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Assessment of air quality of Tirana, Albania by measuring ultrafine particulate matter (PM25), Al, and Pb

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Abstract

Air quality in Tirana (Albania) was assessed by daily measurements of PM2.5, Al, and Pb in June 2021. Al and Pb concentrations in PM2.5 samples were quantified on Teflon-coated glass fiber filter samplers along five monitoring sites in Tirana city. The measurements were carried out in three heavy traffic crossroads and two residential areas during a summer day with elevated air temperatures up to 23 °C. The results of PM2.5, and Al and Pb in solid particles of PM2.5 were discussed through data treatment through statistical analysis. A moderate variation (25% < CV% < 75%) was found for all parameters under investigation. Site concentration data were compared with the respective recommended values of the European Directives for each parameter. The results showed higher concentration levels compared with the allowed data for rural and residential areas, but lower than the recommended values for urban and industrial areas, throughout all stations. Correlation analysis revealed high and significant correlations ($r > 0.85$, $p < 0.05$) between all concentration data (PM2.5-Al; PM2.5-Pb, and Al-Pb) indicating a high effect of particulate matter on airborne Al and Pb content. It may cause an increase in human exposure to harmful pollutants through inhalation and could lead to harmful health problems. Stronger mases and measures are proposed to improve air quality in Tirana city.

Keywords: air quality, PM2.5, Al, Pb, residential area, traffic area, Tirana, Albania

Introduction

Air pollution is a global challenge, as it has adverse effects on the environment and human health. Together with SO_2, NO2, and O_3, particulate matter (PM) is classified as a main air pollutant, and is used as an indicator for fuel combustion and traffic-related air pollution (Chen and Kan 2008). Industrialization and increasing demands for improving the quality of life are followed by an increase in industrialization, traffic, and energy production, which has led to a greater exposure to air pollutants. The measurement of metal concentration in total suspended particles (TSP) provides some indication on general levels of pollution without providing information on the size distribution of the pollutants (Krzemińska-Flowers et al. 2006). The size distribution of metals is a useful tool for the characterization and apportionment of the sources of urban airborne particulate matter (Swietlik& Trojanowska 2022).

Epidemiological studies showed a statistically significant correlation between exposure to classical air pollutants, particularly airborne particulates, and mortality and morbidity in children (Lee 2021), and adverse health effects including mortality and morbidity (Chen and Kan 2008). PM2.5 mass consists of a heterogeneous mixture of solid and liquid particles generated by many sources (for example, cars and trucks, fossil-fuel combustion, industrial emissions, biomass, and windblown dust), but there is limited evidence about the trace constituents or sources of PM2.5 mass and its associated environmental and health risks (Thurston et al. 2021). The emissions inventory is important to account for pollutant emission sources based on up-to-date emission factors and detailed activity data (EMEP/CORINAIR 1999). The health burden due to particulate matter (PM) air pollution (PM10 and PM2.5) is one of the biggest environmental health concerns in the WHO European Region (2013) and around the world. Fine particles with a diameter of 2.5 micrometers and smaller have been established as more detrimental than PM10

(WHO European Region 2013). This fraction of size can penetrate deeper into the airways and be mainly deposited in the alveolar region of the lungs, where absorption efficiency for trace elements varies from 60-80% (Guan et al. 2016). Fine PMs are associated with harmful metals, an increase in the mortality or morbidity rate with the increase of PM2.5 concentration in air (Moryani et al. 2020, Dominici et al. 2013, Li et al. 2013, Anenberg et al. 2010).

This research aimed to investigate the air quality by measuring PM2.5 and elements linked to fine and ultrafine particle emissions (Al) and traffic emissions (Pb) in street canyons of the urban area of Tirana city.

Material and Method

Sampling

This study was conducted at five sites in Tirana to assess the quality of the air due to ultra-fine dust particles (PM2.5) and trace metals Al and Pb, that are linked with dust emission (Al) and traffic emission (Pb). In June 2021, PM2.5 sampling was carried out during peak traffic times (morning, midday, and afternoon) for a total of 240 minutes for each time sequence (8AM, 9AM, and 10AM; 1PM, 2PAM, and 3PM; 6PM, 7PM, and 8PM). PM2.5 was sampled using the MCZ Micro PNS/LVS-1 instrument, equipped with a small volume air sampling pump (flow rate of 38.5 L/min), a cyclone sampler heads, and Teflon filters to support air particle collection in pre-conditioned high purity quartz filter papers (Whatman grade, 47 mm). Samplings were performed following European Legislation UNI EN-12341:2014 procedures. The filters were dried to a constant weight and then kept for less than one day in Petri dishes and stored at 4°C in a refrigerator till the next analysis.

Three heavy traffic sites and two residence sites were selected as monitoring sites, which will serve as a reference point. The sampling area was free of trees, balconies, walls, etc. that affect the air flow. Samples were collected according to the standard monitoring guidelines (SIST EN 12341:2014) at least 0.5 m from the nearest buildings and 1.7 m above ground level. PM2.5 content was calculated by the following equations:

$$PM(\mu g/m^3) = \frac{w2 - w1}{Q * T} \times 10^6$$

and:

$$Me(\mu g/m^3) = \frac{Me(\frac{\mu g}{filter})}{Q * T} \times 10^6$$

W_1 = weighing before sampling (g);

W_2 = weighing after sampling (g);

Q = flow rate (38.5 l/min = 2.31 m^3/h);

t = sampling period (9 h);

$Me(\frac{\mu g}{filter})$ = Fe content in PM2.5

The concentration of Al and Pb in PM2.5 was determined by the graphite furnace atomic absorption spectrometer (GFAAS), ANALYTIK Jena novAA400. PM2.5 filters were digested with aqua regia ($3HCl:1HNO_3$) and diluted to 50 ml for further determination of the concentration of Al and Pb. Table 1 shows the coordinates of each sampling site.

Table 1. Data for each monitoring sites (dry precipitation, t = 21 to 24°C)

Sites	Latitude N	Longitude E	Land use class
S1	41.334451	19.816408	Urban cross road
S2	41.339104	19.853321	Residential
S3	41.319122	19.838978	Residential
S4	41.302852	19.838113	Elbasan Hw
S5	41.325070	19.803570	Urban cross road

Figure 1. GIS map of Tirana with the position of sampling sites and their geographical coordinates

Data analysis

Anderson-Darling test, confirmed at $p > 0.05$, was used to check the normal distribution of concentration data. The associations between parameters were investigated and assessed by Pearson linear at the similarity levels of very strong (r>0.8), strong (r = 0.6 – 0.8), and moderate (r = 0.4 – 0.6) correlations, confirmed at $p<0.05$. Cluster multivariate statistical analysis (CA), was used to investigate and differentiate the data in clusters based on their similarity levels (Michalik 2008). The Hierarchal cluster method, which differentiates the data into different clusters with a multi-level hierarchy by calculating the distance between observations in the data set and their similarity, was applied to the raw data (Charreire et al. 2012). It is a method that made possible the visualization of clusters and presents a picture of cluster proximity with a distinct reduction in the dimensionality of the original data (Michalik 2008).
Pollution index (PI) was calculated as the ratio between the concentrations of each parameter to the corresponding value at the control site (Chen et al. 2015).

$$\mathrm{PI} = \frac{Ci}{Si}$$

Ci - concentration of parameter i;
Si - concentration of parameter I in control site.
Pollution level established as:

1. PI ≤ 0.7, clean
2. 0.7 < PI ≤ 1.0, no-contaminated
3. 1.0 < PI ≤ 2.0, slight pollution
4. 2.0 < PI ≤ 3.0, moderate pollution
5. PI ≥ 3.0, serious/very high pollution

Data analysis was performed using MINTAB 21 software package.

Results and discussion

The results obtained in relation to the concentration of PM2.5, Al, and Pb in solid fine PM2.5 are shown in Table 2, and descriptive statistics data are shown in Table 3.

Table 2. The concentration of PM2.5, and Al and Pb in solid fine PM2.5 (in µg/m^3)

Parameters	S1	S2	S3	S4	S5
PM2.5	47	22	34	76	55

Al	1.7	1.02	1.14	2.27	1.99
Pb	0.033	0.011	0.015	0.0275	0.0268

The concentration data for PM2.5 and Al and Pb in solid fine PM2.5 follow normal distribution (Anderson-Darling test, $p > 0.05$) (Fig. 2), indicating the data are relatively stable.

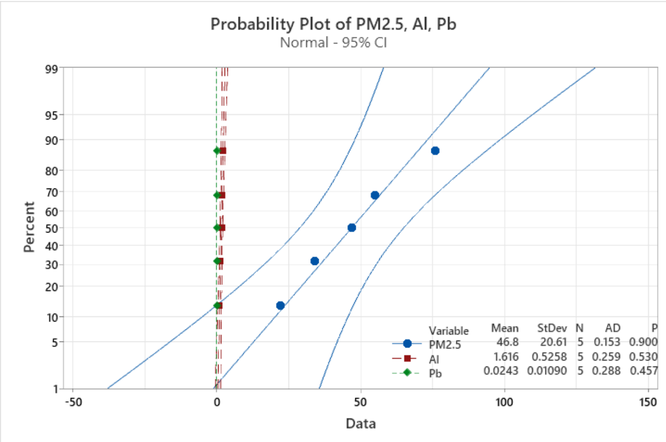

Figure 2 Propability plot of PM2.5, Al, and Pb concentration data

Table 3. Descriptive Statistics data of PM2.5, Al, Pb (* in in $\mu g/m^3$)

Variable	N	Mean*	StDev	CV%	Min*	Median*	Max*
PM2.5	5	46.8	20.61	44	22.00	47.00	76.0
Al	5	1.62	0.526	33	1.020	1.700	2.23
Pb	5	0.024	0.011	45	0.011	0.0268	0.036

PM2.5 content in the air ranged from 22 $\mu g/m^3$ to 76 $\mu g/m^3$, Al varied from 1.02 $\mu g/m^3$ to 1.7 $\mu g/m^3$, and Pb varied from 0.011 $\mu g/m^3$ to 0.036 $\mu g/m^3$, and showed moderate variations (25 % < 33% to 45 % < 75%). Only S2 shows a PM2.5 content in the air smaller than the WHO permissible value of 35 $\mu g/m^3$ (WHO 2021), and low concentration levels of Al and Pb compared with other stations. For this reason, this site was selected as the control site. In general, the concentrations of Al and Pb in the atmosphere differ significantly in the air of various regions compared to their contents in the air of remote regions (Kabata-Pendias & Szetke 2019). The concentration of Al in urban areas is 0.150–1.3 $\mu g/m^3$, and the maximum may be up to 3.5 $\mu g/m^3$, whereas in remote regions it ranges from 0.046–0.070 $\mu g/m^3$ (Kabata-Pendias & Szetke 2019). The concentrations of Al in PM2.5 samples from S2 and S3 residence sites were comparable with those from urban areas (< 1.3 $\mu g/m^3$) and in PM2.5 samples from S1, S4, and S5 were lower than the maximum value (up to 3.5 $\mu g/m^3$). Normal Pb concentration in air ranges from 0.005–0.010 $\mu g/m^3$, and 0.070–8.0 $\mu g/m^3$ in polluted air (Kabata-Pendias & Szetke 2019). Pb in PM2.5 samples of S2 and S3, residence sites, were higher than those in the normal range (0.005–0.010 $\mu g/m^3$), and in PM2.5 samples of S1, S4, and S5 were inside the range of polluted air (0.070–8.0 $\mu g/m^3$).

Multivariate analysis

As the concentration data for PM2.5, Al, and Pb followed a normal distribution, a Pearson linear correlation analysis was performed on those data. The results are shown in table 4.

Table 4. Pairwise Pearson Correlations of PM2.5, Al and Pb concentration data

	Element				
1	**2**	**N**	**Correlation**	**95% CI for ρ**	**P-Value**

Al	PM2.5	5	0.966	(0.571, 0.998)	0.007
Pb	PM2.5	5	0.895	(0.059, 0.993)	0.040
Pb	Al	5	0.917	(0.181, 0.995)	0.028

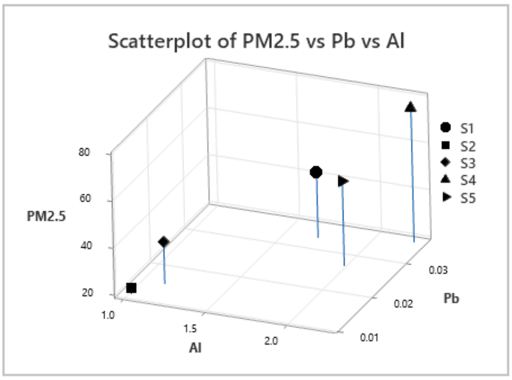

Figure 3. Scatterplot of PM25 – Pb – Al relation

Very strong and significant correlations ($r > 0.8$, $p < 0.05$) were found between PM2.5 and Al and Pb, as well as between Al and Pb, indicating very good associations between them. Cluster analysis was performed for better visualization of correlations between these parameters (Fig. 4) and the environmental associations of sampling areas (Fig. 5).

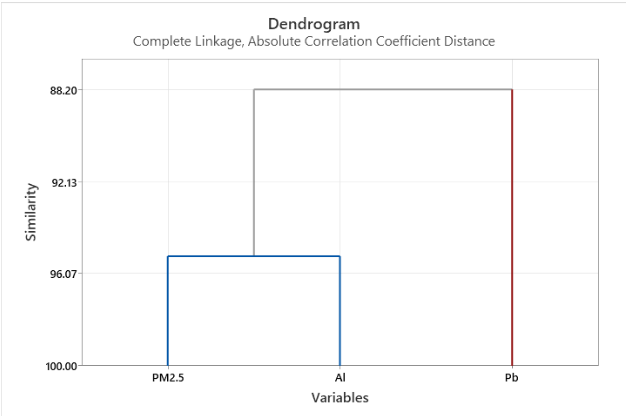

Figure 4. Cluster Analysis of Variables: PM2.5, Al, Pb

Absolute Correlation Coefficient Distance, Complete Linkage

	Variables
Cluster 1	PM2.5 Al
Cluster 2	Pb

PM2.5 and Al are associated with the same cluster (cluster 1). Al is a chemical component of road dust and fine soil particles, and this association is reasonable, while Pb is mostly sourced from traffic emissions and trapped in PM2.5, so its association with PM2.5 and Al is weaker compared with the PM2.5-Al association. Cluster analysis (Euclidean Distance, Complete Linkage) of PM2.5, Al, and Pb observations made possible the separation of sampling sites along three different clusters (Fig. 5).

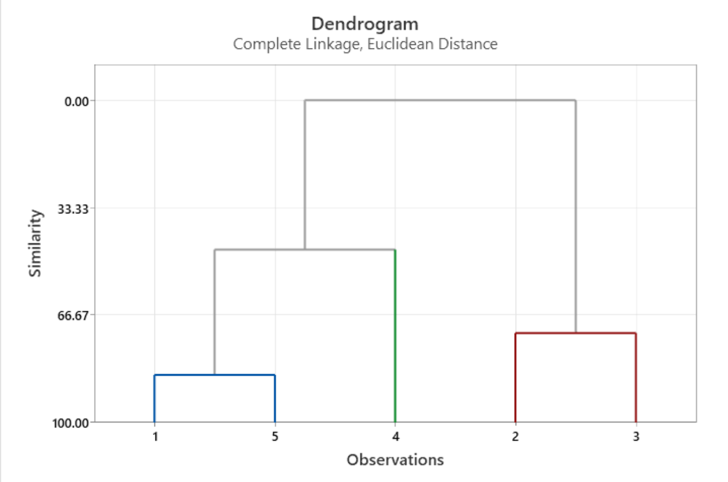

Figure 5. Cluster analysis (Euclidean Distance, Complete Linkage) of PM2.5, Al, and Pb observations

The result of cluster analysis (Euclidean Distance, Complete Linkage) of PM2.5, Al, and Pb observations could be explained in combination with PI pollution index data (Table 5).

Table 5. PI pollution index data

Parameters	S1	S2	S3	S4	S5
PM2.5	1.34	0.63	0.97	2.17	1.57
PI index*	**Slight**	**Clean**	**No-pollution**	**Moderate**	**Slight**

* Pollution level

S1 and S5 sites resulted in a slight pollution level (PI = 1–2) and are classified in the same cluster (cluster 1) with a similarity higher than 90%. S4 shows a moderate pollution level and is classified in cluster 2, with a similarity of about 47% with cluster 1. S2 and S3 showed a clean to no pollution status (PI < 1) and are classified in the same cluster (cluster 3), with a similarity of about 70%. S2 and S3 residential sites differ significantly (similarity 0 %, Fig. 5) from S1, S2, and S3 sites positioned in traffic areas by showing different levels of environmental status. Similar results were obtained by Aničić-Urošević et al. (2023) for the air quality of Tirana evaluated by contamination factor (CF) data of trace metals atmospheric deposition and active moss biomonitoring conducted at the same monitoring sites in Tirana. Slight contamination was detected at S2 and S3 residential sites and moderate to high contamination at S1, S4, and S5 cross-road sites (Aničić-Urošević et al. 2023).

Conclusions

This research shows the daily mean results of particulate matter PM2.5 and elements linked with soil dust and/or road dust emission (Al) as well as traffic emission (Pb). The content of PM2.5 in residential sites was lower than in high-traffic areas. In general, the content of PM2.5 in Tirana measured during high traffic periods exceeds the limit values suggested by WHO and EU Directives, which may pose a health risk to the people living in Tirana. The increased level of PM2.5 at heavy traffic crossroads sites compared to residential sites, chosen as control sites, suggested high effects of traffic on the generation of PM2.5 and an additional health risk for people living near the crossroads and heavy traffic sites. The spatial distribution of PM2.5 and its very good association with Al and Pb indicate that it is dominated by soil and road dust emission, traffic emission, open burning, and secondary species.

The findings of this study are limited because they were derived from daily measurements made at a few monitoring sites during three separate traffic peaks (morning, midday, and evening). The results of this research suggest some crucial improvements in monitoring systems that could help to evaluate the processes and factors that affect air quality and the effects on the health of those who live in polluted areas that are caused by short- or long-term exposure.

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