# THE WIND INFLUENCES OVER THE POLLUTION CONCENTRATION IN THE URBAN ENVIRONMENT IN THE CITY OF CLUJ NAPOCA

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**Abstract:** Currently, 55% of the world's population lives in urban areas, a proportion that is expected to increase by 2050 to 68% (ec.europa.eu). Urban air quality continues to be an essential health issue, accompanied by the fact that one of the fundamental global sources of air pollution in the city is traffic emissions (Kumar et al., 2015). The purpose of this study is to highlight the effects on wind flows in an urban environment, especially on atmospheric pollutants. For this purpose, the main arteries of Cluj-Napoca were selected as a case study, Marasti -BRD, - Orthodox Cathedral- St. Michael's Church - Calea Motilor - Calea Manastur. These areas were chosen because they were monitored by different measuring instruments from several / various locations, which provided input data for the present study. Likewise, two situations were considered regarding the winds in the municipality of Cluj, from a seasonal point of view: summer and winter. Were distinguished 11 sectors on the west-east alignment, having specific characteristics, depending on the existing buildings and spaces. There were significant differences between the wind rose in the winter and the summer. This results leads to local air movements more pronounced than in winter period, having as an effect a quasi-constant state of pollution. As a result, it is necessary to "help" the improvement of air quality by planting a mix of arboreal species in these areas, which we call „oxygen fountains".

**Keywords:** oxygen fountains, polluting factors, wind frequency, laminar flow, swirling

## INTRODUCTION

Currently, 55% of the world's population lives in urban areas, a proportion that is expected to increase by 2050 to 68% (ec.europa.eu). This rapid and unprecedented growth has led to notable challenges such as loss of natural habitat, species diversity, environmental degradation and increased risks to human health associated with wind, heat and weather; noise, pollution and agglomeration. This reveals that the population and especially children grow up and live in environments with increasing pollution, intense heat and less access to the most diverse green spaces (Cohen, et al., 2012; Moore et al., 2003; Newman & Jennings, 2008).

Urban air quality continues to be an essential health issue, accompanied by the fact that one of the fundamental global sources of air pollution in the city is traffic emissions (Kumar et al., 2015). There are six major components that are specified as indicators of air quality, based on their effects on health or the environment, which are called air pollutants criteria. Carbon monoxide (CO), ozone (O3), nitrogen dioxide

($NO_2$), sulfur dioxide ($SO_2$), suspended particles (PM10 and PM2.5) and Lead (Pb) are defined as air pollutant criteria in environmental conditions (US EPA, 2015). In the urban environment, the pollutants present and their concentrations vary substantially over time and space, depending on those factors that control the inputs; these include the number and resistance of sources of pollution emissions and atmospheric conditions, as well as those affecting the rates of elimination from the atmosphere, especially the climate, the type and shape of urban infrastructure.

The scale of cities has developed rapidly, simultaneously with the development of the urbanization process. The urban construction has changed the natural geomorphological conditions and an urban microclimate has formed which differs greatly from the natural climate, being replaced by built materials and, consequently, the roughness of the land surface is significantly changed (Roth, M., 2000, Oke, TR, 1997). The urban climates are distinguished from the areas less built by the differences in air temperature, wind speed and direction, humidity and the amount of precipitations. These differences are largely attributed to the modification of the natural terrain by the construction of artificial structures and surfaces (britannica.com/science). Wind flow and precipitation leakage are affected by tall buildings, paved streets and parking lots, so wind convergence in urban environments is low (the air tends to flow in a city from all directions), and high buildings obstruct and separate the wind. (Ng, E., 2009, Gu, ZL et al., 2011) and canyon swirls form in canyons of urban streets (Oke, TR, 1988, Hang et al., 2012), often leading to a low wind speed close to the ground or pedestrian level. The decrease of the wind speed at the pedestrian level determines a significant threat for their thermal comfort in the urban areas (Nazarian, N. et al., 2017). A fundamental component of the urban microclimate is considered the urban wind environment. The role of urban morphology and architectural elements on the urban flow and the thermal field is undeniable. One of the most important parameters in the classification of the flow field within an urban street canyon was identified the canyon aspect ratio (height-width) (Li, X.X., et al., 2009). In-city wind research is an essential basis and a prerequisite for evaluating and improving the urban wind environment and plays an important role in improving the quality of the urban environment (Yang, J.; Zhang, T, 2016).

Although the degradation of air quality is inevitable as a consequence of urban development, it is well known that urbanization and associated activities are vital to the development of the world. Thus, given these challenges, researchers, engineers, environmentalists and urban planners identified the need for opportunities to maximize well-being opportunities and reduce air pollution resulting from urbanization (Saunders et al., 2011). In this regard, a viable urban planning solution for improving air quality, the sustainability of cities for growing urban populations is identified green infrastructure (Irga et al., 2015; Salmond et al., 2016). These green solutions include oxygen fountains - street bumps, vegetation barriers (including living fences), walls and green roofs. They act as porous bodies that influence the local dispersion of pollution and help the deposition and elimination of atmospheric pollutants, which makes the air cleaner.

The purpose of this study is to highlight the effects on wind flows in an urban environment, especially on atmospheric pollutants. The starting point in this approach was the "Integrated air quality plan for Cluj Napoca agglomeration" elaborated by Cluj Napoca City Hall. For this purpose, the main / interest arteries of Cluj-Napoca were selected as a case study, Marasti -BRD, - Orthodox Cathedral- St. Michael's Church-Calea Motilor -Calea Manastur. These areas were chosen because they were monitored by different measuring instruments from several / various locations, which provided input data for the present study. They consist of weather stations and continuous air quality monitoring, equipped with automatic equipment for measuring the concentrations of the main atmospheric pollutants. The locations are particularly interesting because the observations show that in Cluj Napoca the prevailing wind is from E-SV to V-NV.

## MATERIAL AND METHOD

The paper presents the action mode of the winds on the place of concentration of the polluting factors existing in the atmosphere of the city of Cluj Napoca, as well as their places of dispersion (Fig. 1).

In this way, it can apply specific solutions to reduce pollution such as "oxygen fountains". Planting in these places a tree, up to groups of trees can produce a large flow of oxygen, thus improving the air quality. For example: an adult beech tree with a height of 25 m and a diameter of the crown of 15 m, produces in an hour 1.7 kg $O2$, needed for a person for a period of 72 hours.

**Method:** Two situations were considered regarding the winds in the municipality of Cluj, from a seasonal point of view: summer and winter. Also, the wind rose for Cluj was studied and were expressed the frequencies and speed of the winds in the two recording stations from the western part of the city and the one located at the Avram Iancu International Airport. (Table 1)

Based on the calculated values, was prepared the wind rose for the seasons analyzed in this paper (Fig. 2a and Fig. 2b).

Following the city map of Cluj Napoca in the west-east direction, several sectors were isolated that have specific characteristics, depending on the existing buildings and spaces. Thus, 11 sectors are distinguished according to the division illustrated in Figure 3a and Figure 3b, of which the first 6 sectors in the western part of the city and 5 sectors in the eastern part of the city.

**The 11 sectors mentioned above have the following characteristics:**

**Sector 1 -** represents a canyon street type with discontinuous fronts, with buildings of the same height, about 30 m and vegetal intercalations (Fig. 3a).

**Sector 2 -** has the characteristic of discontinuous fronts, having different heights of the buildings between 4 and 30 m.

**Sector 3 -** is characterized by discontinuous fronts, having buildings of the same height of about 30 m and also has vegetal intercalations, similar to sector 1.

**Sector 4 -** urban canyon, with discontinuous fronts having buildings with heights of aproximately 30 m on the south side and open front with vegetation on the north side.

**Sector 5 -** represents a sector with continuous fronts, with buildings having different heights, between 4 m and about 30 m.

**Sector 6** - is characterized by continuous fronts, with buildings having variable heights between 4 and 35 m, being a canyon type street, similar to sector 5.

**Sector 7** - similar to sector 5 and 6, being a canyon street that presents discontinuous fronts, having buildings of different heights, between 5 - 20 m.

**Sector 8** - is a special case, being totally uncharacteristic to the other sectors, being present the BRD bank building, which has a height of 50 m and the St. Peter's Church with a garden in the center of the artery.

**Sector 9** - is an urban canyon with continuous fronts, having buildings with a constant height of about 30 m

**Sector 10** - there are discontinuous fronts with buildings of the same height of about 25 m and vegetal intercalations. The air circulation scheme is similar to sectors 1 and 3.

**Sector 11** - is a discontinuous front, with variable heights on the south side and an open front on the north side. It resembles sector 4.

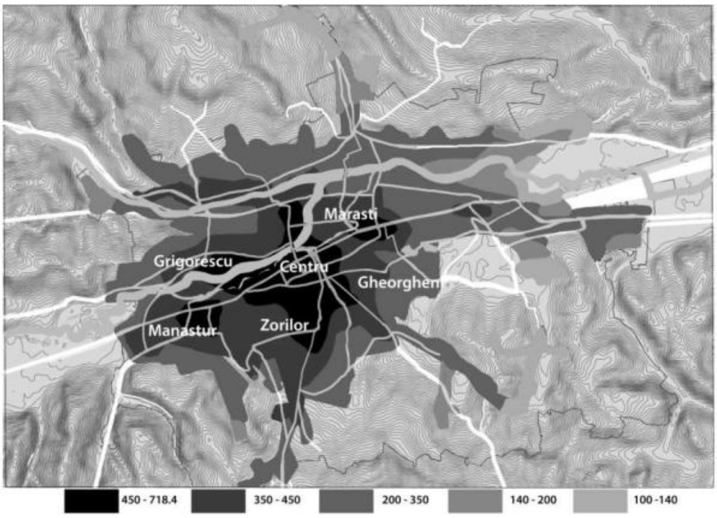
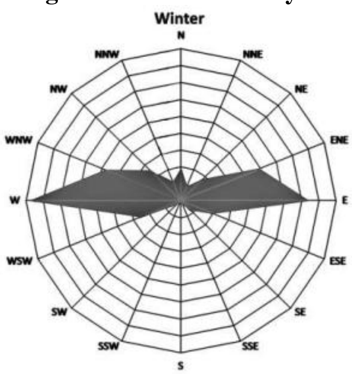



**Fig. 1. Maximum hourly concentrations for NO2 in Cluj Napoca (ug/mc)**



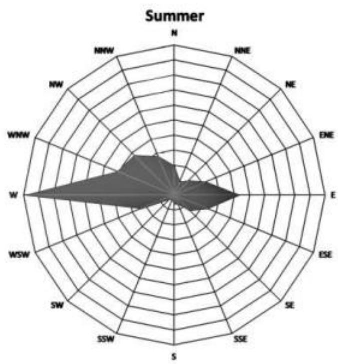




**Fig. 2a. The wind rose in the winter season** **Fig. 2b. The wind rose in the summer season**

(Source: original)

**Table 1.**

**Frequencies and wind speed in the winter season and the summer season**

| Wind during the **winter** time in Cluj Napoca | | | | Wind during the **summer** time in Cluj Napoca | | |
|---|---|---|---|---|---|---|
| **Wind direction** | **Wind hours count** | **Average of wind speed (m/s)** | | **Wind direction** | **Wind hours count** | **Average of wind speed (m/s)** |
| Wind blowing from the west | 438 | 3.5 | | Wind blowing from the west | 494 | 2.7 |
| Wind blowing from the east | 371 | 2.9 | | Wind blowing from the east | 216 | 2.3 |
| Wind blowing from the east-northeast | 246 | 2.5 | | Wind blowing from the west-northwest | 205 | 3.4 |
| Wind blowing from the west-northwest | 237 | 5.0 | | Wind blowing from the north-west | 188 | 4.1 |
| Wind blowing from the west-southwest | 126 | 2.3 | | Wind blowing from the north-northwest | 140 | 4.1 |
| Wind blowing from the north-west | 125 | 4.6 | | Wind blowing from the east-southeast | 119 | 3.1 |
| Wind blowing from the east-southeast | 99 | 3.1 | | Wind blowing from the west-southwest | 117 | 2.4 |
| Wind blowing from the north | 94 | 3.2 | | Wind blowing from the east-northeast | 115 | 2.2 |
| Wind blowing from the north-east | 89 | 2.5 | | Wind blowing from the north | 98 | 3.2 |
| Wind blowing from the north-northwest | 60 | 3.2 | | Wind blowing from the south-east | 73 | 3.6 |
| Wind blowing from the north-northeast | 45 | 2.7 | | Wind blowing from the north-east | 69 | 2.2 |
| Wind blowing from the south-east | 39 | 2.8 | | Wind blowing from the north-northeast | 48 | 2.5 |
| Wind blowing from the south-west | 15 | 1.9 | | Wind blowing from the south-southeast | 33 | 2.9 |
| Wind blowing from the south-southeast | 12 | 2.1 | | Wind blowing from the south | 30 | 3.1 |
| Wind blowing from the south | 9 | 1.9 | | Wind blowing from the south-southwest | 19 | 3.8 |
| Wind blowing from the south-southwest | 5 | 1.6 | | Wind blowing from the south-west | 19 | 2.6 |

Source: https://rp5.ru/

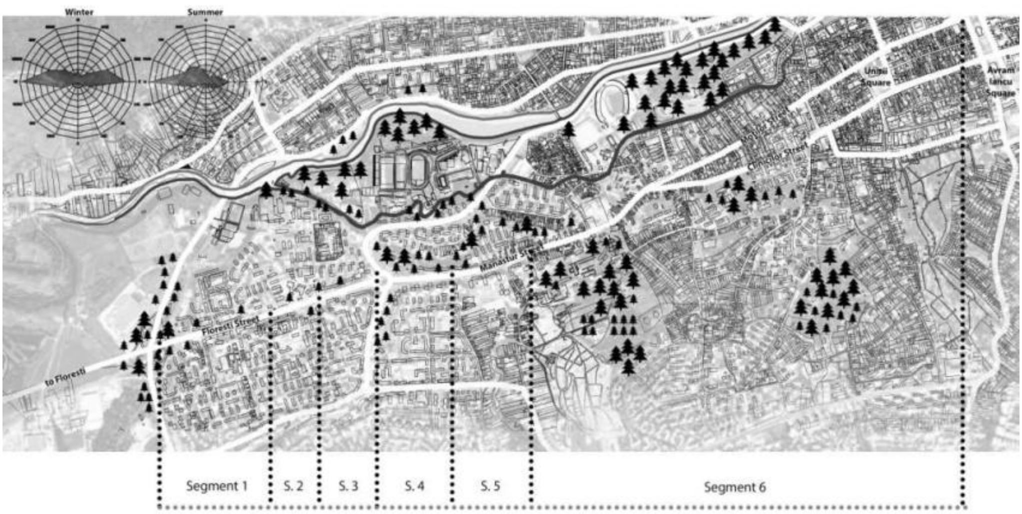



**Fig. 3a. The city map of Cluj Napoca with the sectors in the west-east direction, from Calea Floresti to Avram Iancu Square**

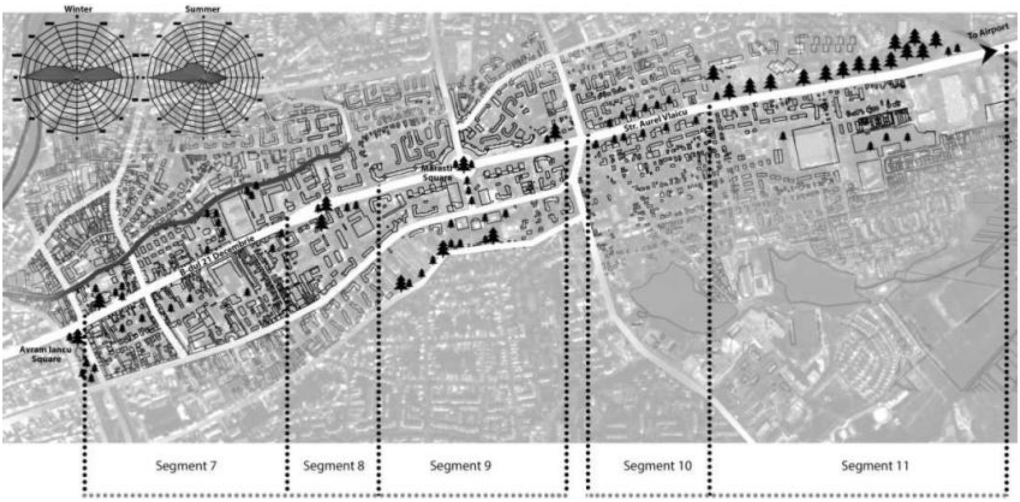



**Fig. 3b. The city map of Cluj Napoca with the sectors in the west-east direction, starting from Avram Iancu Square towards Avram Iancu Airport**

## RESULTS AND DISCUSSIONS

Studying the air circulation in the sectors 1, 3 and 10, the intensity of the dominating wind increases alongway the canyon and its crossing with the transversal wind leads to creation of vortices which helps the dispersion of the pollution particles.

In such types of situations, the dispersion of the pollution particles is much more emphasized and the air dynamic increases, leading to a better air purrification (Fig. 4).

In the 2$^{nd}$ sector, the dominant wind flows alongway the canyon, crossing the least dominant wind, which flows approximately perpendicular on the dominant wind. Following this crossing, there is a light dispersion and vortices of the wind currents and also of the pollution particles carriend by the wind.

Because the canyon effect is diminuated by those spaces between the buildings, which allows the air to flow with less resistance along its way, there is a less pollution particles accumulation in such areas (Fig. 5).

The dominant wind on the 4$^{th}$ and 11$^{th}$ sectors has a semilaminar flow because of the buildings alignment.

The vegetation side located on the opposite side from the buildings alignment, acts likes a buffer to the wind intensity and also for the pollution particles transportation, which also, it diminuates the air dinamics in such areas.

In the 5, 6 and 7$^{th}$ sectors, because of the friction forces between the wind and the existing material shapes and the street surface, the intensity of the dominant wind decreases. The air movement in the crossing area between the winds, represents very well the tipical canyon effect but with less intensity than a normal canyon.

The 5$^{th}$ sector represents a particular case compared with the 6$^{th}$ and 7$^{th}$ sector, having a secondary alignment.

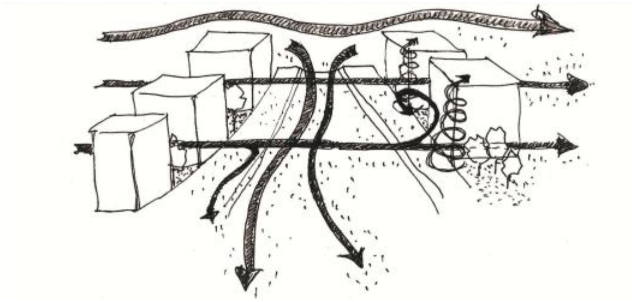


**Fig. 4. Discontinuous canyon alignment with same size buildings**

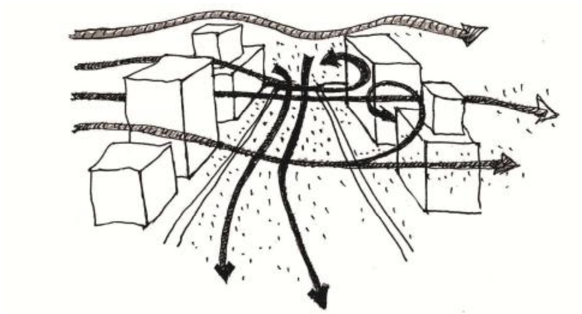


**Fig. 5. Discontinuous canyon. Buildings heights between 4 and 30 m.**

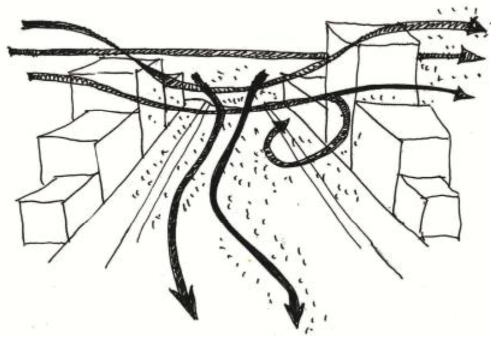


**Fig. 6. Continuous canyon. Buildings with heights between 4 and 45 m**

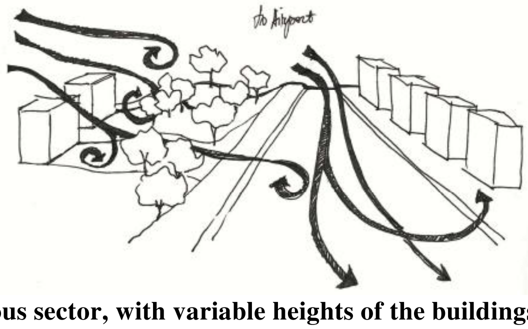



**Fig. 7. Discontinuous sector, with variable heights of the buildings and a vegetation section on the southern side**

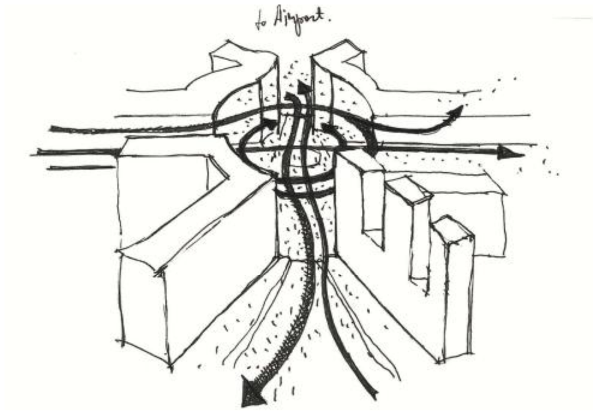



**Fig. 8. Continuous canyon, with same heights buildings of approximately 30 m.**

In the 9th sector, the dominant wind which flows alongway the west-east direction, and also east-west direction, is crossing another wind, intensified by the north-south canyon. Following this crossing, it leads to a spiral movement of the air, which helps the dissipation of the pollution particles (Fig. 8).

## CONCLUSIONS

Following the analyse of the situation, we can observe significant diffrences between the winter wind and the summer wind. In the summer wind rose there is a major increasment of the west side winds. This leads to major air movements more intensified than in the winter time leading to a constant air pollution.

Durring the winter time the rose wind shows an almost equal wind between the west and the east side.

According to the situation it is necessary to help the air quality improvement, by planting a mix of tree species in areas with low air quality, called ”oxygen fountains”.

The analysis study of the maximum and minimum wind activity shows us with a good precision the locations where we can create these oxygen fountains. In such way we can contribute efficiently to increase the well being.

The case of the Cluj Napoca city, where there is the posibility to counterfight the pollution effect in a short term or on a long term period of time, by planting trees is complex but plausible. Of course, alone it would not have the necessary impact, but it can be the perfect background for implementing new solutions for the environment. Less traffic by improving the common transportation in the city and less cars on th roads could have a great impact. Also designing and increasing the green areas in the city is a must for the future city planning.

For this planting operation to be efficient in an complex urban reality like in the city of Cluj Napoca, it should be immediate, big and efficient, located in the main poluted areas with tree species special selected for those areas, accordingly to the soil, exposure and climate aspects.

The city of Cluj Napoca is located on the corridor of Somesul Mic River, at a medium altitude of 363 m, in a valley area, sided by hills of over 500 m altitude and over 700 m in the southern side (Fig. 9).

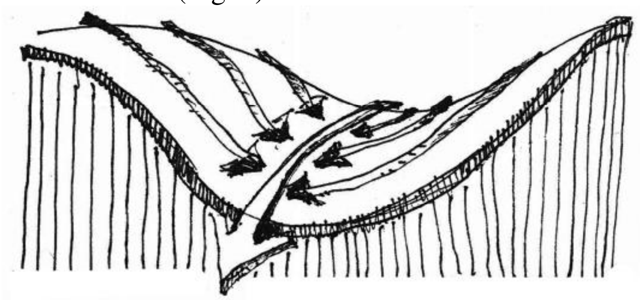


**Fig. 9. The air circulation in a valley shape relief.**

The main phenomenon manifestating in this area and with decissive influence along the air quality in the city is the vertical air temperature inversion, caused by the valley in which the city is located with the hills around the city. This leads to creation of diffrent phenomenons like mist and it keeps the pollution in the valley. It also leads to the formation of heat islands inside the urban area where the temperature is higher with 8 Celsius degrees, than the surroundings, with extreme values indicated in the southern side of the city. The east side of the city is more sensitive thermical because of the industrial located in that area, the airport located near and the Pata Rat. Also from the eastern side there is a more intensified wind activity, which does not follow the main arteries orientated from east to west, but because of the new high buildings, it spredeas irregularly creating new particularities of the air circulation.

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