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Air Quality in the City of Erzurum: Strategies for Climate Sensitive Urban Design

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15 June 2015

Abstract

In this paper, it is claimed that the relationship between urban design and climate conditions enable the emergence of sustainable urban physical environments that will be the places of the world of the future. After serious ecological problems like urban heat island and urban air pollution in this century, researchers began to focus on bioclimatic- and eco-comfort in urban areas. Air circulation or ventilation channels as one the climate and comfort related variables is essential for the mitigation of air pollution, heat temperature, cooling and ventilation.

The main objective of this paper is to explore the relationship between the wind flow, air pollution and physical structure of the built environment in the city of Erzurum, Turkey. It attempts to understand the reasons of the environmental problems and propose climate sensitive urban design approaches by emphasizing green air corridors or wind channels for Erzurum. In this study, it is questioned whether the urban form and geometry (size, density, street orientation and ventilation), street and public space layout, height and shape of the buildings, vegetation, energy flow and water cycle in selected corridors of Erzurum are designed according to the prevailing wind direction and climate conditions. In this direction, by considering the general features of the ventilation channels, orientation and continuity of open spaces, streets and parks, dimensions and shape of open spaces, settlement patterns, density, average height, hard-surfaces, property relations, flora and density of green areas are analyzed for the axles extending parallel to the wind direction towards agglomeration areas of air pollution in the city.

The findings show that urban built environment in the Erzurum prevent the ventilation. Existing air pollution, ventilation problems and high temperature differences in the city are the threatening factors for ecologically sustainable urban development. Settlement pattern and urban form of the selected corridors or axles must be reconsidered with ventilation perspective. Creation of green ecological spaces in old areas, new green public spaces, and reasonable range of building density can be accepted as the first stage solutions for the city. Otherwise, central areas of the city and its urbanization process will again be unsustainable in the future and have low quality of life. For ecologically sustainable urban development, climate sensitive urban design approaches and ventilation channels must be developed and designed for Erzurum.

Keywords: Climate, Air Pollution, Ventilation, Built Environment, Urban Design

1. Introduction

There is huge consensus and vision in the world that the local concentration of air pollutants are affected by the form of the city (Spirn, 1986). In the last years, growing interest can be observed related to the urban form based solutions of air pollution. Urban design, including the quality of public spaces and green areas, ventilation channels, green corridors, location of housing and other uses in urban area, could play an important role for decreasing street level air pollution. In order to decrease this pollution, it is necessary to understand and apply climatic information in the urban planning and design processes. Especially for Turkey, green corridors or ventilation channels has never been considered in urban planning practices. There is a need to bridge the gap between urban climatology and town planning and urban design, and to transfer the climatic knowledge into planning languages (Ren, et.al., 2010). Urban climate and air quality is affected by the physical structure of the city and urban planning controls this structure. Location and size of the city, density of built up area, urban geometry, land coverage, orientation and width of the streets, ventilation and particular land use are the design based factors having big effects on urban climate and improve outdoor comforts of inhabitants (Milosovicova,2010, p.21-33; Givoni, 1998, p.275-301). In this study we focused on the ventilation factor due to the air pollution problem in the city of Erzurum.

2. Ventilation

In addition to the climatic sensitive planning solutions, ventilation channels must be considered in the urban planning processes. It is one of the solutions of air pollution problem and climatic comfort in urban areas and one of the main research fields in this study. Ventilation is essential to decrease air temperature and push the polluted air in the centre upwards in urban areas. So, the main urban design features affecting wind conditions such as *urban density, street orientation, open spaces and height and shape of buildings* (Milosovicova 2010) must be analysed in this study.

As it is explained in Milosovicona's study (p.26), the ***urban density*** is the decisive factor on the ventilation conditions of the streets and natural ventilation of buildings. Built environment and physical characteristics of the urban areas are the factors defining the conditions in this process. Contrary to the main expectations, dense urban areas can provide wide range of wind conditions with the help of different urban design solutions. As Givoni stated (1998, 284), a mixture of high and low buildings in higher density areas provide good ventilation conditions than lower density areas having same height buildings.

The other urban design feature is related to the ***combined impact of street orientation and width*.** It is the factor influencing airflow in urban area depending on the wind direction and the level of compactness. It is accepted in the urban design literature that higher level of compactness hinders ventilation. Street orientation determines the climatic condition in urban areas. As Givoni explained (1998, 290), streets oriented *parallel to the wind direction* create obstacle free ventilation lanes and wider streets are less resistant to the airflow. On the other hand, when the streets are oriented with *an oblique wind direction,* on the street spaces different conditions emerge. On the upper and lower side of the streets, wind conditions change and in the case of wider streets, better wind conditions can be observed. If the streets are *perpendicular to the wind direction* with same height buildings, the first row of buildings diverts the approaching wind upwards and cause an increase for the level of air flow which becomes above the buildings in the following building rows. They are behind the first row and stay in the wind shadow. When the height/width ratio is higher than 2, the streets are narrow and the wind flow cannot reach pedestrian level (Milosovicova 2010). Givoni suggested the use of high-rise buildings in suitable places for the creation of vertical currents stirring the urban air and providing better ventilation on near-ground level (1998, 290-293).

Open spaces and green shelter belts are the other urban design features providing transportation of air flows into the settlement areas. So, they are as ventilation channels used in urban design for the cooling or ventilating of densely populated urban areas. In terms of open spaces, radial, wedge formed space system is accepted as the most effective way for sufficient ventilation of whole city (Milosovicova 2010, 28). The topography is the other important factor for the air currents (Givoni 1998, 285) as it can be observed in Erzurum case. Under these circumstances, different urban design solutions should be considered for better air ventilation. Open parks, green fingers and wide avenues with lower air resistance can be accepted as the solution in this process. There are two types of ventilation channels as fresh air and cold air ventilation channels. While the former one is referring to the channel producing and transporting pollutant free fresh air such as grassy and bushy areas, the latter one refers transportation of cool air into urban areas such as linear water bodies and railways. In this study, fresh air channels will be used as ventilation channels for the city of Erzurum. In order to evaluate the existing condition of the case study area, we should know the general features of ventilation channels. Kuttler's (2008 cited in Milosovicova 2010, 28) study provides detailed framework for the ventilation channels and direct us in this study. According to him, the general features of the ventilation channels should be as following:

"roughness length zo < 0.5 m; zero plane displacement do: negligible; length ≥ 1,000 m; width ≥ 50 m (depends on lateral obstacles), according to various investigations, a width of 100 – 200 m is, due to its effectiveness, more desirable; width of obstacles within the ventilation channel is 2 – 4 times the height of the lateral obstacles (min. 50 m); height of obstacles within the ventilation channel ≤ 10m".

In addition to these features, the form and design of the green areas and building blocks, type and density of trees in these areas are decisive for better ventilation of urban areas.

The last urban design feature is based on the ***height and shape of the individual buildings*.** Average height of the buildings and the distances between them determine the urban ventilation conditions. In order to increase wind speed and flow pattern at pedestrian level, high rise individual buildings can be used in specific urban areas. The location of those building is important because it can block the wind and reduce the wind speed at the same time. Especially for the city centres, high concentration of tall buildings can be observed for all cities in the world. If the streets are not designed according to the wind direction, this type of urbanization reduces wind velocity and cooling effect near ground level. Ideal solution for the use of high rise buildings is the use of them with large open spaces. As a micro-scale solution, design based factors of the buildings is decisive on the wind flow such as the building's own H/W ratio, form of façade, specific design details (setbacks) and shape of roofs (Milosovicova 2010).

When we consider all of those design features affecting urban wind conditions, it can be summarized that a mid-density urban form having angled main streets in parallel direction to the prevailing wind (or in a small angle), and having a few consciously placed high-rise buildings stirring up of the wind masses on the street level would provide sufficient ventilation while preventing street canyons from over-radiation. In addition to these, some other ventilation channels reaching from the urban peripheries into the urban core and inner-city green areas to water bodies will provide ventilation on the level of the whole city (Milosovicova 2010, 30). On the street level, winds are always needed for the climatic comfort. But, design based factors changes depending on the seasonal effects of wind. In winter months, cold winds does not preferred in the residential areas for the thermal comfort but it is needed because of the seasonal problems such as air pollution. Therefore, both parallel (main roads, avenues) and perpendicular (pedestrian ways and other streets) street orientation can be used in urban design processes according to the climate conditions and environmental problems.

Although, there are so many studies in the literature related to the climate factors, they are not sufficiently incorporated into the urban planning projects. There may so many reasons in this process such as cost problems, knowledge problems, policy problems, absence of interest and working practices at municipal level (Ebrahimabadi, 2012). They are important research fields for the climate sensitive urban design but in this study, these problem areas will not be evaluated. It will be more concentrated on the existing situation of built environment according to the air pollution concentrated areas.

3. The Case of Erzurum

In this part of the study, three most polluted districts of Erzurum city are analysed with the factors deduced from the literature as density, floor area ratio, building coverage ratio, average height, sealed surface, sky view factor (svf), green areas and street orientation. These analyses are made with the aim of demonstrating the inconsistencies between settlement patterns and prevailing wind flow. For this reason, existing urban structure is reviewed within this framework.

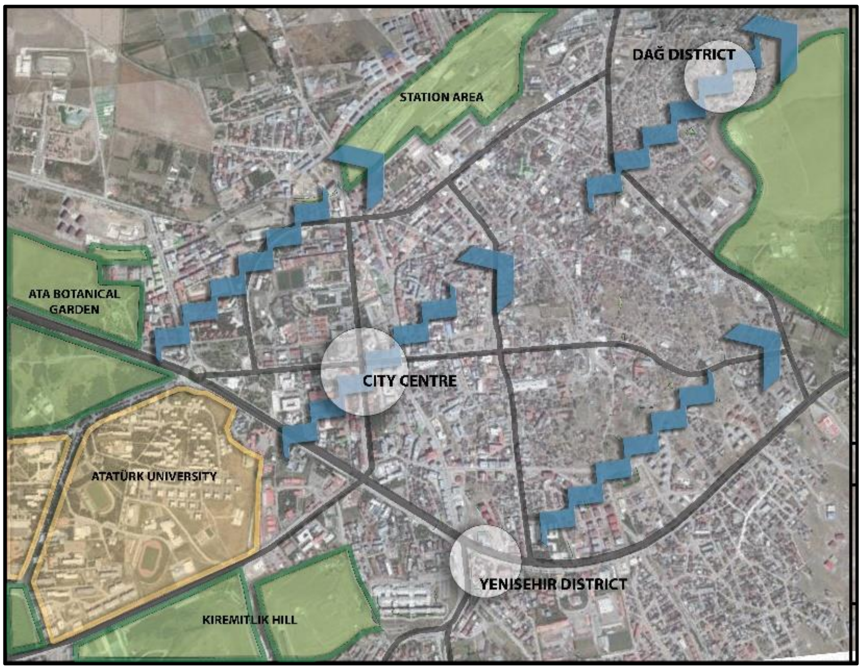

Fig.1 Mostly Polluted Areas and Prevailing Wind Direction

As it is demonstrated in figure 1, Erzurum has serious air pollution problem in the city centre. City centre, Dag district and Yenisehir districts are the three places air pollution mostly concentrated. Quality of life are very low for these places especially for cold winter months. When the source of pollution is analysed, it is understood that use of sulphur coals for heating is the problem. On the other hand, settlement pattern negatively support this situation and unhealthy urban environment become reality for the city of Erzurum.

In the first part, city center is analyzed due to the serious pollution problem. In the winter months, due to the very narrow structure, it is almost not possible to pass across from some of the streets in city center. Air pollution is the main problem of this area. Urban geometry as the climate related factor is analyzed with Sky View factor (SVF) with the aim of evaluating existing situation of built environment. Height/Width ratio is calculated as 4,2 in this area by demonstrating that there are shallow streets, and wind and sunlight cannot reach the street ground. On the other hand, Sky view factor is determined with the fisheye photograph taken in the selected streets as 0.27 and 0,35 by using RayMan module (Matzarakis et al. 2010). It shows that the ratio of sky visible at the middle of the street is 27 and 35%. It can be said for the general structure of the city centre of Erzurum that there are so many deep street canyon forms and blocking buildings for wind flows. If we use the Emmanuel's (2005) suggestion as the ideal value of H/W ratio of urban canyon as 0.4-0.6, city centre of Erzurum has serious problem related to this ratio. The built environment decreases the solar access in the streets and limits the wind flows. As the other urban parameter, building volume is analysed for this region.

They are six to seven floor multi-unit buildings covering big parts of the building blocks. It seems positive at first glance but there is no height difference and open places providing ventilation and solar radiation absorption. When the street orientations are analyzed, it is observed that they are perpendicular with the prevailing wind direction. Design and positioning of the high density built-up areas do not led them to enter city center. Setbacks on the building surfaces, strategically located few high-rise towers, bridge-buildings, corridors and green fingers have not been considered in the planning process. The configuration of streets are narrow and deep in this place by slowing airflow and causing air pollution.

Density as the important parameter of urban climate is measured for this area and seen that it is very high density region with nearly 800 dwellers/ha. High population density, which is more than 250 dwellers, is the reason of high thermal loads and pollution in this area. It has eighty-five percentage sealed surfaces and limited green areas causing higher heat load and polluted air. High urban density and compact or small size urban form in the city center can be considered as positive due to the effects on the climatic comfort with the low ratio of settlement areas and road infrastructure. With the help of short walking and driving distances, they decrease transportation problem. However, no ventilation channels and green corridors and the length of the shadow are the problems of this part. As Givoni (1998) suggested, two-to-three floor buildings oriented towards to south and street orientation according to the wind direction can be considered for this region of the city.

Fig.2 Settlement Pattern in Area 1: City Centre

The air circulation as the essential feature of climatic comfort in urban areas can be provided by the green areas. They transfer exhaust gases, sounds, heat and moisture from urban cores to the other parts of the city. Therefore, ventilation aspects of the design process of settlements should be considered at first stage with the green areas especially in the city center. When the settlement pattern is analyzed (fig.2), high density spontaneous development can be observed. Togetherness of office buildings, houses and stores with appropriate vertical and horizontal separation and location of these buildings according to wind can be the solution for the climatic comfort of city center.

In the second part, Yenisehir Bridge district (NewCity) is analyzed because of its polluted air (Fig.3). As an important urban parameter, geometry is analyzed with H/W ratio and SVF. H/W ratio is calculated as 0.5 in this area. It provides sunlight and radiation to reach the street ground and heat the air near the ground. On the other hand, Sky view factor is measured as 0.36 by using RayMan module. It shows that the ratio of sky visible at the middle of the street is 36%. It can be said for the NewCity of Erzurum that it has an ideal value of H/W ratio of urban canyon as 0.4-0.6. But in this area, there are many unsettled places decreasing this ratio. The built environment increases the solar access in the streets. Building volume as the other urban parameter is analysed for this region. They are five to seven floor buildings covering big parts of the building blocks. It is positive for the climate sensitive consideration but there is no height differences providing ventilation and blocking undesired cold winds. Open places as the positive design elements leading solar radiation absorption are exist in this part of the city but they are not designed places and considered solutions. When the street orientations are analyzed, it is observed that they are blocking prevailing wind flows. As it is emphasized in the literature, they should be planned as perpendicular to the cold winds but should allow the entrance of flow for some spaces. And also, design and positioning of the high-rise buildings in some part of the region can be the strategy for blocking cold winds. The configuration of street has been made as wide providing increase in the speed of airflow. On the other hand, orientations of the building have been planned consisting with the south-north direction providing sunlight reach.

Density as the second urban parameter influencing climate is measured for this region. It is high density region over 500 dwellers/ha. It has limited green areas (15%) increasing higher heat load and air pollution. Urban form in this part of the Erzurum is linear starting from south and developing to south-north direction. It is not in compact form. While the high urban density and linear urban form in this area can be evaluated as negative due to the effects on the climatic comfort, existing low building coverage ratio are the positive aspects. In some parts of this area, the length of the buildings and width among them is casting a shadow over the other buildings. Lower buildings oriented towards to south are the ideal conditions, so these buildings should be designed in this region. When the settlement pattern is analyzed (Fig.3), high density and unorganized development can be observed.

Fig.3 Settlement Pattern in Area 2: Yenisehir Bridge District

In the last part, east-edge of the city is analysed due to its location over hill, air pollution problem and squatter settlement characteristics. This region is very interesting case for this study because its location over the hill create very strange situation for air pollution and wind flow relation. It is expected that there should not be air pollution problem but location of the buildings, heights and distances between them produce these problems and creates unhealthy urban areas. It has very different settlement patterns such as squatter houses and no green areas. In the winter months, due to the coal based heating systems and narrow streets, air pollution is seen in housing area. Urban geometry as the climate related factor is analysed with SVF ratio with the aim of evaluating existing situation of built environment in this place. SVF ratio is calculated as 40 % in this housing area by demonstrating that it has open streets, and sunlight and radiation can reach the street ground and heat the air near the ground. When the street orientations are analysed, it is observed that they are organic form and not parallel to the prevailing wind direction. There is no high rise building creating wind flow and directing them to the building area. As it is emphasized in the literature, setbacks on the building surfaces, strategic location of few high-rise towers, bridge-buildings, corridors and green fingers have not been considered in the planning process. The configuration of street determining airflow in urban areas has been made as narrow in this part by slowing airflow and causing air pollution.

Density as the important parameter of urban climate is observed as low in this place. Low population density, which is lower than 250 dwellers, is positive for thermal loads in this urban area. It has hundred percentage sealed surfaces causing higher heat load and polluted air. Low urban density and compact urban form can be considered as positive due to the effects on the climatic comfort with the low ratio of settlement areas and road infrastructure. However, location and distances of buildings prevents solar and wind accesses in streets.

Land use and settlement pattern of this area showed that there is no green areas. The air circulation as the essential feature of climatic comfort can be provided by the green areas but it is not possible for this place. When the settlement pattern is analysed, low density spontaneous development is observed.

When these three case study areas are evaluated together, it can be said that Erzurum has shown inconsistent urbanization practices with climatic conditions and environmental problems. It is clear that reconsideration of the urban planning method, style and solutions are urgent for this city.

Fig.4 Settlement Pattern in Area 3: Dag District

4. Conclusion

As it can easily be understood, climatic data and wind flow information is not used in urbanization practices of Erzurum. In fact, it can be designed by considering ventilation channels and green corridors because of the air pollution problems in central area. However, there is no awareness about the positive aspects of green corridors and way of coping with the pollution in Erzurum at both municipal and grassroot levels. Ventilation channels can be embraced by them as an opportunity to decrease pollution in urban area. It is crucial for cities to minimize the negative effects of pollution and high density spontaneous urbanization. Wide ranging strategies are available to modify climate and urban design for both winter conditions and pollution in Erzurum. These strategies can be used for the polluted districts of Erzurum to protect them from the terrible cold weather in winter and reduce the need for artificial heating and cooling.

Climatic comfort and urban design has a complicated relationship in urban planning including different scale interventions depending on the land uses in urban area such as built-up, green area, water surface and industrial areas. For the city of Erzurum, compact city form; apartment buildings around courtyards; connected buildings; windscreen buildings; tall and low-rise buildings; less grey and white and more pastel buildings, green corridors and ventilation channels are the design based factors will be considered and planned in urban area. The key strategies should be based on the ventilation of the city, maximisation of solar radiation gain, the use of insulation and the provision of a concentrated plan" (St.Clair, 2010, p.9).

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