STUDY OF PM_{10} LEVELS IN URBAN AIR OF TIRANA (VASIL SHANTO CROSS-ROAD) AND STATISTICAL ANALYSIS OF DATA COLLECTED

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Abstract

The main objective of this paper is to analyze the PM_{10} concentration levels in one of the main Tirana city crossroad and to evaluate how these levels are influenced by road traffic density and weather conditions. The measurements have been carried out from May to July 2012, by the Laboratory of Chemistry in Faculty of Mathematical Engineering and Physical Engineering. During 70 days, 12-hours particles samples were collected two times in each day, with a total of 140 samples. One-way Analysis of Variance (ANOVA) was applied to the data collected, to statistically confirm if factors, such are the time of sampling (day-night; weekdays-weekend days) and meteorological conditions (day with or without precipitation) have impact on the PM_{10} concentration. The average of mass concentration for PM_{10} was 34.25 $\mu g/m^3$. Only 11.4% of daily concentrations measured exceeded the EU limit value of 50 $\mu g/m^3$, whilst all of them were well below the limit value of 150 $\mu g/m^3$ defined by Albanian Standard of Air Quality. The data obtained are conform the trend described in last years air monitoring reports, which show a reduction of particulate matter level of urban air in Tirana. This demonstrates that actions undertaken on controlling the air pollution sources and improvements made in infrastructure have positively contributed in the air quality.

Key words: *air pollution, PM_{10}, one-way ANOVA*

1. Introduction

Among the main pollutants of air, the suspended particulate matter is evaluated as one of the most widespread and dangerous contaminant, for the human health. (WHO, 2000) Urban particulate matter originates from a variety of stationary and mobile sources and can be directly emitted or can be formed in atmosphere when gaseous pollutants such as SO_2 and NO_x react to form fine particles. Car engine combustion accounts for the significant contribution in urban particulate matter load (Fraser et al., 2003). Numerous studies have demonstrated the negative effect of particulate matter on human health and environment. Elevated particulate matter concentration, measured as PM_{10} or $PM_{2.5}$, (small particles with aerodynamic diameter respectively less than 10 μm and than 2.5 μm) have been long implicated in contributing to respiratory problems, increased mortality (Schwartz et al., 2002; Pope and Dockery, 2006; Ostro et al., 2007) and their role in climate change (Girgždeinė and Rameikytė, 2007). Two cohort studies conducted in United States suggest that life expectancy may shortened by more than one year in communities exposed to high particulate matter concentration compared to those exposed to low concentrations (Dockery et al., 1993; Pope et al., 1995). These health effects deal with the fact that the small particles penetrate the human respiratory system and can reach the lung alveoli causing serious damage to health. Generally epidemiological studies indicate also that particularly the fine particle fraction have considerable impact on human health even in concentration below the present ambient air quality standards. In fact, the World Health Organization reports that there is no safe level for PM below which no negative effects occur (WHO, 2000). Children, elderly people and individuals with impaired lung or heart function are especially susceptible to the adverse health effects associated with inhalation of airborne particulate matter.

Tirana is situated in the central part of Albania, 110 m above sea level. Tirana has a maritime Mediterranean climate, with hot, dry summers and mild, wet winters. During the summer, the main wind direction is NW and during the winter is SE. After the end of the communist system in 1991, a great number of people moved from rural areas to Tirana looking for better economic opportunities, bringing a large growth of population. This fast increasing of population brings also much environmental problems such as high level of air pollution, noise pollution, uncontrolled waste generation, etc. Before '90 years, in Tirana, as well as in other Albanian cities, air pollution was caused by industry. Due to the very low number of the vehicles in this period pollutants emission by road traffic was insignificant. At present, the situation is the opposite as higher pollutants emission takes place due to the immense increase of vehicular transport, while industrial emission is low because of the limited industrial activities.

Air quality monitoring and studies carried out in the last two decades has indicated that air pollution from particulate matter is the main problem of the air quality in Albanian capital (SoE, 1999; Totoni & Cullaj 2001; ECAT Tirana, 2008). During all these years, the concentration of PM_{10} in urban air of Tirana has resulted to be high and obviously exceeded the long-term and short-term limits defined by Albanian standards and EC Directives. This pollution is especially high close to areas with a great traffic density, thus showing that road traffic remains the main source of air particulate matter emissions. The old age cars, their bad technical condition, the fact that the majority of them run on diesel are some of the main factors that had influenced in high concentrations of particulate matter measured in urban air of Tirana. However it should be noted that a downward trend is observed the last years in the PM_{10} levels in urban air of Tirana (Totoni et al., 2012). This improvement can be explained by measures undertaken on controlling the air pollution sources and improvements made in infrastructure. Despite this, the PM_{10} content in Tirana air remains generally above EU limit value of 50 $\mu g/m^3$ and is far being "safe" for public health. This fact, as well as the findings on harmful impact of PM_{10} in human health underlines the need for continuous study and monitoring of PM_{10}. The main aim of this study is to analyze the PM_{10} concentration in one of the main Tirana city crossroad and to evaluate how these levels are influenced by road traffic density and weather conditions.

2. Experimental

Samples of PM_{10} were collected between May 2012 and June 2012 in Vasil Shanto crossroad, which is situated in the western part of Tirana center, in a relatively high traffic density zone. 12-hours particles samples (7.30-19.30 and 19.30-7.30) were collected two times in each day, with a total of 140 samples. Sampling was performed using Zambelli PF 20630 air sampler with a sampling flow rate of $1m^3$/hour. The mass of PM10 collected in filter was determined gravimetrically by weighing the filter before and after the sampling. The concentration of PM_{10} in air was obtained dividing the mass of PM_{10} by volume of air passed through the sampler, which is automatically measured and registered by the instrument. Sampling and determination of PM10 is carried out by the Laboratory of Chemistry in Faculty of Mathematical Engineering and Physical Engineering.

3. Results and Discussion

PM_{10} levels measured during period 04.05.2012-12.07.2012 in Vasil Shanto crossroad, broken up in day and night averages are shown in Table 1, while in figure 1 are presented the 24-hours means for each of sampling days.

Table 1. Overall statistics of PM_{10} mass concentration ($\mu g/m^3$) in Vasil Shanto crossroad

Parameters		**All samples**	**Time of sampling**	
			Night	**Day**
Number of samples		140	70	70
Arithmetic Means		34,28	34,34	34,21
Standard Deviation		14,86	14,41	15,40
Minimum		8,33	8,33	8,38
Maximum		92,14	68,06	92,14
Percentiles	10%	16,74	16,74	16,74
	90%	51,04	51,04	51,61

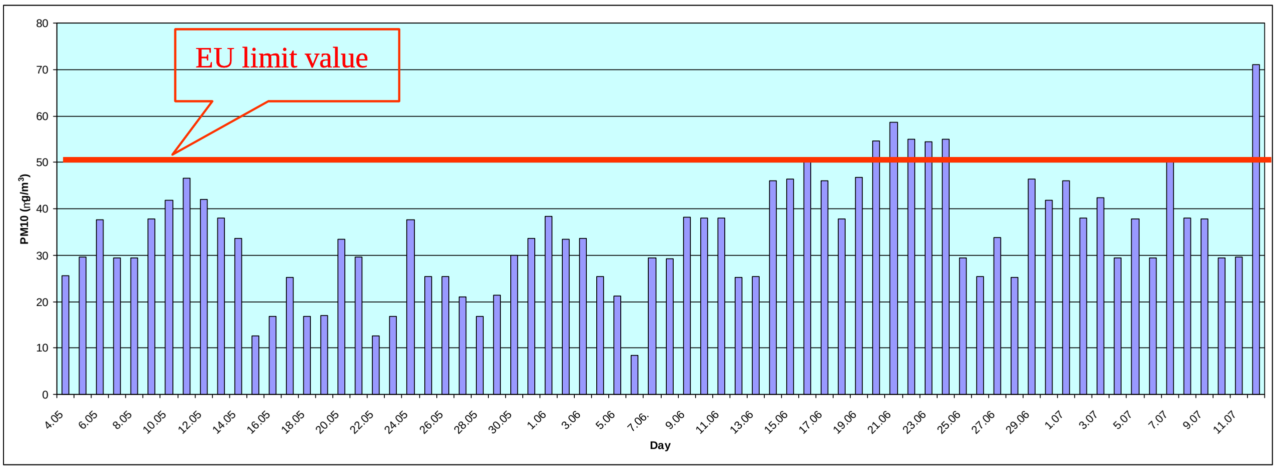


Fig. 1. Daily PM_{10} levels in Vasil Shanto crossroad

The concentrations of PM_{10} range from 8.33 $\mu g/m^3$ to 92.14 $\mu g/m^3$ and the average of mass concentration for PM_{10} is 34.25 $\mu g/m^3$. Only 11.4% of daily concentrations measured exceeded the EU limit value of 50 $\mu g/m^3$, whilst all of them are well below the limit value of 150 $\mu g/m^3$ established by Albanian Standard of Air Quality. The

minimal concentration is measured during the night, while the maximal concentration is measured during the day. At the same time it is noticed that the standard deviation is higher for the concentrations recorded during the day compared to the concentrations measured during the night. This may explain by the variability of traffic level during the hours of the day, where peak hour of traffic volume are often observed.
Frequency distribution of 12-hours average concentrations for PM10 (n=140) is shown in figure 2. It can be seen by this histogram that the distribution can be approximated by log-normal distribution.

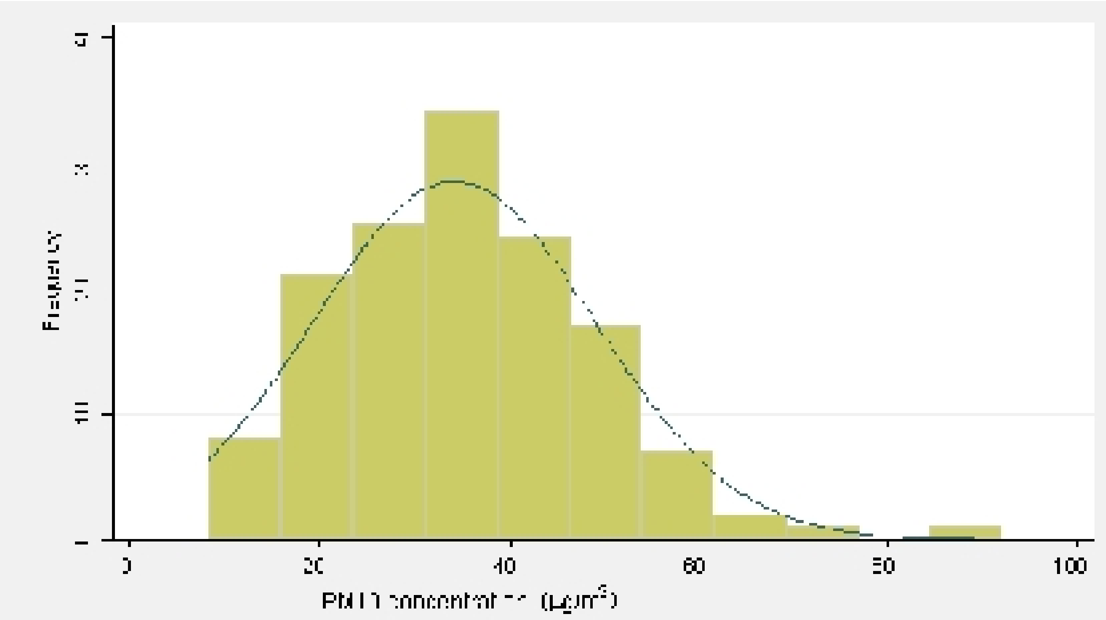


Figure 2. Frequency distribution of 12-hours means

If we compare the data presented above with values reported by previous studies for air quality in Tirana City, the PM10 concentrations measured at Vasil Shanto crossroad result much lower. So, the PM10 average concentration in Vasil Shanto crossroad is ~3 times lower than average measured during 2008-2009 in another crossroad of Tirana (21 Dhjetori Crossroad), characterized by a huge traffic load (Totoni, Prifti and Mulla, 2011). This difference can be explained by the fact that Vasil Shanto crossroad has a moderate traffic in comparison with big traffic of the 21 Dhjetori Crossroad. To the other side, the data obtained by our study are quite similar with those reported by the Ministry of Environment, Forests and Water Administration of Albania, (SoE 2009), for a monitoring station situated in the periphery of Tirana, in an area with a relatively low traffic density. Also, the average of 34.25 μg/m^3, is comparable with PM10 levels reported for some of the main European capitals in year 2004, ranging from 11μg/m^3 for Paris to 63 μg/m^3 for Sofia (World Bank, 2007).

Study of PM10 variations according time of sampling and weather conditions

The data obtained for PM_{10} concentration are grouped and analyzed according time of sampling (day-night, weekdays-weekend days) and weather conditions (day with or without precipitation). Main descriptive statistics of the grouped data are shown in Table 2.

Table 2. Overall statistics of grouped data for PM_{10} concentrations (μg/m^3

Parameters	All samples	Sampling time		Days		Weather	
		Night	Day	Weekdays	Weekend days	Days with precipitation	Days without precipitation
Number of samples	140	70	70	100	40	27	113
Arithmetic Means	34.25	34.35	34.21	32.5	38.2	26.19	36.2
Standard deviation	14.86	14,41	15,40	12.77	10.067	16.82	13.75

By comparing of arithmetic means it seems that the differences exist between groups, but to confirm statistically that the time of sampling and weather conditions influence the concentrations of PM10 in atmosphere, a study of Analysis of Variance was applies to the database. The results are shown below.

a. Time of sampling: day-night

PM_{10} concentrations measured in Vasil Shanto crossroad result almost the same during the day hours and night hours (the 12-hours means during the day hours is 34.21μg/m^3 and during the night hours is 34.35μg/m^3). The one-way ANOVA confirms also that there is no apparent distinction between 12-hours averages of days and night hours (F=0.0029, d.f=139 and significance level=0.9566). The opposite might be expected: the levels of PM10 must be higher during day hours, because the traffic and other daily activities are much more intense. The similar levels in both part of the day may be explained considering that in condition of a calm weather and the absence of vehicular movements, the settling of particles emitted during the day hours takes place during the night hours.

b. Study of PM_{10} concentration during weekdays and weekend days

From one-way ANOVA results a significant differentiation between two groups: weekdays and weekend days (table 3). As shown in table 2 and figure 3, the mean concentration of PM10 is higher during the weekend days comparing with weekdays. The higher levels of PM10 in air during the weekend days can be explained by taking into account that the sampling period coincides with the beginning of beach season. During the weekend days a huge number of vehicles pass in this crossroad for leaving Tirana city and for going toward Albanian coastal areas.

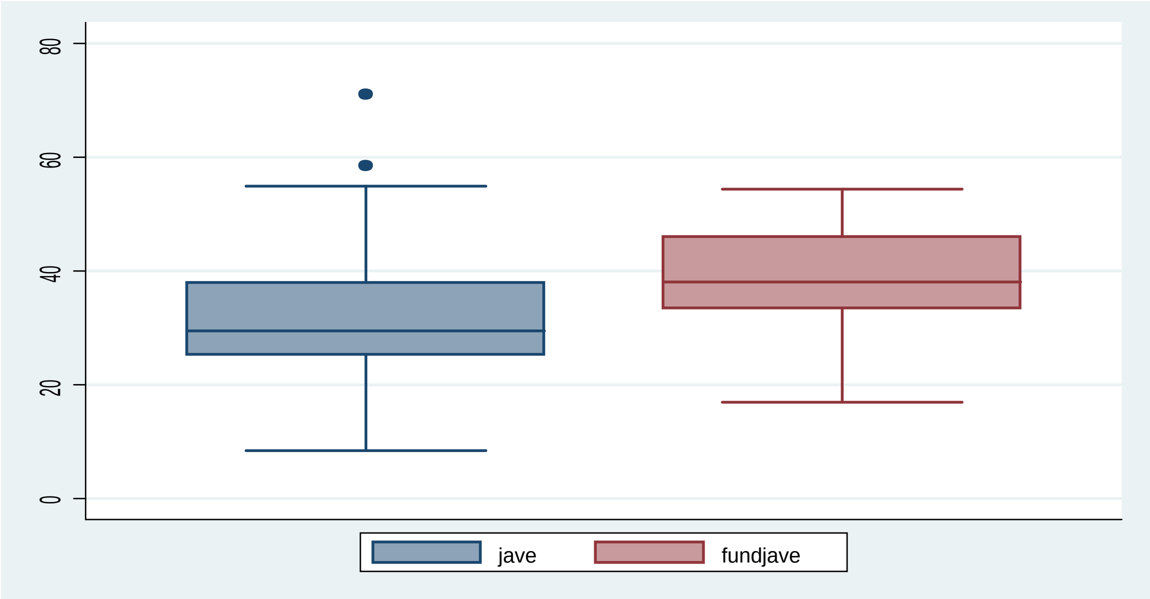


Figure 3. Boxplot of PM_{10} concentration during weekdays and weekend days

Table 3. Analysis of variance (week and weekend days)

Group	*Variance*	*Source of variance*	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*	*P-value*	*F crit*
Week days	236.75	Between groups	981.15	1	981.15	4.56	0.034	3.91
Weekend days	161.09	Within groups	29720.32	138	215.36			
		Total	30701.47					

c. Study of PM10 concentration by weather condition (days with or without precipitation

The weather condition regarding precipitation was recorded for each day of PM_{10} sampling. As shown in table 2 and figure 4, the mean concentration of PM_{10} is higher during the days without precipitation (36.2 $\mu g/m^3$) against the mean concentration in rainy days (26.19 $\mu g/m^3$). It seems clear that raining has positively influenced in air quality and has caused the reduction of air pollution by particulate matter. One-way ANOVA confirms also that the differentiations between these two grouped data are statistically significant. (table 4)

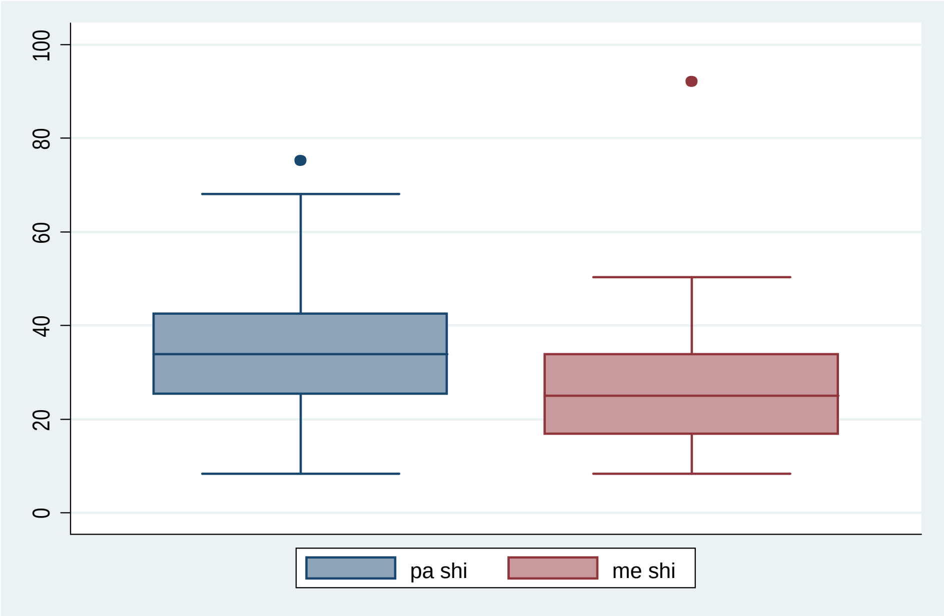
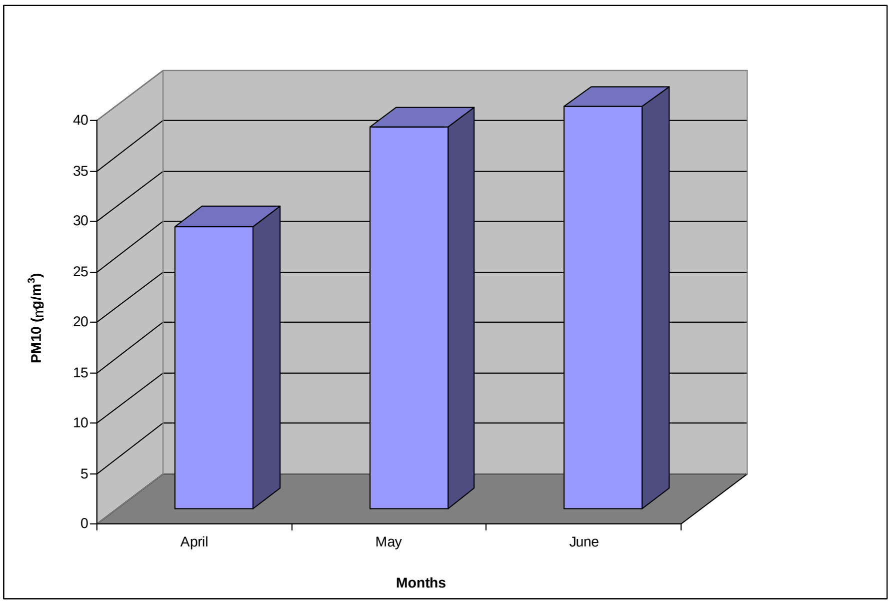


Figure 4. Boxplot of PM_{10} concentration in days with or without precipitation

Table 4. Analysis of variance (days with or without precipitation)

Group	*Variance*	*Source of variance*	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*	*P-value*	*F crit*
Without precipitation	188.95	Between groups	2184.94	1	2184.94	10.5736	0.00144	3.90973
With precipitation	282.85	Within groups	28516.5	138	206.642			
		Total	30701.5					

The influence of weather conditions in the levels of PM10, can be clearly noticed also if we look over the monthly mean concentrations (figure 5). Lower concentration of PM10 belongs to May, which was a rainy month, while the higher concentration were recorded during June and July, which were characterized by high temperature and dry weather.



Conclusions

The measurements carried out during a 70 days period regarding PM_{10} content in the air of one of the main crossroads of Tirana City show levels which are within norms. The average concentrations of this pollutant resulted 34.25±14.86 µg/m$^{3.}$ Only 11.4% of daily concentrations measured exceeded the EU limit value of 50 µg/m^3, whilst all of them were well below the limit value of 150 µg/m^3 defined by Albanian Standard of Air Quality. The data obtained are conform the trend noticed in last years by different studies and air monitoring reports, which show a reduction of particulate matter level of urban air in Tirana. This demonstrates that actions undertaken on controlling the air pollution sources and improvements made in infrastructure have positively contributed in the air quality.

PM_{10} concentrations measured in Vasil Shanto crossroad results almost the same during the day hours and night hours and the one-way ANOVA confirms also that there is no apparent distinction between 12-hours averages of days and night hours. Although during the day hours the traffic and the others activities that generate the particulate matter in the air are much intensive, the settling of course participles during night may explain the same level measured for PM_{10} in the night hours.

The average concentration of PM_{10} results to be higher in weekends compared to weekdays. Given that our measurement period match up to the opening of the beach season, during the weekend an increased number of vehicles leaving the capital pass through this crossroad, creating congestion problems and contributing in increasing of air pollution.

The role of weather condition in the particulate matter pollution is reflected by the fact that the PM10 concentrations measured during the rainy days are obviously lower compared with days without precipitation. Studying the variation of PM_{10} concentration by months, it is noticed that the lowest PM_{10} average belongs to May (which was characterized by a wet weather) and the highest levels belong to Jun and July, which were characterized by dry weather and high temperature of air.

The data presented in this paper, are only a part of a study which is being performed to assess the air quality in Vasila Shanto crossroad. This study will last one year in order to provide a more complete assessment of seasonal variation of PM10 concentration in Tirana.

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