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Particulate matter concentrations over the region of North-West of Albania

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Abstract
Aerosol mass concentrations, called PM_x, are the key parameters of air quality index. The most measured mass concentrations are $PM_{2.5}$ and PM_{10}. Despite of this, nowadays exist many international and national limits on these two quantities. Recent studies focus the interest more on smaller aerosol modes (like PM_1), as well as on aerosol number concentrations. In this study, we have focused our work on estimation of PM_x concentrations over a wide geographical range; north – west of Albania. This region contains urban and rural centers, mountainous and remote areas, zones near Shkodra Lake and Adriatic Sea. Here we present average values of PM_1, $PM_{2.5}$ and PM_{10} concentrations over all above-mentioned areas. The results of this study give valuable information regarding on the air quality index in this region.

Keywords: air quality, PM concentrations, north – west of Albania.

Introduction
Air pollution is generally studied in terms of immediate local concerns rather than as a long-term "global change" issue. In the coming decades, however, rapid population growth and urbanization in many regions of the world, as well as changing climatic conditions, may expand the scope of air quality concerns by significantly altering atmospheric composition over broad regional and even global scales [1, 2]. Ozone and PM are of particular concern because their atmospheric residence times are long enough to influence air quality in regions far from their sources and because they also contribute to climate change.
Human activities have also increased airborne particulate matter (PM), which encompasses a diverse class of chemical species including sulfates, nitrates, soot, organics, and mineral dust [3, 4]. These gases and particles are relatively short-lived, remaining in the atmosphere for only days up to months near the surface. Ozone and PM are of particular concern because their atmospheric residence times are long enough to influence air quality in regions far from their sources and because they also contribute to climate change [5, 6].
Environmental pollution surrounds us in the air, food, soil and drinking water. Air pollution is one example of man-made environmental problems produced by a multitude of technological activities. Air pollution has been investigated more systematically since the 1950s as a factor in dirty environments and environmental episodes.
Airborne PM is a generic term applied to a broad class of particles ranging in size from molecular clusters less than 0.001 μm to particles of more than 50 μm in diameter. The particles are composed of chemically diverse materials. They are transported in the air as solid particles or liquid droplets. Outdoor particles originate from varied natural processes and human activities, including forest fires, wind erosion, agricultural practices, fossil-fuel combustion, industrial manufacturing, and the construction and use of buildings and roads [7]. The particles can be emitted directly from the sources or formed in the atmosphere from gaseous precursors, such as sulfur dioxide, nitrogen oxides, and hydrocarbon vapors [8, 9]. The variety of sources of particles and gases and the transformations of particulate matter in the atmosphere produce airborne particles of different sizes and chemical composition [10, 11]. For example, the particles can contain heavy metals, acids, biological or biogenic material, or other organic and inorganic compounds.
Previous studies about air quality in Albania, are related mainly to the estimation of ion and aerosol concentrations [12-18].

2. Materials and methods

Our investigation was spread in the region of Shkodra, which area is about 2,500 km^2 (fig. 1). In fields, mountains, populated rural centers and city of Shkodra, were carried out all the measurements.
The period of the measurement campaign begins in January 2009 up to March 2012. Measurements are repeated periodically over the entire monitoring period.
Measurement region is presented in blue rectangle (fig. 1). This region is located in the North – west part of Albania (red rectangle).

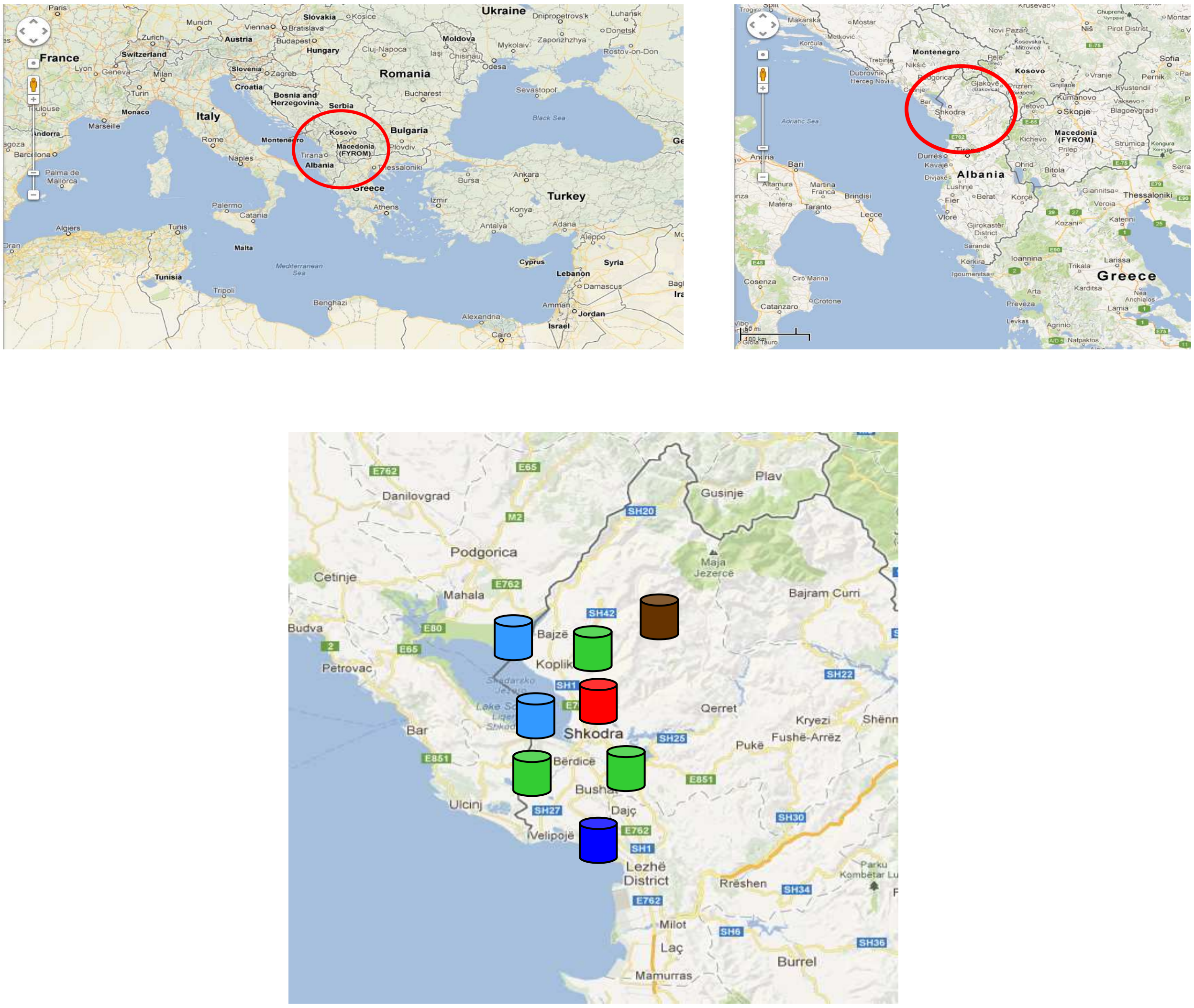

Figure 1. Measurement region in the North – west Albania

In figure 1, colored cylinders show the locations of the measurements; red-urban, green-rural, brown-mountain, blue-seashore and light blue-lake bridge.
Measurements of PM_x concentrations were realized using Environmental Dust Monitor, model GRIMM180. This instrument measures aerosol number concentrations (separated into 31 bins) as well as aerosol mass concentrations (PM_1, $PM_{2.5}$ and PM_{10}). In this study we are focused only on the estimation of PM_x values. Looking for its characteristics, we can see that the Environmental Dust Monitor is a good alternative of the TEM. Table 1 gives all the characteristics of these six locations, together with the exact period of measurements.
Urban center of Shkodra and seashore (during summer season) is characterized by a high traffic rate, intensified commercial and residential activities and low industrial activities. Rural centers are characterized by moderate traffic rate and residential activities. The centers along the Shkodra Lake bridge are characterized by moderate traffic rates and commercial/residential activities. Mountain sites and seashore (during winter

season) are characterized by low traffic rates and human activities. One photo of the measurement instrument is presented in figure 2.

Table 1. Characteristics of measurement locations

	Altitude (m)	Population density (km^{-2})	Traffic activity	Period of measurements
Urban Centre	5-10	10000-20000	High	Jan 2009 – Mar 2013
Rural centers	10-100	1000-5000	Medium	Jan 2009 – Mar 2013
Mountain centers	700-1500	100-500	Low	Jan 2009 – Mar 2013
Seashore (summer)	0-3	20000-30000	High	Jan 2009 – Mar 2013
Seashore (other seasons)	0-3	100-300	Low	Jan 2009 – Mar 2013
Lake bridge centers	0-10	1000-5000	Medium	Jan 2009 – Mar 2013

Figure 2.Environmental Dust Monitor

Despite of this the instrument measures also some meteorological parameters, like air temperature, atmospheric pressure, relative humidity and wind speed. All the measurement campaign was conducted under fair – weather conditions. Table 2 presents average values of the meteorological parameters.

Table 2.Values of meteorological parameters

	Min.	Avg.	Max.
Temperature (^oC)	5	23	35
Relative humidity (%)	43	63	85
Atmospheric pressure (hPa)	950	1026	1036
Wind speed (m/s)	0.1	0.7	5.3

3. Results and discussion

An assembly of monitoring results in PM_x concentrations is given in tables 3-5. In this table there are presented average values of PM_x concentrations in several measurement sites.

Table 3. Average PM_1 values over monitoring sites ($\mu g/m^3$)

	Min	Avg	Max
Urban Centre	14.0	39.6	123
Rural centers	11.2	18.8	27.7
Mountain centers	7.2	23.2	23.5
Seashore (summer)	17.5	15.8	30.9
Seashore (other seasons)	7.6	26.1	18.5
Lake bridge centers	7.0	22.5	25.2

Table 4. Average $PM_{2.5}$ values over monitoring sites (µg/m^3)

	Min	Avg	Max
Urban Centre	18.3	47.3	132
Rural centers	16.4	18.2	30.9
Mountain centers	8.2	22.4	32.2
Seashore (summer)	21.7	10.7	39.9
Seashore (other seasons)	10.0	28.8	20.1
Lake bridge centers	8.1	24.2	29.3

Table 5. Average PM_{10} values over monitoring sites (µg/m^3)

	Min	Avg	Max
Urban Centre	38.0	105	164
Rural centers	25.3	25.32	58.3
Mountain centers	12.4	12.40	97.6
Seashore (summer)	40.9	97.50	117
Seashore (other seasons)	20.3	22.92	26.0
Lake bridge centers	11.0	24.46	47.7

We have classified these measurement sites into main groups, depending on their principal characteristics. The principal characteristics of these sites are the density of population, anthropogenic activities, altitude, forestry, passing roads, etc. All these factors contribute to particulate matter especially on the values of PM_1, $PM_{2.5}$ and PM_{10}. We have divided almost all measurement sites into two main groups called centers and areas. This was because anthropogenic activities like combustion and traffic are more intense on populated sites. We have also divided measurement results on seashore sites into two periods; summer (when anthropogenic activities are very intense because of tourist activities) and during the other part of the year (a period which is characterized by low anthropogenic activities). Lake bridge centers are populated centers near Shkodra Lake, like Shirokë, Zogaj, etc.
We have presented average values graphically, in order to be more clear. Figure 3 presents the graphics of average values of PM_x.

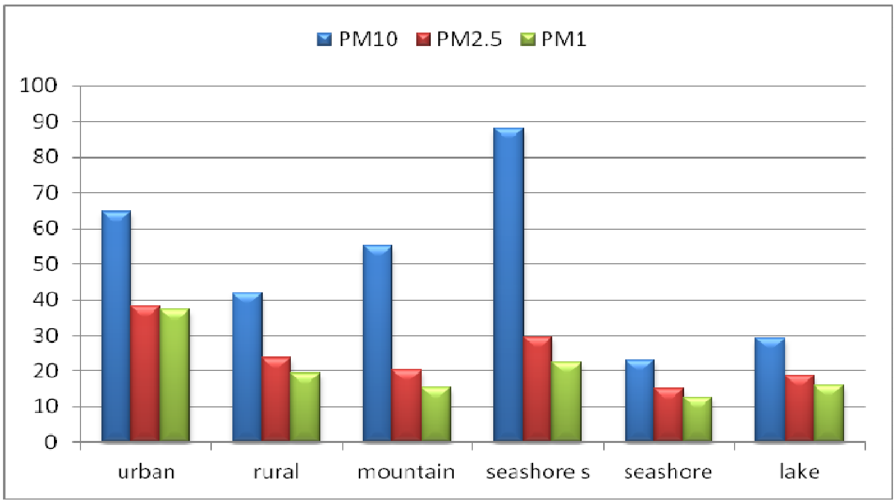

Figure 3. Average PM_X concentrations over monitoring sites

In figure 3 color codes are; green for PM_1, red for $PM_{2.5}$ and blue for PM_{10} concentrations.
As it is clearly seen from the values in tables 3-5 and figure 3, the main sources of PM concentrations are located in the urban center and seashore site (during summer season). While urban center is characterized by aerosols of low and middle modes, seashore site is more characterized by aerosols of higher modes. Thus in the urban center dominates aerosol sources, like traffic and combustion processes, which emits aerosols in

sub-micrometric mode. In seashore site, especially during tourist season, dust resuspension processes enhance the values of aerosols of super-micrometric modes.
Lowest PM_x concentrations are encountered at seashore sites (except summer season), mountain sites and lake bridge centers. Seashore and mountain sites have rare population and very few anthropogenic activities are carried out on those sites. Low PM_x values in lake bridge sites are related mainly to the large surface covered by water in that region. This fact reduces the activity of dust resuspension processes.
Meanwhile rural centers reach intermediate values for; PM_1, $PM_{2.5}$ and PM_{10} concentrations. In these areas, main aerosol sources may be local combustion processes, biomass burning, traffic, etc.
As we can see, average values of PM_{10} in seashore sites vary in the order of four during the seasons. For lower aerosol modes, this variation is in order of two.
PM_x values differ much many times in several sites of the urban center. In this area are obtained maximal differences on PM_x concentrations, especially if we compare these values on near-roads measurements and in the inner part of the city (distant from the principal roads). The first site is influenced directly by traffic, whilst the second site represents the concentration background in the city. Measurement values before presented are carried out on the measurements in the inner part of the city.
PM_x concentrations are usually higher in the inner part of the city, except PM_{10} concentrations during the cold season when domestic combustion processes like heating and cooking are more intensified. The values of PM_{10} in the near-roads sites are 1.9 times higher than their values in the inner part of the city. Meanwhile the values of PM_1 are 1.3 times lower and the values of $PM_{2.5}$ are approximately equal.
PM_x values on near-roads measurements undergo to clear diurnal cycles, because the traffic has a strong diurnal pattern. Meanwhile PM_x values of the measurements on the inner part of the city, are characterized by smooth diurnal cycles [19].
Values of PM_x and wind speed are well correlated. It is observed that wind speed influence on the reduction of PM_1 and $PM_{2.5}$ (dispersion process) and increase of PM_{10} (resuspension process). The trajectories of the air masses relate to the wind direction. This factor determines also the origin of air masses and so the characteristics of the particulate matter. Meanwhile the influence of the other meteorological parameters is somewhat weak.
We can mention that there are established international regulations for $PM_{2.5}$ and PM_{10} values, whilst PM_1 is under discussion. Thus, the estimation of these quantities gives valuable information about the environmental status of monitoring region. On the environmental point-view, we can compare our $PM_{2.5}$ and PM_{10} values to international recommendations for air quality. We are based on WHO[1] and EPA[2] limits for such comparisons.

Table 6. International regulations on $PM_{2.5}$ and PM_{10} concentrations ($\mu g/m^3$)

	$PM_{2.5}$	PM_{10}
WHO	25	50
EPA	35	150

Comparing our average measurement results to the values in table 6, we can see that in the urban center and seashore site (during summer season) $PM_{2.5}$ values exceed both WHO and EPA limits, whilst PM_{10} values in these sites exceed only WHO limits. Meanwhile $PM_{2.5}$ and PM_{10} values don't exceed international limits, although PM_x values in rural sites are quite near WHO limits.
Based on the WHO values, PM_{10} values over urban centers of our region (Montenegro, Serbia, Rumania and Bulgaria) are about 53-56 $\mu g/m^3$ [20].
Average values of PM_{10} over the entire region of the North-West of Albania are about 65.1 $\mu g/m^3$. This value is about 1.2 times higher than the region mean.

Conclusion

Here in this paper there are presented overall results of PM_1, $PM_{2.5}$ and PM_{10} concentrations in several sites in Shkodra region (North – West of Albania). All these sites are grouped into six main groups; urban center, rural centers, mountain centers, seashore (summer), seashore and Lake bridge centers. The overall results

[1] World Health Organization; allowed exceedance 35 times a year
[2] US Environmental Agency; 24-hour average

show that highest PM_x concentrations were encountered on the urban center and seashore site (during summer season). The lowest concentrations were encountered on seashore sites, especially during cold season. Also low values on PMx concentrations were encountered on mountain and lake bridge centers. Meanwhile in rural centers these concentrations were somewhat high. Comparing to international regulations, $PM_{2.5}$ concentrations in the urban center and seashore sites (during tourist season) exceed WHO and EPA limits, whilst PM_{10} concentrations at these sites exceed only WHO limits. Despite of this, average values of PM_{10} in populated centers are about 1.2 times higher than the regional mean.

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