereby circumventing the potential inconsistencies associated with CFD simulations. (Smagorinsky, 1963)

One of the central debates revolves around the impact of urban density on air quality. Some scholars argue that higher densities can lead to increased pollution levels due to concentrated human activities and vehicular emissions (Stone Jr., 2008). In contrast, others contend that denser urban forms can facilitate more efficient public transportation and reduce the reliance on private vehicles, thereby lowering overall emissions (Newman, 1989).

Another significant debate concerns the role of urban green spaces in mitigating air pollution. While numerous studies highlight the positive impact of vegetation in absorbing pollutants and improving air quality (Nowak, 2006), some researchers caution about overestimating this capacity. They argue that the effectiveness of green spaces in pollution mitigation varies significantly depending on the type of vegetation, urban layout, and the specific pollutants in question (Pugh, 2012).

Finally the influence of urban morphology on pollution dispersion is also a key area of debate. Research indicates that the layout and physical structure of urban areas can significantly affect the dispersion patterns of pollutants (Vardoulakis, 2003). Compact city models, characterized by high-rise buildings and narrow streets, may restrict airflow and trap pollutants, exacerbating exposure levels in certain areas (Jeanjean, 2017).

Urban canyons, created by rows of high-rise buildings along narrow streets, exemplify a key urban design feature that affects pollution dispersion. These configurations can lead to reduced wind speed and limited vertical mixing of air, trapping pollutants at street level. Studies have quantified the impact, showing that in some urban canyons, pollutant concentrations can be up to twice as high as those in more open areas (Arnfield, 2003). The aspect ratio of building height to street width is a critical factor, with higher ratios leading to more pronounced pollution trapping effects.

The orientation and connectivity of streets also play a significant role in urban air quality. Research utilizing fluid dynamics simulations has demonstrated that cities with a grid-like street pattern promote better ventilation compared to those with a more haphazard arrangement (Salim, 2011). The presence of open spaces, such as parks and plazas, within urban grids further enhances air circulation, reducing pollutant concentrations.

Empirical data from urban pollution monitoring stations corroborate the influence of urban form on air quality. For instance, a comprehensive study in London found that areas with dense building configurations and limited street connectivity experienced NO₂ levels that were, on average, 25% higher than in more openly designed areas (Greater London Authority, 2016). This evidence highlights the need for urban designs that consider air quality impacts.

Recognizing the critical relationship between urban form and pollution dispersion, policymakers and urban planners have begun to incorporate air quality considerations into urban design. The concept of "breathable buildings" that facilitate natural ventilation and the inclusion of green belts and corridors to enhance urban air flow are examples of strategies being adopted (Hebbert, 2013).

While specific statistics on pollution retention in urban areas due to their form can vary significantly from one city to another, studies often focus on general trends and comparative analyses across different urban configurations. Direct, quantifiable data linking urban form to pollution levels can be found in various case studies and environmental assessments. Here are a few examples that highlight how urban morphology influences pollution retention:

1. **New York City, USA:** Research on New York City's air quality highlighted areas like Midtown Manhattan, where the dense skyscraper environment contributes to higher levels of particulate matter (PM2.5) compared to more open, less densely built-up areas of the city (NYC Environmental Protection., 2016).
2. **Beijing, China:** In Beijing, a study utilizing satellite data and ground observations found that areas with high-rise buildings and compact urban forms had significantly higher concentrations of PM2.5 than peripheral areas, due in part to restricted air flow and pollutant dispersion capabilities (Wang, 2015)
3. **Copenhagen, Denmark:** Analysis of air quality in Copenhagen showed that green spaces within the urban area played a crucial role in mitigating pollution, underscoring how urban form, including the presence and distribution of green spaces, can influence air quality (City of Copenhagen, 2019).

The debates and facts highlighted above underscore the complexity of the relationship between urban form and air quality. While denser urban areas can potentially exacerbate air pollution due to concentrated emission sources, they also offer opportunities for more sustainable transportation options and reduced per capita emissions. Moreover, the incorporation of green spaces into urban design emerges as a vital strategy for mitigating pollution, though its effectiveness is contingent upon careful planning and consideration of local environmental contexts. Finally, the morphology of urban environments plays a crucial role in the dispersion of pollutants, with certain configurations posing challenges for air quality management.

Collectively, these debates emphasize the need for integrated urban planning approaches that consider the multifaceted impacts of urban form on air quality and quality of life. Achieving optimal outcomes requires a nuanced understanding of the local context, including geographic, climatic, and social factors, to design urban environments that are both livable and sustainable.

4.11. Epilogue

The urban form evolution of Tirana, Albania, reflects a complex interplay of historical, political, and socio-economic transformations that have shaped its architectural and urban development over the past century. From its modest beginnings as a small town in the early 20th century to its status as the capital and largest city of Albania today, Tirana has undergone profound changes that mirror the country's turbulent history and aspirations for modernization and integration into the European landscape. Unlike to many capital cities in the Balkans, Tirana's architectural and urban landscape is engaged in a continual struggle to supplant its historical landmarks with newer developments, each aiming to assert its legacy as superior to its predecessors. Consequently, Tirana presents a cityscape where its built heritage does not form a coherent narrative through overlapping layers of history; rather, it exhibits a tendency towards exclusion, where successive architectural styles and urban planning philosophies do not integrate with, but instead seek to replace, those that came before. This dynamic results in a city that offers limited insights into its historical evolution, as each era attempts to redefine the urban and architectural identity of Tirana without a harmonious integration of its historical contexts.

The early 20th century marked the beginning of Tirana's transformation with the designation of the city as Albania's capital in 1920, a strategic move aimed at centralizing governance and facilitating the modernization of the country (Hall, 1994). This period saw the introduction of Italian architectural influence, particularly during the interwar period, as part of Mussolini's ambition to exert influence over Albania. Architects such as Armando Brasini envisioned and implemented monumental buildings and boulevards, laying the groundwork for a modern capital (Prato, 2007).

The communist era (1944-1991) introduced a new phase in Tirana's urban development, characterized by the expansion of the city's boundaries and the construction of large residential blocks to accommodate the rural population migrating to the city. The focus was on creating a socialist urban form that emphasized functionality, collective living, and the erasure of pre-socialist architectural identities. Public spaces and housing projects from this period were designed to reflect the ideals of the communist regime, often at the expense of historical and architectural heritage (Agolli, 2012).

The collapse of communism in 1991 ushered in a period of rapid and often chaotic urban growth, marked by unregulated construction and the emergence of informal settlements as the city struggled to accommodate the influx of people from rural areas. The post-1991 era has been

characterized by efforts to modernize Tirana and address the challenges posed by its earlier unplanned expansion. Initiatives such as the Tirana 2030 Master Plan, spearheaded by architect Stefano Boeri, aim to redefine the city's urban form through sustainable development, green spaces, and the revitalization of public spaces, reflecting a commitment to creating a livable and environmentally sustainable capital (Boeri, 2016).

Throughout its evolution, Tirana has remained at the heart of Albania's political, economic, and cultural life. The city's urban form is a testament to its resilience and ability to adapt to changing political landscapes and development paradigms. As Tirana continues to evolve, it stands as a symbol of Albania's aspirations and challenges in the 21st century, striving to balance growth with sustainability and tradition with modernity. The current urban challenges facing Tirana, including congestion, informal construction, and the need for green spaces, also present opportunities for innovative urban regeneration (Aliaj, 2003).

Since 2016 until the end of 2023, Tirana experienced a marked phase of intensification in urban development, characterized by a surge in residential construction primarily within the urbanized zones. This period saw the transformation of spaces previously designated for public use, parks, or occupied by old villas into densely built residential areas. City governors and urban planners exhibited a tendency to accommodate densification, showing limited resistance to the economic incentives driving investment predominantly in the city's middle-ring. This approach not only contributed to a significant phase of air pollution during the construction stages, culminating in what the author identifies as the most detrimental period for Tirana's air quality based on a comparative analysis with historical data but also instigated a subsequent environmental challenge. The phenomenon of reduced natural ventilation emerged as a critical concern, leading to the formation of pollution retention zones within the city. The author, drawing parallels to the Urban Heat Island effect, designates these zones as "Air Pollution Cavity Areas." This terminology is derived from the observed combination of diminished natural ventilation in densely constructed areas and the impact of urban morphology on vortex formation. Such conditions contribute to the prolonged retention of air pollutants and the amplification of their concentrations, exacerbating the city's environmental and public health challenges.

In this transformative period, the deliberate choice by city officials and planners to pursue densification strategies, with a discernible lack of opposition to the prevailing economic motivations for central urban investments, has fundamentally altered the urban landscape. The resulting

scenario has not only led to a transient phase of escalated construction-related air pollution, recognized by the author as a historical nadir in terms of air quality metrics for Tirana but has also precipitated a critical and enduring issue. The advent of "Air Pollution Cavity Areas" as coined by the author, signifies a problematic intersection of reduced natural airflow due to dense urban development and specific urban forms conducive to vortex effects. This synergy between urban design and environmental dynamics results in the sustained entrapment and concentration of air pollutants, underscoring a pressing need for reevaluating urban densification policies and practices to safeguard the environmental integrity and healthful living conditions within the city.

This study represents the first research effort in Albania to investigate the impact of the built environment's form on the natural dispersion of air pollution within the central urban area of Tirana. Despite the interplay of exogenous and endogenous factors leading to aggregate pollution levels surpassing threshold concentrations in Tirana, the findings corroborate that unintended consequences stemming from "economic-driven" urban densification, coupled with a deficiency of comprehensive studies, culminate in a long-term diminution of public health due to the creation of Air Pollution Cavity Areas. Certain locations within neighborhoods, characterized by inadequate natural ventilation and the manifestation of vortex effects, exhibit a sustained presence of air pollutants. In particular scenarios, such as during extended drought periods, these pollutants may accumulate to levels that render these areas akin to emission hotspots within the city.

This research has however applied a practical approach given that such phenomena was previously identified by the author during his monitoring practices for the Green-Lungs project. A phenomenon that initially was linked only with the increased activities on construction, infrastructure and congestion throughout the city but latter indicated the important role of meteorological conditions and urban form. The comprehensive monitoring and analysis undertaken within four distinct complexes in Tirana—namely, Magnet, Delijorgji, Ish-Ekspozita, and Kika—have provided valuable insights into urban air quality and the role of natural ventilation in the dispersion of pollution. This detailed examination involves data collected from over 1350 monitoring exercises per complex, encompassing NO₂, PM_{2.5}, PM₁₀, wind speed, wind direction, humidity, and weather conditions. Such an endeavor aims to elucidate the complex interplay between urban form, wind patterns, and the dynamics of pollutant concentrations.

Magnet Complex emerged as a focal point for studying the vortex effect and its implications on air pollution retention. Being a dense and closed-edge block the discovery of Air Pollution Cavity Areas,

particularly at monitoring points MP5 in January and MP1, MP4, and MP5 in February, underscore the significant impact of urban morphology on pollution distribution. The overall correlation coefficient between air pollution and wind present within the complex is $r^2=0.506$ indicating a moderate links on the role of wind to pollution dispersal. On the other hand, even though being the only block which is not bordered by any major road in its perimeter and totally pedestrian within the complex, and similar to all the other monitoring locations it has a nearby construction site, the pollution concentration and the vortex effect accumulating or prolonging pollution concentration indicate that being far from the pollution source or even having a car-free area within the complex do not mitigate the issue of pollution being retained within the complex due to its form and obstruction of natural ventilation.

Table 68: Monthly average concentration of pollutants registered in each monitoring area.

	NO2			PM10			PM2.5		
	J	Sh	M	J	Sh	M	J	Sh	M
Deli	77	97,8	66,4	23	28,2	19,2	13,5	19,4	10,4
Ekspo	64,4	80,7	40,4	15,5	26,1	17,8	9,8	14,3	12,4
Kika	66,6	87,8	29,2	24,1	31,7	15	17	16,7	10,4
Kontakt	66,3	66,8	32,8	14,5	23,8	14,9	13,3	15,2	10,6
	68,6	83,3	42,2	19,3	27,5	16,7	13,4	16,4	11,0
	64,7			21,2			13,6		

Source: Author

During January at MP1 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) exhibited an 11.3% increase in pollution levels compared to the averages for the area. Similarly, MP4 showed a 6.7% increase in pollution concentration, while MP5 revealed a 10.5% increase. Collectively, during January, these three monitoring locations also demonstrated a temporal effect on pollution retention, extending from 36 to 48 hours, in contrast to other monitoring sites where the natural dispersion of air pollution is more effectively facilitated by wind presence.

During February, at MP1 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) exhibited an 2,8% increase in pollution levels compared to the averages for the area. Similarly, MP4 showed a 8,8% increase in pollution concentration, while MP5 revealed a 19,7% increase. Collectively, during February, these three monitoring locations also demonstrated a temporal effect on pollution retention, extending from 24 to 36 hours, in contrast to other monitoring sites where the natural dispersion of air pollution is more effectively facilitated by wind presence.

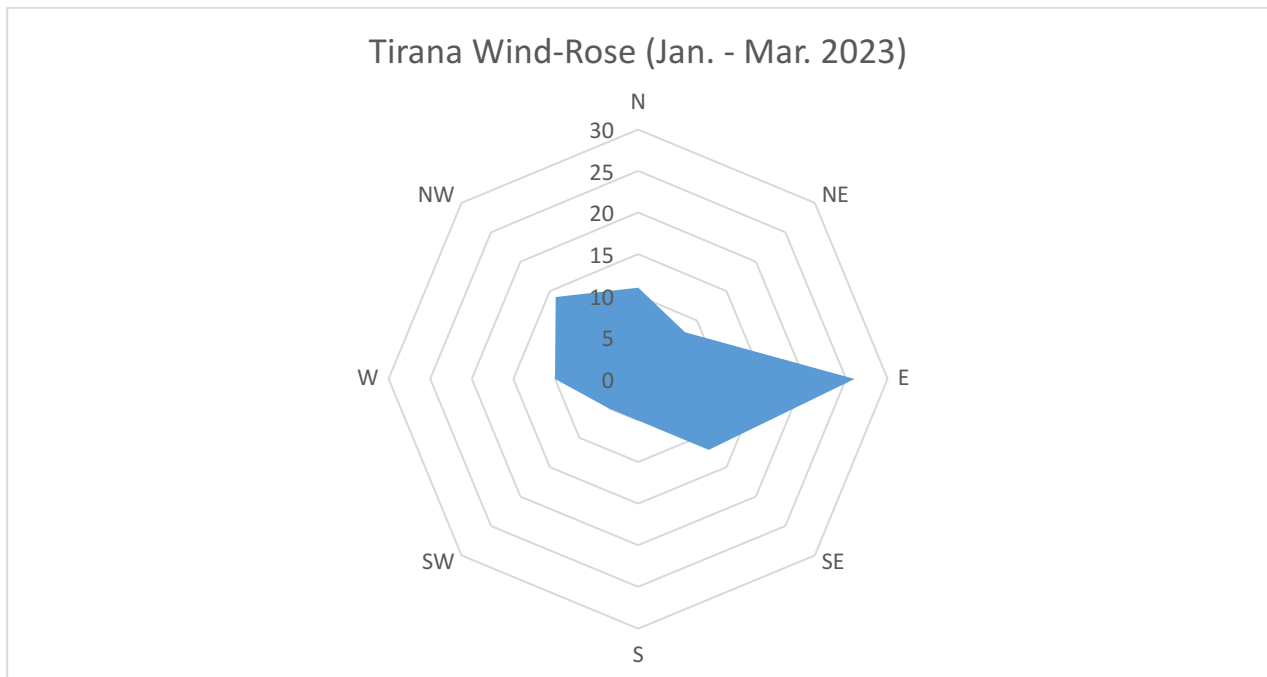
Finally during March at MP1 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) exhibited an 4,1% increase in pollution levels compared to the averages for the area. Similarly, MP4 showed a 1,3% increase in pollution concentration, while MP5 revealed a 2,5% increase. Collectively, during March, these three monitoring locations also demonstrated a temporal effect on pollution retention, extending from 12 to 24 hours, in contrast to other monitoring sites where the natural dispersion of air pollution is more effectively facilitated by wind presence.

The variability in wind directions, coupled with specific meteorological conditions, contributed to a notable fluctuation in pollutant levels, affirming the hypothesis that urban design profoundly influences air quality. The analysis of monitoring outcomes suggests that the urban morphology of this complex fosters the formation of three Air Pollution Cavity Areas. Notably, MP5 is identified as the most adversely affected location, exhibiting the most significant pollution retention, with a 10.9% increase in pollution concentration compared to other sites where natural pollution dispersion occurs more efficaciously.

Delijorgji Complex, characterized by its strategic design conducive to natural ventilation, showcased the pivotal role of wind in dispersing pollutants. Despite its proximity to construction sites and major traffic roundabouts, the complex demonstrated a robust capacity for pollution mitigation, attributed to its architectural orientation and the presence of wind tunnels. This observation underscores the potential of urban planning and design in enhancing air quality, even in densely populated urban environments. The overall correlation coefficient between air pollution and wind present within the complex is $r^2=0.46$ indicating a moderate link on the role of wind to pollution dispersal. Even though expected to have the strongest correlation, the urban form and orientation facilitating the ventilation from Northwest and Southwest winds did not occur due to the fact that only 1/3 of the monitoring period these wind directions were present.

During January at MP4 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) saw a 6.6% escalation in pollution levels relative to the area's average. Likewise, MP5 registered an 13% surge in pollution concentration. Together, throughout January, these two monitoring locations exhibited no discernible temporal effect on pollution retention. However, the observed increases in concentration at these two points are directly attributed to their proximity to construction sites and significant traffic congestion along the complex's perimeter also to the wind direction facilitating the transportation of pollution within the complex.

Figure 97: Monitored wind-rose (prevailing directions) from January to March in all 4 locations in Tirana



Source: Author

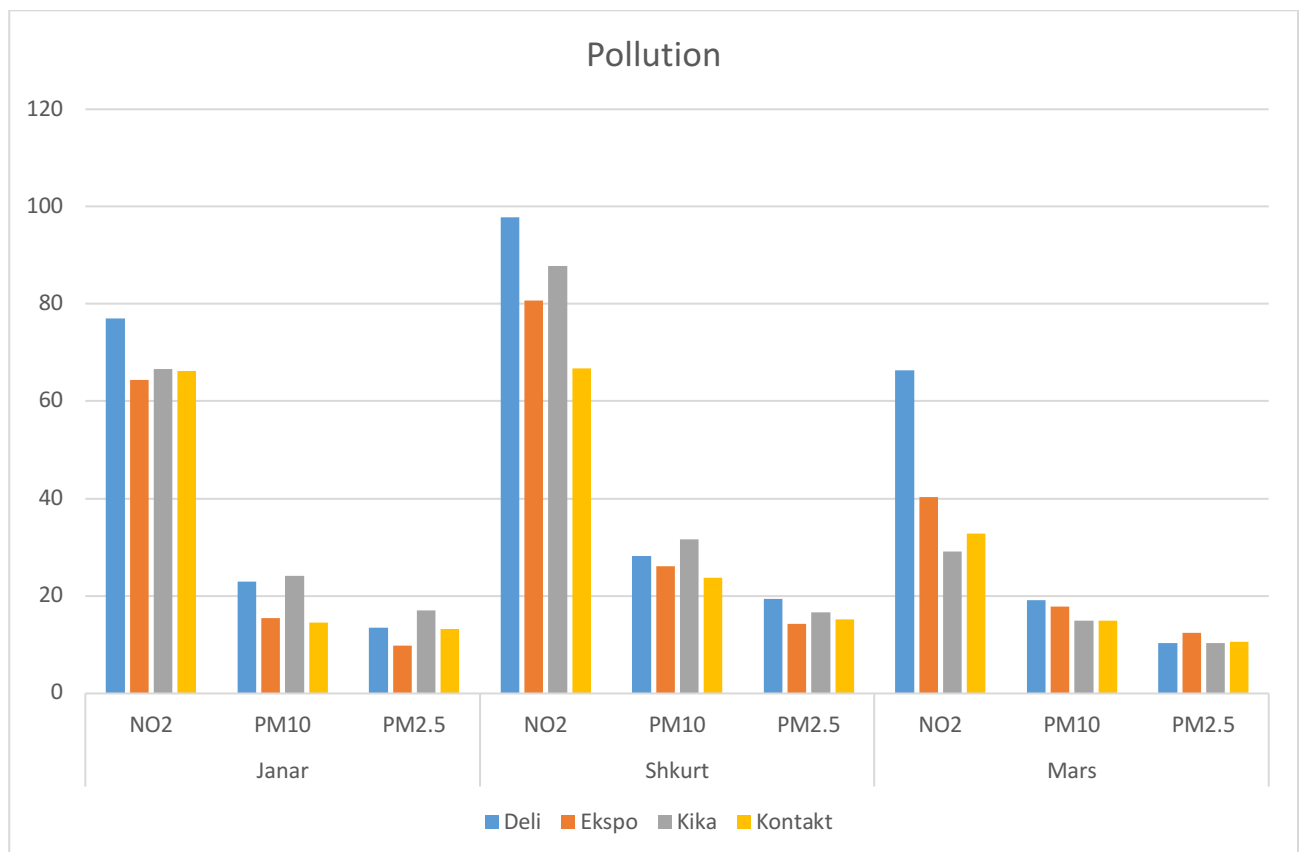
During February at MP4 the average concentration of all pollutants (NO_2 , $\text{PM}_{2.5}$, PM_{10}) saw a 10% escalation in pollution levels relative to the area's average. Likewise, MP5 registered an 20,9% surge in pollution concentration. Together, throughout February, these two monitoring locations exhibited no discernible temporal effect on pollution retention. The observed elevations in pollutant concentrations at these two locations can be directly linked not only to their closeness to construction sites and notable traffic congestion around the complex's boundary but also to wind direction, which plays a significant role in transporting pollution within the complex.

Finally during March at MP4 the average concentration of all pollutants (NO_2 , $\text{PM}_{2.5}$, PM_{10}) exhibited an 15,1% increase in pollution levels compared to the averages for the area. Similarly, MP4 showed a 25,9% increase in pollution concentration. The increase in pollution levels at these two sites is directly correlated with their proximity to construction activities and substantial traffic congestion at the complex's edge. Additionally, the direction of the wind significantly contributes to the movement of pollutants within the complex, further influencing the concentration levels observed.

The disparities observed in pollutant concentrations during the monitoring activities at Delijorgji can largely be ascribed to fluctuations in wind patterns and specific meteorological conditions, reinforcing the premise that the configuration of urban environments exerts a considerable influence on air quality. A comprehensive analysis of the collected data reveals that the architectural

layout of this complex is not conducive to the formation of Air Pollution Cavity Areas. However, the pronounced elevation in pollutant levels at monitoring points MP4 and MP5, which register 15.3% above the mean pollution concentration compared to other surveyed locations within the complex, is attributed to heightened emissions stemming from adjacent construction endeavors and vehicular congestion. This phenomenon underscores the fact that wind patterns do not merely facilitate efficient ventilation of the area but also play a pivotal role in the transportation of emissions originating from proximate sources, as evidenced by peak levels recorded at buffer monitoring points 1, 2, and 3. This analysis not only highlights the critical role of urban design in air quality management but also underscores the dynamic interaction between local emission sources, urban form, and atmospheric conditions in shaping the urban air pollution landscape.

Graphic 77: Indicative visualization of the most polluted locations



Source: Author

Despite the Delijorgji complex exhibiting significantly elevated pollutant concentrations compared to the Magnet complex—for example, NO₂ levels are at least 25% higher than the aggregate NO₂ concentrations monitored across all locations from January to March, while PM₁₀ and PM_{2.5}

concentrations are 10.7% and 6% higher, respectively—none of the monitoring sites within the Delijorgji complex demonstrate any evidence of a temporal pollution retention effect nor any cavity areas due to its urban form. This observation rather suggests that while the complex experiences higher levels of air pollutants, the specific urban form do not contribute to prolonged retention of these pollutants over time but it rather creates urban wind canyons that do ventilate pollution in and out the complex. It is noted that wash out effect both from wind and rain is far more efficient at Delijorgji than at Magnet complex.

Kika Complex, with its unique closed corners and strategic tunnels, presented a compelling case of how urban form can both hinder and facilitate pollutant dispersion. The complex's design, which theoretically should have optimized natural ventilation, was found to be susceptible to retaining pollutants under specific wind conditions. This paradox highlights the complexity of designing urban spaces that are both aesthetically pleasing and environmentally functional. The overall correlation coefficient between air pollution and wind present within the complex is $r^2=0.66$ indicating the strongest link on the role of wind to pollution dispersal compared to all other monitored complex. This is mainly attributed to the slightly higher altitude of the terrain at Kika's.

During January at MP1 the average concentration of all pollutants (NO_2 , $\text{PM}_{2.5}$, PM_{10}) exhibited an 14.4% increase in pollution levels compared to the averages for the area. Similarly, MP3 showed a 6.9% increase in pollution concentration. Collectively, during January, these two monitoring locations also demonstrated a temporal effect on pollution retention, extending from 24 to 36 hours, in contrast to other monitoring sites where the natural dispersion of air pollution is more effectively facilitated by wind presence.

During February, at MP1 the average concentration of all pollutants (NO_2 , $\text{PM}_{2.5}$, PM_{10}) exhibited an 20,5% increase in pollution levels compared to the averages for the area. Similarly, MP3 showed a 11,3% increase in pollution concentration. Collectively, during February, these two monitoring locations also demonstrated a temporal effect on pollution retention, extending from 36 to 48 hours, in contrast to other monitoring sites where the natural dispersion of air pollution is more effectively facilitated by wind presence. This temporal effect is believed to have been stimulated given the dry period that characterized February during 2023.

Finally, during March at MP1 the average concentration of all pollutants (NO_2 , $\text{PM}_{2.5}$, PM_{10}) exhibited an 22% increase in pollution levels compared to the averages for the area. Similarly, MP3 showed a 16,8% increase in pollution concentration. Collectively, during March, these three

monitoring locations also demonstrated a temporal effect on pollution retention, extending from 12 to 24 hours, in contrast to other monitoring sites where the natural dispersion of air pollution is more effectively facilitated by wind presence.

The variability in wind directions, coupled with specific meteorological conditions, contributed to a notable fluctuation in pollutant levels, affirming the hypothesis that urban form profoundly influences air quality. The analysis of monitoring outcomes suggests that the urban form of KIKA complex fosters the formation of two Air Pollution Cavity Areas. Notably, MP1 is identified as the most adversely affected location, exhibiting the most significant pollution retention, with a 19% increase in pollution concentration compared to other sites where natural pollution dispersion occurs more efficaciously. Given the similarity of urban form with Magnet complex, KIKA registers higher pollution concentration given its proximity with main road and congestion in Tirana. KIKA is the second most polluted area out of the four monitored locations during January – March 2023.

Ekspozita, characterized by its strategic design conducive to natural ventilation, showcased the pivotal role of wind in dispersing pollutants. Despite its proximity to construction sites and major traffic roundabouts, the complex demonstrated a robust capacity for pollution mitigation, attributed to its architectural orientation and the presence of wind tunnels. This observation underscores the potential of urban planning and design in enhancing air quality, even in densely populated urban environments.

Table 69: Summary of observed meteorological conditions from January to March 2023

	January			February			March				Average		
	Sun	Cloud	Rain	Sun	Cloud	Rain	Sun	Cloud	Rain		Sun	Cloud	Rain
Morning	16	9	6	14	13	1	13	11	7	Delijorgji 07:30 - 09:30 am	43	33	14
	52%	29%	19%	50%	46%	4%	42%	35%	23%		48%	37%	16%
Noon	16	9	6	14	13	1	14	10	7	Kontakt 10:00 - 12:00 am	44	32	14
	52%	29%	19%	45%	42%	3%	45%	32%	23%		49%	36%	16%
Afternoon	15	11	5	15	11	2	14	7	10	KIKA 13:30 - 16:00 am	44	29	17
	48%	35%	16%	54%	39%	7%	45%	23%	32%		49%	32%	19%
Evening	15	7	9	18	8	2	17	10	4	Ekspozita 17:00 - 19:40 am	50	25	15
	48%	23%	29%	64%	29%	7%	55%	32%	13%		56%	28%	17%

Source: Author

The overall correlation coefficient between air pollution and wind present within the complex is $r^2=0.489$ indicating a moderate link on the role of wind to pollution dispersal. Even though expected to have the strongest correlation, the urban form and orientation facilitating the ventilation from Northwest and Southwest winds did not occur due to the fact that only 7% of the monitoring period these wind directions were present.

During January at MP3 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) saw a 3,1% escalation in pollution levels relative to the area's average. Likewise, MP5 registered an 12,3% surge in pollution concentration. During the month of January, only monitoring point MP3 demonstrated a temporal effect on pollution retention, attributed to a minor vortex effect resulting from a ground-floor extension added to a household. Conversely, MP5 did not exhibit any temporal retention of pollution. The increased pollutant concentrations observed at MP5 can be directly linked to its proximity to a construction site and notable traffic congestion along the sole thoroughfare that connects the Tirana Ring Road with Myslym Shyri street through this complex. This distinction underscores the influence even of minor specific structural modifications and urban activities on the dynamics of air pollution dispersion and retention within the area.

During February at MP3 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) saw a 6,1% escalation in pollution levels relative to the area's average. Likewise, MP5 registered an 17,6% surge in pollution concentration. Consistent with observations made in January, only MP3 exhibited a temporal effect on pollution retention, which is ascribed to a minor vortex effect induced by the construction of a ground-floor extension to a residential building. In contrast, MP5 showed no signs of temporal pollution retention. The elevated levels of pollutants at MP5 are directly associated with its closeness to a construction site and significant traffic congestion on the critical road linking the Tirana Ring Road with Myslym Shyri street, traversing this complex. Additionally, the uptick in pollution concentrations during February is attributed to an extended period of drought, further complicating the environmental challenges faced by this urban area.

Finally during March at MP3 the average concentration of all pollutants (NO₂, PM_{2.5}, PM₁₀) exhibited an 4,8% increase in pollution levels compared to the averages for the area. Similarly, MP5 showed a 14,7% increase in pollution concentration.

An exhaustive examination of the data gathered indicates that the architectural configuration of this complex does not facilitate the development of Air Pollution Cavity Areas (APCAs). Nevertheless, a significant increase in pollutant concentrations was observed at monitoring point MP3, where levels were found to be 4.7% higher than the average pollution concentration across other evaluated locations within the complex. Whilst as mentioned, MP5 higher concentration are attributed to the fact that it is used more frequently by vehicles than the other streets of the complex.

The increase at MP3 is specifically attributed to modifications made to the ground floor at this particular site. It can be inferred that even minor alterations to the urban form, especially those that result in enclosed corners, can lead to the formation of APCAs, with a preliminary augmentation in pollution concentrations by approximately 4-5%. This phenomenon contrasts with similar effects observed at the KIKA and MAGNET complexes, where alterations in urban form are associated with a more substantial increase in pollution concentrations, ranging from 10-15%. This analysis underscores the nuanced impact that specific structural changes within urban environments can have on air quality, particularly in terms of facilitating localized increases in pollutant levels. Across all four complexes, the effect of rain on reducing pollutant concentrations was consistently observed, emphasizing the natural wash-out mechanism's role in air quality management. However, the resurgence of pollution levels post-rainfall, particularly in areas identified as Air Pollution Cavity Areas, indicates the need for more holistic and adaptive urban planning strategies that consider the dynamic interplay between weather patterns, urban form, and air quality.

In conclusion, the architectural configuration characterized by high-rise structures (from 7 to 14 floors) with closed perimeters around the block emerges as a pivotal factor in the genesis of Air Pollution Cavity Areas (APCAs). Throughout this study, a minimum of six APCAs were identified, illustrating an average increment in pollution concentration of 10.7% relative to locations with more efficient ventilation. Furthermore, a significant temporal effect on pollution retention, extending beyond 24 hours, was observed. This finding underscores the profound impact of urban design on air quality, affirming the critical need for integrating considerations of air flow and pollutant dispersion in the planning and development of urban spaces. This thesis substantiates the hypothesis that the urban form significantly contributes to the formation of APCAs, offering essential insights for the advancement of sustainable urban planning practices aimed at mitigating air pollution and enhancing public health. The author estimates that within these six identified Air Pollution Cavity Areas (APCAs), an average of 150 individuals are subjected to unintended effect on increase concentration in air pollution levels, as they reside, work, or regularly visit these precise locations on a daily basis. This exposure highlights the pressing need for urban planning and architectural strategies that prioritize the health and well-being of city inhabitants by addressing the underlying design elements contributing to localized pollution accumulation. Furthermore, the author hypothesizes that within the city center of Tirana, there may exist approximately 780 to 800 Air Pollution Cavity Areas (APCAs), which could significantly exacerbate the quality of life for individuals exposed to this phenomenon. This estimation underscores the imperative for

comprehensive urban environmental assessments and targeted interventions aimed at mitigating the adverse effects associated with such high concentrations of APCAs on public health and urban livability.

Conclusions:

This intricate analysis advances a sophisticated comprehension of the dynamics governing urban air quality, set against the backdrop of Tirana's distinct climatic conditions and architectural configurations. It casts light on the pivotal influence of urban form in pollution mitigation and accentuates the necessity of embedding environmental considerations within the fabric of urban planning and developmental strategies. Through an incisive exploration of the phenomena of temporal pollution retention, vortex effects, and the consequential impacts of Air Pollution Cavity Areas on the overall ambient air quality, the research elucidates the intricate relationship between urban design principles and environmental health.

As urban landscapes expand and transform, the empirical evidence derived from the examination of the Magnet, Delijorgji, Ish-Ekspozita and Kika complexes epitomizes the capacity of architectural ingenuity and strategic urban planning to cultivate resilient and sustainable urban ecosystems. This study's revelations regarding the processes of pollution dispersion and retention in urban contexts furnish a foundational blueprint for subsequent scholarly inquiry and urbanistic endeavors aimed at ameliorating air quality and enhancing communal health.

Ultimately, this exploration through the domain of urban air quality research reiterates the symbiosis between environmental science, urban planning, and public health disciplines. It heralds a multidisciplinary approach to urban development, aspiring to synchronize the objectives of architectural elegance with the prerogatives of ecological stewardship and human welfare.

By substantiating the hypothesis that urban form exerts a profound effect on air quality, this investigation paves the way for future scholarly pursuits into sustainable urban planning and architectural designs that elevate environmental health. It champions a comprehensive and adaptable urban planning methodology, one that seamlessly integrates the dynamic interactions among meteorological conditions, urban configurations, and air quality considerations into the cultivation and rejuvenation of urban territories.

Across the complexes studied, urban morphology significantly influences the natural ventilation and dispersion of pollutants. The Magnet and Kika complexes, with their unique configurations,

demonstrated the formation of Air Pollution Cavity Areas due to specific urban forms that hinder wind flow, especially noted at Magnet's MP5 in January and Kika's MP1 and MP3. Conversely, Delijorgji and Ekspozita, benefiting from their strategic orientation and wind tunnels, showcased a stronger dispersal capability, underlining the importance of architectural planning in pollution mitigation alongside with the similar results from (Tom V. Kokkonen, 2021) "The effect of urban morphological characteristics on the spatial variation of PM_{2.5} air quality in downtown Nanjing"

The study consistently highlights the dual role of wind and rain in reducing pollutant levels. Notably, at Delijorgji and Ekspozita, a significant washout effect was observed during March, directly attributing to lower pollution levels compared to the drier months of January and February. This phenomenon aligns with findings from (Wu Y, 2022) regarding the air pollution wash-out through artificial precipitation. A case study from Yangtze River Delta.

Ekspozita stand out for their natural ventilation efficacy, attributable to its linear and parallel residential structures as well as to the mature urban greenery present within the area and in its surroundings. Despite the proximity to construction activities, congestion the complexes exhibited lower pollution levels, particularly in March. This resilience to pollution accumulation underscores the lasting benefits of thoughtful urban design and orientation, as discussed in (Wei, 2016) "Impact of Urban Morphology Parameters on Microclimate" whereas their indirect conclusion that areas least exposing Urban Heat Island phenomena are also the best performing with regard to air quality. Hindering therefore the importance and the key role that urban greenery and its ecosystem service can have on mitigating Air Pollution Cavity Areas.

This analysis underscores the imperative for interdisciplinary approaches to urban planning that prioritize air quality. As cities evolve, the lessons from Tirana's complexes highlight the critical role of urban design in sustainable urban management. Future research should further explore the dynamic interplay between urban forms, weather patterns, and air quality, incorporating advanced modeling techniques and long-term data analysis, mapping air pollution cavity areas to supply and materialize findings into policy and oriented decision making in planning practices.

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