

Spatiotemporal Variations of Particulate Matter in Tirana

Medjon Hysenaj^{1*}, Seditë Duraj²

¹ University of Shkodër, Sheshi 2 Prilli 24, Shkodër, Albania

* Corresponding author's e-mail: medjon.hysenaj@unishk.edu.al

ABSTRACT

Air pollution regards all chains of environmental prospective. As an actualized and future issue we concentrate our efforts to set a frame on major air pollutants and their relation. The period of study rely on 15 year time interval (2012–2016) and the geographical area is focused on data retrieved from the capital, Tirana. We canalize our investigation mainly on inhalable particle and their behavior toward other particles. The goal is to establish PM₁₀ (Particulate Matter with a diameter < 10 µm) trend based on significant associations. We develop the analytical process due to air pollution numbers which turn to be of considerable concern in the country. PM₁₀ and Total Suspended Particulate Matter (TSPM) have different diameter but reflect the same trend line. They show strong positive correlation value with O₃ and SO₂ ($r > 0.75$). NO₂ particles seem to be less ($r < 0.25$) involved in this interaction. AQI (Air Quality Index) is fully depended ($r > 0.92$) on PM₁₀ behavior. We test also socioeconomic and meteorological parameters that produce interesting results. IDW (Inverse Distance Weight) interpolation maps resume the geographical dispersion of PM₁₀ values. The reductive emission index retrieved from Euro standard transition for vehicle fleet develops a new situation. We generate potentially future values of PM₁₀ emission. Predictive scenario is created, interpolation maps are the backbone of this methodology.

Keywords: interpolation, PM₁₀, GIS, TSPM, air quality, relationship

INTRODUCTION

Air pollutants have turned into primary factor for human health and governments recognize the fact and the importance to investigate and manage this environmental issue. These adverse health effects increase medical costs, lower workforce's productivity and undermine people's quality of life [Alkoy, 2009]. Controlling air pollution is a complex task due to multiple sources that might cause the issue. Their relevance and behavior are subject to continuous changes. To define strong or moderate association between PM₁₀ and other air pollutants help replenish the scenario. Also the impact that factors of different nature such as geographical area, meteorological conditions, demographic pace, etc have on air pollution lead us to overtake the right measures. The primary interest in these relationship measurements is to define direct or indirect variables close to PM₁₀ which show strong or moderate correlation. PM₁₀ refers to the particle size represented as an aerodynamic

diameter (in microns) cut-off limit. PM₁₀ refers to a concentration of PM with an aerodynamic diameter lesser than 10 µm [Krishna, 2012]. Total Suspended Particles is the fraction sampled with high-volume samplers, approximately particle diameters < 50–100 µm [Steinar et al., 2016].

Given the rapid change in air pollution, it is necessary to determine the characteristic temporal and spatial changes in pollutants as well as their relationships with meteorological conditions, and to evaluate the changes in air quality to formulate preventative and control measures [Kuang et al., 2018]. Spatiotemporal modeling methods offer expanding opportunities to environmental research because they allow a user to display and model the spatial relationships and patterns between causes and effect when geographic distribution also temporal occurrence are part of the problem [Wang, 2008]. Air quality models are designed to create a better perspective for further decision-making and establishment of strong and healthy policies [Hysenaj, 2019]. To create

predictive scenarios helps maintain the right balance through all enrolled actors [Hysenaj, 2019]. Air quality management includes monitoring and analysis of pollutant concentration, spatial distribution of pollutant concentration, and assessment of no. of environmental factors affected by air pollutants, health risk map [Pandey et al., 2013].

EVALUATION STRATEGY

Figure 1 display the geographical areas which dispose data for air pollutants. We believe that correlation and interpolation are mathematical methodologies that help identify relation and visualize dispersion. Combined they offer a useful tool for air pollution management for better environment policies. They create predictive scenarios that forego air pollution trend. Associations help us understand reasons for variability. Our investigation concentrates on fragmenting potential parameters that may induce PM_{10} emission. We use a linear regression model (LR) to study the correlation of PM_{10} particles to other air pollutants. Daily variations in meteorology parameters such as temperature, relative humidity (RH), precipitation, are important factors that determine PM_{10} trend. Sources of PM_{10} include institutional and domestic energy according to the European Environment Agency (EEA) accounting for nearly

29% and 36% of all EU countries. Thus socioeconomic factors such as population and GDP that have direct impact on numbers of materials, goods and services play an important role for PM_{10} . Geographical dispersion of air pollutants analyzed through GIS software combined with deterministic methods (IDW) produce significant evaluation maps.

Correlation analysis between PM_{10} and socioeconomic parameters

We observe the relationship between socioeconomic parameters and PM_{10} . If considered the main origin source of particles generation a significant share of PM_{10} is generated from a set of anthropogenic activity. Combustion of fossil fuels, vehicle emissions, power plants, road dust, covers large part of the overall percentage factors. Population and GDP represent an important unit of consumption measurement. Regions with a large amount of population would consume large quantities of materials, goods and services [Siyuan et al., 2016]. The growth of possession of civil vehicles stimulates and promotes a series of industries production and supply, which is a trigger for PM_{10} emissions [Siyuan et al., 2016].

Population and GDP (Figure 2a, b) turn to be an important factor on PM_{10} emission. Based on their correlation values population shows to have

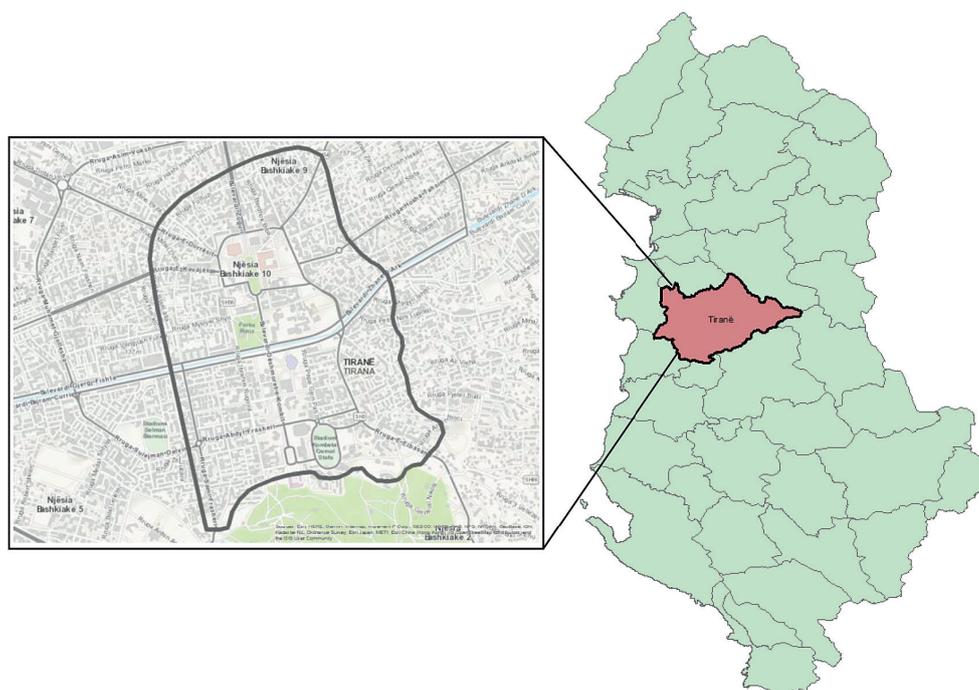


Figure 1. Area of Interest for PM_{10} values, District of Tirana

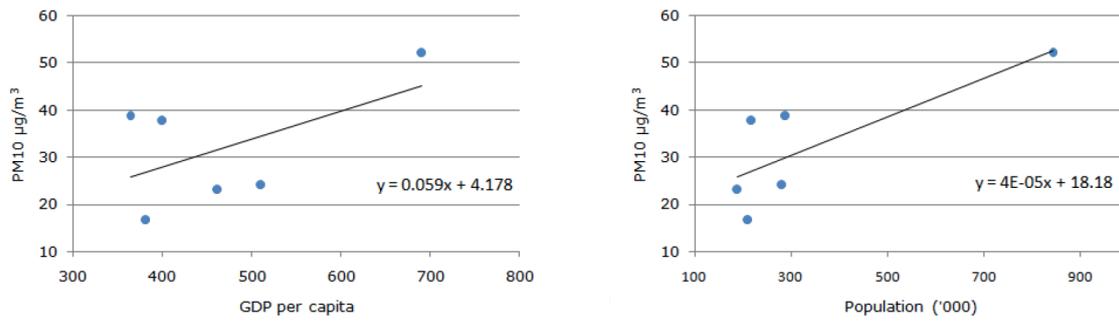


Figure 2. PM_{10} – GDP correlation (a), PM_{10} – population correlation (b)

a stronger impact ($r = 0.78$) than GDP ($r = 0.55$). Still they both rely on positive trend and the relationship seems to be solid.

Correlation analysis between PM_{10} and meteorological parameters

Temperature is observed to have a strong negative ($r = -0.876$) correlation with PM_{10} . We notice an increment of PM_{10} concentration on winter season reaching the peak during December – January and the lowest value on August (figure 3a). Previous studies [Hysenaj, 2019] showed that vehicle emissions are the lead factor of PM_{10} generation. The effects of temperature on vehicle emissions was most pronounced during the initial start-up of the vehicle (cold start phase) when the vehicle was still cold, leading to inefficient combustion, inefficient catalyst operation, and the potential for the vehicle to be operating under fuel-rich conditions.

RH has a weak correlation factor ($r = 0.21$) but still generally showed a positive association (Figure 3b). From the Hernandez G et al, 2012 study, PM_{10} increase up to a threshold value of 75% RH, beyond which the correlation cease. RH affects the natural deposition process of PM_{10} , whereby moisture particles adhere to PM_{10} [German et al., 2012], accumulating atmospheric PM_{10} concentration.

Correlation analysis between PM_{10} and other air pollutants

Table 1 reports the correlation between single air pollutants with emphasis to PM_{10} and TSPM behaviour. PM_{10} shows both strong positive correlation toward O_3 ($r = 0.84$) and SO_2 ($r = 0.78$) but not influential to NO_2 ($r = 0.14$). Correlation value ($r = 0.77$) with TSPM shows that PM particles although different diameter follow the same trend

not only within the same category but also with particles of different nature. According to table 1 we denote that TSPM shows strong correlation with O_3 ($r = 0.79$) and SO_2 ($r = 0.85$) and weak relation with NO_2 particles ($r = 0.25$). The AQI, is the standardized system that state and local air pollution control programs use to notify the public about levels of air pollution [ALA, 2020]. We retrieved AQI values [Saurabh et al., 2012, Sahoo et al., 2017] based on the formula derived from the following computation (1):

$$AQI = \frac{1}{4} \times (ITSPM / STSPM + IPM_{10} / SPM_{10} + ISO_2 / SSO_2 + INO_2 / SNO_2) \times 100 \quad (1)$$

where: $ITSPM$, IPM_{10} , ISO_2 and INO_2 – Individual values of total suspended particulate matter, inhalable particulate matter, sulfur dioxide and nitrogen dioxide respectively. $SSPM$, $SRSPM$, SSO_2 and SNO_2 – Standards of ambient air quality.

Table 1 reflects perfect correlation respectively ($r = 0.96$) and ($r = 0.92$) between AQI and PM particles.

Interpolation map methodology

We use Geographical Information System (GIS) software to assess spatial trend of air pollution across the area of interest. Tirana is located DMS Lat $41^\circ 19' 40.6308''$ N and DMS Long $19^\circ 49' 8.4900''$ E. Tirana has an urban area of about 16 square miles. The interpolation technique combined with map editor software implies analytic results of air quality dispersion. ArcMap 10.2 software is used to exploit IDW technique. IDW interpolation accords to the First Law of Geography “everything is related to everything else, but near things are more related than distant

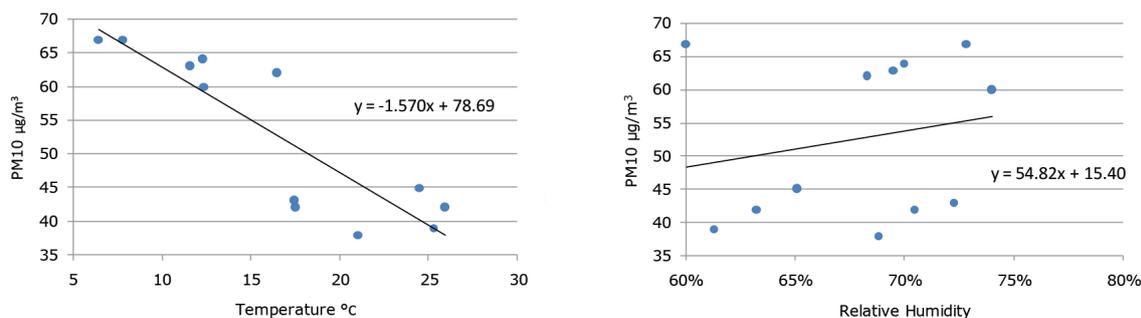


Figure 3. PM₁₀ – temperature correlation (a), PM₁₀ – relative humidity correlation (b)

things.” [Zhengquan et al., 2018]. The general concept of IDW is to estimate the unknown value of $Y(X_0)$ in location X_0 , given the observed Y value at sampled locations X_i according to the formula in equation 2 [Rahman et al., 2015].

$$Y(X_0) = \sum_{i=1}^n \lambda_i Y(X_i) \quad (2)$$

From previous studies [Hysenaj, 2019] we ranked vehicle emissions as the primary factor that induce to high values of PM₁₀ dispersion. An old range fleet that mostly fall into Euro 3 standard plays a key role for air pollution issue. Based on the emission index we settle a proportionally report between (Euro 3 – Euro 4 reduce emission by 50%) and (Euro 3 – Euro 5 reduce emission by 91%). We exploit current PM₁₀ value emissions retrieved from monitor points distributed geographically in areas with intense vehicle activity. If applied, the reductive emission index generates potentially future values of PM₁₀ emission. Predictive scenario is created developing interpolated maps.

The area of study recalls a perimeter of 7.5 km and area 2.9 km². Within this zone we find the arterials which register every year the highest frequency of road traffic. As we observe from Figure 4 with the current vehicle fleet we face many geographical areas which register concerning

PM₁₀ values. These areas cover high population density increasing health exposure. A possible fleet transition into Euro 4 (Figure 5a) or Euro 5 and higher standards (Figure 5b) with significantly reduce PM₁₀ emissions to EU threshold standard. The zones of risk shrink to discrete areas.

CONCLUSIONS

The aim of the study is to assess some significant air pollutants and their correlative behavior. We focus our investigation on inhalable particulate matter particles. At first we conclude that regardless their diameter both PM₁₀ and TSPM follow the same trend toward other air pollutants. Correlation values above ($r > 0.75$) with O₃ and SO₂ determine a strong positive relationship. NO₂ seems to follow positive but weak interaction. Inhalable particles share a determinant role on AQI indices ($r = 0.96$).

The research continues on socioeconomic factors. Population and GDP are chosen as significant representative models. Based on the role that anthropogenic factors play on PM₁₀ emissions we checked the correlation which turned to be moderate for GDP ($r = 0.55$) and strong ($r = 0.78$) for population. Both reveal to follow positive trend line as they represent straight indices of consume of materials, goods and services.

Table 1. Correlation of main air pollutants

Air pollutant parameters	O ₃	PM ₁₀	NO ₂	SO ₂	TSPM	AQI
O ₃ (µ/m ³)	1					
PM ₁₀ (µ/m ³)	0.84	1				
NO ₂ (µ/m ³)	-0.24	0.14	1			
SO ₂ (µ/m ³)	0.69	0.78	0.1	1		
TSPM (µ/m ³)	0.79	0.77	0.25	0.85	1	
AQI	0.87	0.96	0.24	0.85	0.92	1

Note: SO₂ – Sulfur Dioxide; PM₁₀ – Particulate matter with less than 10 µm in aerodynamic diameter; O₃ – Ozone; NO₂ – Nitrogen Dioxide; TSPM – Total Suspended particulate matter; AQI – Air Quality Index

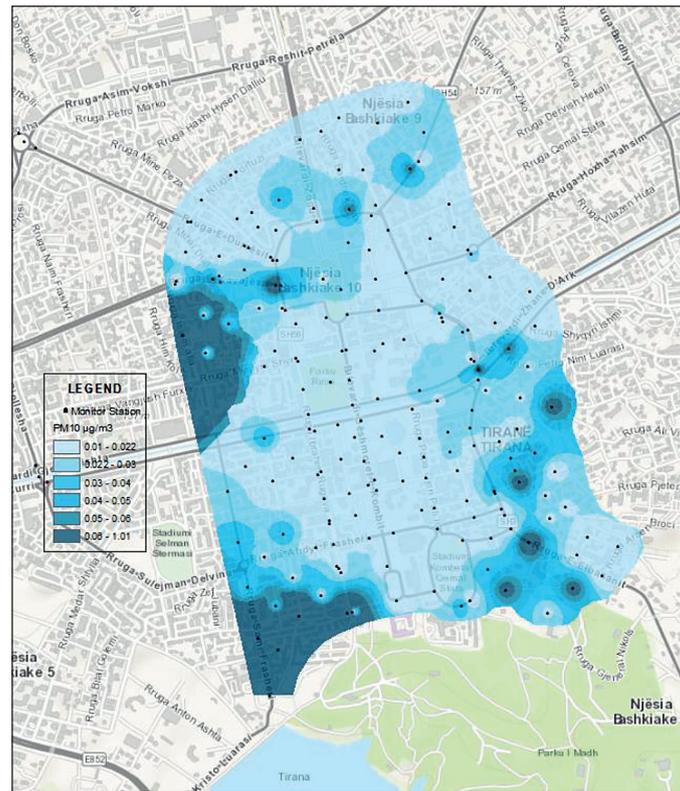
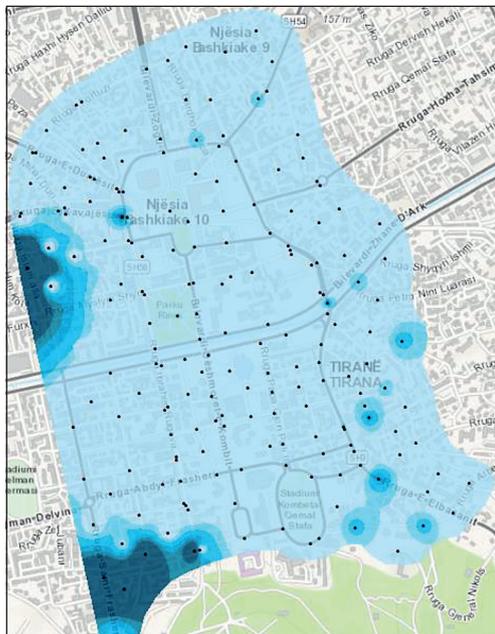


Figure 4. PM₁₀ dispersion, Data Source: Co-PLAN – Institute for habitat development, Milieukontakt Albania (Green Lung Project)

a)



b)

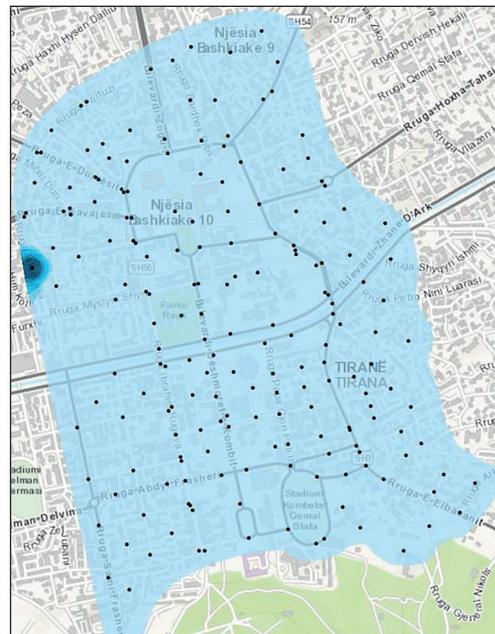


Figure 5. Euro 4 vehicle fleet transition (a), Euro 5 > vehicle fleet transition (b)

We check meteorological parameters *relative humidity* and *temperature*. Relative Humidity has a weak correlation factor ($r = 0.21$). RH affects the natural deposition process of PM₁₀ accumulating atmospheric PM₁₀ concentration. Temperature

has a strong negative correlation ($r = -0.876$). According to the final result PM₁₀ concentration increase on winter season (December – January) represent the months of peak and fall on its lowest levels on summer (August). The effects of low

temperature on vehicle emissions are related to inefficient combustion leading to the increase of PM_{10} emission.

Correlation methodology is an efficient way to understand behavior and association. Meanwhile through interpolation maps we improve the concept of dispersion. Interpolation as correlation, tries to create a predictive scenario based on actual data. IDW interpolation is a deterministic method based on nearby weighted locations. We exploit PM_{10} data combined with Euro standard emissions coefficient to understand air pollution reaction. The experiment ends with noticeable improvement of air quality with fleet replacement.

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