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A COMPARATIVE STUDY OF AMBIENT AIR QUALITY STATUS IN MAJOR CITIES OF ALBANIA

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Abstract

This paper presents the evaluation of air quality status performed during the period 2002-2011, in the major cities of Albania. We attempted to investigate four key pollutants (SPM, PM_{10}, SO_2 and NO_2) and their annual averages were used for the calculation of the air quality index (AQI) and the air quality sub-indices (AQSI) for each of the pollutants. The highest sub-index value was taken as the year overall air quality index (YOAQI). The AQSI values showed that PM_{10} and SPM significantly contributed toward the deterioration of the air quality and according to their values the air quality was poor or very poor. The AQI values with a range of over 75 signify the prevalence of high and critical pollution levels. A similar situation was indicated also by the YOAQIs evaluation, with a heavier atmospheric pollution. To communicate the health risks caused by air pollution we recommend using AQI, based on the ambient concentrations of four pollutants simultaneously.

Keywords: air pollution, air quality index, sub-index, overall assessment, PM_{10}, SPM.

1. INTRODUCTION

The urban areas are often characterized by high levels of air pollution. Air pollution is one of the most important environmental problems in the world (Alkoy et al., 2008) and is becoming a very important factor of the quality of life in urban areas (Žujić et al., 2005). For decades, it has been well known that air pollution causes adverse health effects on humans (Shandilya et al., 2012). It is widely acknowledged that both long- and short-term exposure to air pollutants contributes to morbidity and mortality (Künzli et al., 2000; Zhao et al., 2013; WHO, 2006; Alkoy et al., 2008). These adverse health effects increase medical costs, lower workforce's productivity and undermine people's quality of life. Thereby, the World Health Organization (WHO) and other international agencies have identified urban air pollution as a critical public health problem (UNEP, 2005).
The monitoring of air quality has become very important due to the harmful effects on the biosphere and thus on human health (Eötvös, 2007). The monitoring and evaluation of ambient air quality is the first important step in controlling the air pollution (Roy et al., 2010; Singh, 2006). One way of assessing the air quality in an area is to use the Air Quality Index (AQI). In essence, an AQI is constructed to express the levels of one or more air pollutants, over various critical averaging periods, against a reference. The national air quality standards (NAQS) are usually used as the reference for the index (Roy et al., 2010; Wong et al., 2012). There are variations among the AQI systems developed by different countries (Damo and Icka, 2012; Wong et al., 2012), which are designed to report the state of the air quality in a specific area or region, and to communicate its associated health risk (Wong et al., 2012). The AQI Reporting System is an important tool of risk communication. It informs the public of the local level of ambient air pollution, and the potential health risk it would impose (Wong et al., 2012). Because of its simplicity, AQI is one of the most important tools available for analyzing and representing air quality status uniformly (Chauhan et al., 2010; Mamta and Bassin, 2001), and serves as a convenient early warning tool (Kowalska, 2009).
Air pollution problems have been met in urban areas of Albania during the last two decades. However, the absence of AQI evaluating system in Albania remains a problem for the assessment of the ambient air quality (Damo and Icka, 2012). To furnish the public with information on local air-pollution levels, the Ministry of Environment, Forestry and Water Administration (MoEFWA) has compared the average annual values of key air pollutants for the monitoring stations with the annual average values of Albanian standards and the values of the European Union standards (AEF, 2008; 2009; 2010; 2011; 2012). The use of standards is important in administrating and enforcing a desired policy, but they are not a complete tool for evaluating environmental quality (Panda and Panda, 2012). A comparison of data with standards serves to find out the extent values, but this cannot map the periodical degradation in the air quality, particularly if the measured values remain below NAAQS (Roy, 2010; Singh, 2006). Further, the awareness of high air pollution concentrations or even the frequency of which the national air quality standard are exceeded is not sufficient for the citizens to assess urban air quality (Nagendra, 2007). The inhaled air contains a vast number of chemical pollutants. These chemicals not only interact with each other, but also with the cells and cell compounds of respiratory and cardiovascular systems of human (Alkoy et al., 2008). Therefore, controlling air pollution is a complex issue, because the air quality in a given area is a multi-scale problem (Juda-Rezler, 2010), a multi-pollutant problem (Cofala et al., 2010).

There are different ways to convert the ambient concentrations for each pollutant into an index value. The used function varies by pollutant, and is different in different countries, but Elshout et al. (2012) mentioned that one way is not necessarily better than the other. The most common way to do so is generally based on a number of sub-indices for individual pollutants (single-pollutant indices). The air quality sub-indices (AQSIs) for each pollutant are usually obtained by dividing observed concentration by a reference value and multiplying by 100. After calculation of each of the sub-index values, the highest of these is taken as the overall air quality index (Plaia and Ruggieri, 2010; Wong et al., 2012; Bishoi et al., 2009; van den Elshout et al., 2012). Another way of making an index is the approach of a multi-pollutant index, which takes in consideration the conjoint effect of more than one pollutant to formulate an aggregate air quality index (AQI). The overall air pollution index for a site or region is calculated from a combination of concentration of common air pollutants which are known to harm human health (Plaia and Ruggieri, 2010). A graded assessment scale is available in order to classify the final value of the AQI, which e.g. can serve as basis for planning specific recommendations with respect to the air quality (Makra et al., 2003).
The purpose of this study is to bring objective information to the air quality in seven major cities in Albania by examining long-term monitoring data (for the period 2002 – 2011). It was focused on four major air pollutants: total suspended particulate matter (SPM), respirable suspended particulate matter (PM_{10}), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). The level of air pollution is described in different ways, using air quality sub-indices (AQSI) and the air quality index (AQI), to provide information on air quality and associated health concerns for the citizens.

2. MATERIALS AND METHODS

2.1. Description of study area

The Republic of Albania lays in the South-East Europe, in the Balkan Region, along the Adriatic and Ionian coast (Fig. 1). The country covers a total of 28,000 square kilometers and its population is about 3.2 million. The country geography is mostly mountainous (covers 77% of its territory). The average altitude is 708 m, i.e. two times higher than of Europe. Albania is part of the subtropical Mediterranean climate, with relatively short and humid winters and very dry and hot summers. The average temperatures vary between 3.5ºC to 8.9ºC during the winter time and between 17.8ºC to 24.6ºC during the summer. The average annual precipitation is about 1480 mm, and it varies from West to East.

Figure 1. Map of Albania and monitoring cities

The Ministry of Environment, Forestry and Water Administration (MoEFWA) is the main actor for Environmental issues in Albania and the main institution for environmental data. The air quality in Albania has been monitored since 1976, but the systematic monitoring of air pollution levels was established in the last decade under National Environmental Monitoring Program. Monitoring process includes 7 major cities (Tirana, the capital; Shkodra, Durrës, Elbasan, Fier, Vlora and Korça) and is based on a set for six common air pollutants (often called ‘criteria’ pollutants: SPM, PM_{10}, NO_2, SO_2, O_3 and Pb.

2.2. Air quality sub-indices determination (AQSI)

In our study, based on the annual average concentration of the main pollutants of the ambient air in Albania (SPM, PM_{10}, SO_2 and NO_2), in different cities on different years, an air quality sub-index (AQSI) was calculated using the following equation (DSEWPaC, 2011; ARPA, 2013; Barman et al., 2010; Gupta, 2012).

$$AQSI = \frac{C_o}{C_s} \times 100 \qquad (1)$$

Co - Observed annual mean concentration of a pollutant,
Cs - Annual standards of the respective pollutant. The used Cs values are the recommended national ambient air quality standards (DCM, 2003) (Table 1).
The air quality for each pollutant is divided into 5 classes (Table 2), depending on the computed value of AQSI (DSEWPaC, 2011; ARPA, 2013). Each class of the AQSI corresponds to a different level of air quality and associated health risk. An index value less than 100 means the pollutant has not exceeded the standard. A value equal to or greater than 100 means the pollutant has exceeded the relevant air quality standard (DSEWPaC, 2011; Wong et al., 2012).
In the present study, in order to get an overall appreciation of air quality in a particular monitoring city, the year overall air quality index (YOAQI) is equal to the highest of the determined sub-indices for one particular pollutant for that monitoring city (DSEWPaC,

2011; Wong et al., 2012; ARPA, 2013; Shandilya at al., 2012; van den Elshout et al., 2012; Bishoi et al., 2009).

Table 1. Albanian Standards for pollutants content in the air (DCM, 2003)

Pollutant	The annual average values, µg m-3
SPM	140
PM_{10}	60
SO_2	60
NO_2	60

2.3. Air quality index determination (AQI)

Air quality indices aim at expressing the concentration of individual pollutants on a common scale where effects, usually health effects, occur at a value that is common to all pollutants (Shooter and Brimblecombe, 2009; Plaia and Ruggieri, 2010). It is an environmental index which describes the overall ambient air status and trend of a particular place based on specific standard (Bhuyan, 2010; Panda and Panda, 2012).

Table 2. Air quality classes and the connection between health impacts

Classes of air quality	Index range	Health effects
Very good	0- 33	Air quality is considered very good and air pollution poses little or no risk.
Good	34 – 66	Air quality is considered good, and air pollution poses little or no risk.
Fair	67 – 99	Air quality is acceptable. However, there may be a health concern for very sensitive people.
Poor	100 - 149	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range.
Very Poor	> 150	Air quality is unhealthy and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects.

There are several methods and equations used for determining the aggregated AQI. However, the below mentioned equation (Banerjee and Srivastava, 2011; Joshi and Semwal, 2011; Kumar et al., 2011; Panda and Panda, 2012; Yadav et al., 2012; Gupta, 2012), which is based on the combined effects of four criteria pollutions: SO_2, NO_2, PM_{10} and SPM, has been used for computation of AQI value:

$$AQI = \frac{1}{4}\left(\frac{PM_{10}}{sPM_{10}} + \frac{SPM}{sSPM} + \frac{SO_2}{sSO_2} + \frac{NO_2}{sNO_2}\right)x100 \qquad (2)$$

Where:

PM_{10}, SPM, SO_2 and NO_2 represent the actual average monitored values of pollutions obtained on sampling.

sPM_{10}, sSPM, sSO_2 and sNO_2 represent the standards of ambient air quality.

The selection of equation (2) was done for the fact that particulate matter is one of the most important indoor air pollutants involved in a number of adverse health effects (Eštoková et al. 2010) and it is an important marker of air quality (Castro et al., 2010). Furthermore, particulate pollution is a very serious problem in the urban areas of Albania.

After compiling the monitored value, the concentrations of each pollutant were converted into annual aggregated AQI. According to Wong et al. (2012), the annual index, on the other hand, provides an overview of the air quality situation in a given city throughout the year, with respect to the standards. It is developed to reflect the effect of long-term exposure to air pollution. The AQI has a scale from 1 to 100 that describes the range of air quality and its associated potential health effect. The five levels of AQI, with lower rankings representing better air quality, are depicted in Table1 (Banerjee and Srivastava, 2011; Bhuyan et al., 2010; Joshi and Semwal, 2011; Kumar et al., 2011; Panda and Panda, 2012).

The air quality data in this study were collected from the Report on Status of the Environment (AEF, 2008; 2009; 2010; 2011; 2012; ME, 2006), expressed as annual average.

Table 3. Rating scale of Air Quality Index

AQI value	Remarks	Health concern
0-25	Clean air	None, or minimal health effects
26-50	Light air pollution	Possible respiratory or cardiac effect for most sensitive group
51-75	Moderate air pollution	Increasing symptoms of respiratory and cardiovascular illness
76-100	Heavy air pollution	Aggravation of heart or lung disease
>100	Severe air pollution	Serious aggravation of heart or lung disease. Risk of death in children.

3. RESULTS AND DISCUSSION

The values of annually PM_{10} and SPM concentrations measured in the major cities of Albania, during the study period (2002-2011), are presented in table 4 and 5 respectively. The average values were above the annual maximum admissible concentration by NAAQS, for both sorts of pollution. These results indicate that the population is exposed to very high levels of this pollutant for long periods of time. The highest average levels have been noted in Tirana during the period 2002 – 2008 and Elbasan during the period 2002 – 2005, where the high concentrations may be even more problematic in terms of human health due to the fact that most of the particles in these cities are derived from anthropogenic sources. Their concentrations tended to increase for cities of Vlora and Korça, where they achieve maximum average values during 2009 for PM_{10} and 2008 for SPM. On the contrary, the concentrations significantly decrease in Elbasan. A decreasing tendency has been observed in SPM and PM_{10} levels even in Tirana, over the last year, and they remain roughly constant for cities of Shkodër, Fier and Durrës. The higher SPM and PM_{10} concentrations might be due to re-suspension of road dust, soil dust and vehicular traffic, poor maintenance of vehicles and not good conditions of the road. The average concentrations of SO_2 (table 6) in the measuring period were below the standard limit value. The concentration of SO_2 (table 6) was comparatively lower than the prescribed standard of NAAQS in all the monitoring cities. The higher concentrations of this pollutant were observed in the city of Elbasan in the early period (2001-2002), where SO_2 levels were greatly reduced during the later period, 2008-2011. A significant increase of mean SO_2 levels was observed during the latter period, 2008-2010, in the city of Fier, which might possibly be due to emission from industrial area located near the city. In the case of other cities there was not a clear trend throughout the years.

Table 7 presents a summary of the annually averaged concentrations for oxides of nitrogen (NO_2) monitored during the whole period of the study. It can be seen that concentration levels are well below the prescribed annual NAAQS. The highest annually levels are registered in Tirana (50 μg m^{-3}), while the lowest concentrations are registered in Korça city (11 μg m^{-3}). The values registered in Tirana were considerably higher than those observed in other cities in Albania. This elevated level might be attributed to the high traffic density of the town.

Table 4. Annually variations of PM_{10} (μg m^{-3}) in the study cities

City	Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Tirana	152	159.5	167	172	163	160	173	133.5	72.8	82.6
Shkodër	101	102	103	107	100	101	108	112	86	93.9
Durrës	124	109.5	95	91	93	100	116	121	91	104
Elbasan	175	147	119	120	90	103	57.2	51.4	116.5	97.2
Fier	109	92	75	93	106	102	112	110	93	89
Vlora	70	69.5	69	72	86	89	86	91	80	83.7
Korça	70	63	56	63	82	91	92	93	85	84.4

Table 5. Annually variations of SPM (μg m^{-3}) at the studied cities

City	Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Tirana	245	217.5	190	365	338	334	348	223	135.5	165
Shkodër	222	225.5	229	224	216	212	228	230	182	192.2
Durrës	272	240.5	209	201	201	211	234	250	192	217
Elbasan	366	335	304	268	191	216	144.7	143	151	157
Fier	258	215	172	203	219	213	238	225	195	185
Vlora	152	154.5	157	161	187	193	210	203	176	180.3
Korça	155	146	137	140	172	185	228	221	186	180

Table 6. Annually variations of SO_2 (μg m^{-3}) at the studied cities

City	Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Tirana	18	17	16	20	24	20	20.7	13	12.7	7.6
Shkodër	20	14.5	9	12	18	11	16	15	17	12.4
Durrës	27	19.5	12	16	19	15	18	18	20.1	15.1
Elbasan	38	29	20	27	22	19	11	14.4	18.4	16.8
Fier	21	19.8	18.5	18	24	25	32	33	26.7	19.6
Vlora	23	16.5	10	12	16	14	7.8	11	21.8	11.4
Korça	14	11	8	10	17	11	10.6	12	19.9	11.3

Table 7. Annually variations of NO_2 (μg m^{-3}) at the studied cities

City	Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Tirana	35	35	35	36	34	38	50	33.5	32.5	39.9
Shkodër	33	23.5	14	18	21	22	28	24	26.6	25.5
Durrës	27	22.5	18	22	24	23	35	28	28.1	32.8
Elbasan	33	29	25	33	22	24	22	24	29.4	31.8
Fier	21	18	15	23	25	24	33	27	31.0	31.5
Vlora	21	19	17	18	23	23	40.6	35	26.0	25.7
Korça	21	16	11	12	20	15	42	31	24.6	16.9

The results of the air quality monitoring in this study indicate that the concentration levels of SPM and PM_{10} exceed the NAAQS, while concentration levels of NO_2 and SO_2 are below the NAAQS. So, the overall results to the evaluation of air quality according to current approach used in Albania (the comparison of measured concentration of pollutant with standards) do not provide a clear picture about the air quality status of the cities. If all the pollutants exceeded the NAAQS, then the air quality of the cities could be referred to as 'objectionable' or 'unacceptable' (Roy et al., 2010). But this situation does not exist in our study. Wherefore, the application of the air quality index to the observed data, helps to maintain a clearly 'map' for the air quality of the cities.
For all sites, we have calculated the AQSIs to evaluate the air quality according to each of the pollutants. The AQSIs for PM_{10} (figure 2), in generally, were higher than 100, even higher than 150, showing that air quality is poor or very poor. The air quality according this pollutant is unhealthy for sensitive groups, even for everyone and may experience serious health effects. As for AQSIs of PM_{10}, the course of the levels of AQSIs for SPM (figure 3) is similar, showing that air quality was poor and very poor for all cities.

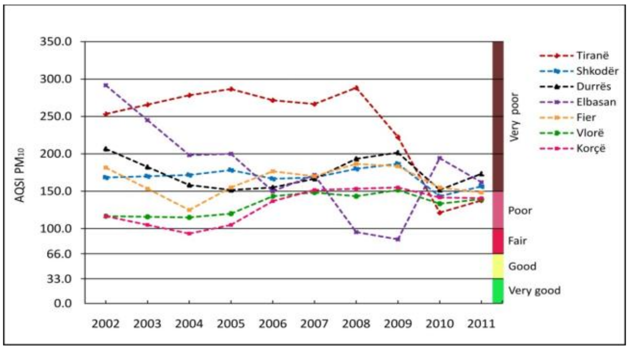

Figure 2. Annually variations of AQSIs for PM_{10}

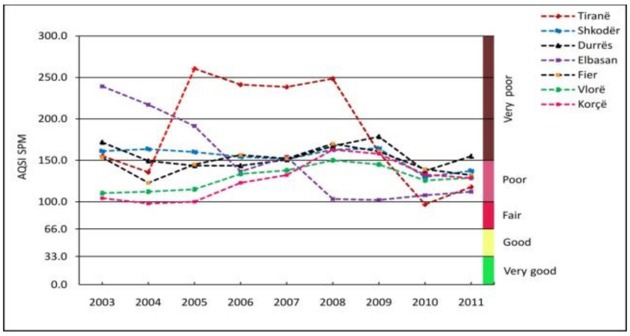

Figure 3. Annually variations of AQSIs for SPM

As can be seen from the figure 4, the SO_2 levels are responsible for causing low pollution at the ambient air quality.
The air quality sub-indices for NO_2 of all the monitoring cities were represented in figure 5. Values show that generally for the whole period of study, the air quality was good and this pollution was responsible for causing moderate pollution in the city of Tirana (2008 and 2011) and in the cities of Korça and Valona for 2008 year. Therefore, it is recommended that adequate managerial practices should be considered for the reduction of the NO_2emission.

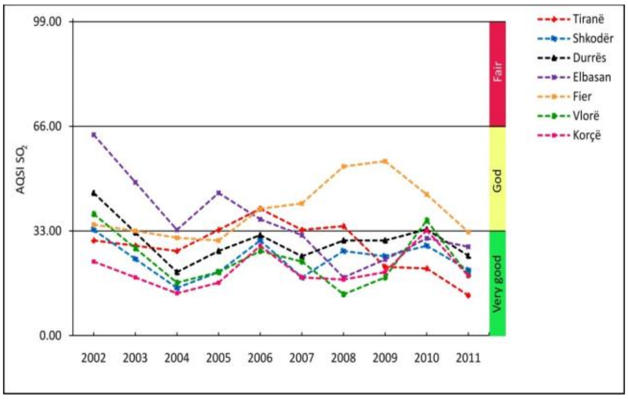

Figure 4. Annually variations of AQSIs for SO_2

The data presented on the graphs show that respirable particulate matter (PM_{10}) is the main air pollutant for public health concern in Albania. It has the highest value of AQSIs among monitored pollutants. Thus, the particulate matter seems to be the dominant problem for the air quality in the major cities of Albania.

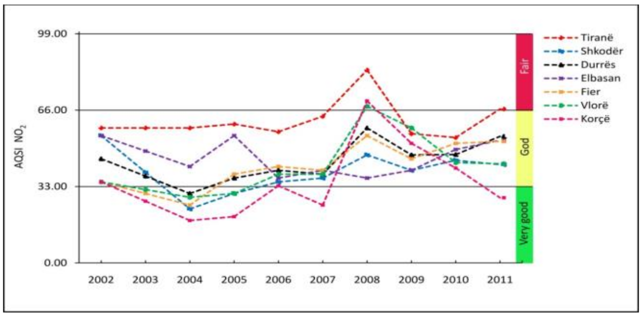

Figure 5. Annually variations of AQSIs for NO_2

Values for YOAQI calculated according to the highest detected value of AQSIs are given in figure 6. The results show that air quality in Albanian's major cities is poor or very poor and the air quality is unhealthy. As a result, everyone may begin to experience health effects. The results also suggest that Korça and Valona cities have the best air quality and the problem is especially severe in the metropolitan area of Tirana and in the Elbasan city.

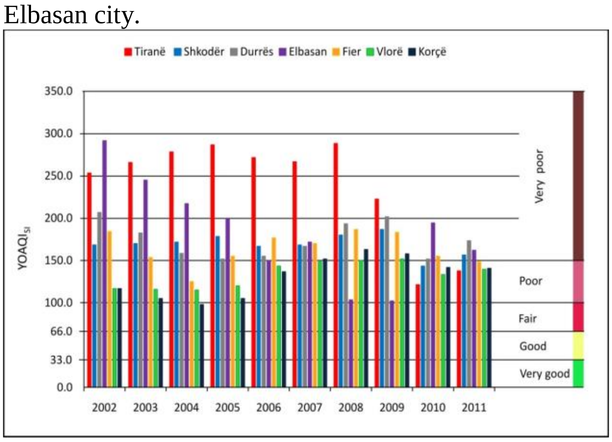

Figure 6. Year overall air quality indices for different air quality monitoring years

The air quality status, according to Air quality index, is given in figure 7, indicating that the cities in Albania have mainly "Heavy" or "Sever" air pollution (AQIs over 75) for throughout the study years. It shows that Albanian air-pollution policies are insufficient and air pollution had exceeds the safe levels.

The AQI values during the period 2010-2011 showed that the state of air quality in Tirana has improved considerably compared with period 2002 -2008. This is a result of the public works on the major road axes during that period, which were the main polluters. The air quality has clearly improved even in Elbasan. In this city, the undertaken environmental policies have contributed to improve the air quality.

The air quality assessment of Korça and Vlora indicate that moderate pollution levels persist during 2002 to 2005 and then subsequently increase to the heavy level. Air quality remains roughly constant for cities of Shkodër, Durrës and Fier. Hence, the computed AQI values clearly indicate that about the alarming air quality in the cities of Albania is recommended to evaluate the efficacy of air quality monitoring and the adoption of appropriate measures in order to reduce the pollution sources.

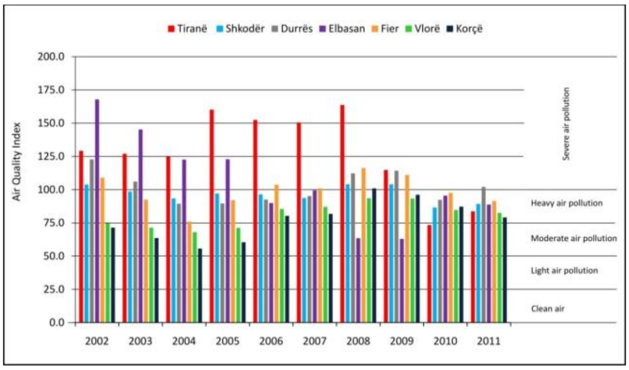

Figure 7. Air quality indices for different air quality monitoring years

Table 8. Frequency (%) of the occurrence of the YOQAI and AQI classes

YOAQI			AQI		
Values	Air quality	Frequency	Value	Remarks	Frequency
0- 33	Very good	-	0-25	Clean air	-
34 – 66	Good	-	26-50	Light air pollution	-
67 – 99	Fair	1.43	51-75	Moderate air pollution	15.72
100 - 149	Poor	32.86	76-100	Heavy air pollution	47.14
> 150	Very Poor	65.71	>100	Severe air pollution	37.14

The values of YOAQI and AQI (graphs 6 and 7) present that air quality in Albanian's major cities is mainly poor (heavy pollution) or very poor (severe pollution). A careful examination of the frequency of the YOAQI and AQI reveals different pollution classes (Table 7). The evaluation according to the YOAQI indicates a heavier atmospheric pollution compared with assessment by AQI (Table 8). But, although the YOAQI conveys the messages that air pollution evaluated by the single-pollutant indices is generally greater, the results are reasonably consistent and the variation in AQI closely follows that of YOAQ.

Reporting the air quality as designated by the level of the single worst pollutant has its limitations (Wong et al., 2012). Shooter and Brimblecombe (2009), also mention that when only a single pollutant is used an air quality index can be misleading. In the real world, multiple pollutants affect the health of the community simultaneously, and the conventional approach simply ignores the joint effects of different air pollutants on human health (Wong et al., 2012). So it is best to express concentration measurements in terms of a multi-pollutant index based on the combined level of the criteria pollutants taking into account the national standards. Hence, to communicate the health risks caused by long-term exposure to air pollutants of Albanian citizens, we recommend using aggregated annual AQI, according to average method, based in part on the ambient concentrations of four pollutant simultaneously, i.e., SPM, PM_{10}, NO_2 and SO_2.

4. CONCLUSIONS

The assessment of air quality in major cities of Albania made by using both aggregated AQI and AQSI methods showed that air quality during the whole study period varies between poor quality (heavy pollution) and very poor quality (severe pollution). The AQSI values of PM_{10} and SPM indicated that they are the main air pollutants in the cities of Albania, causing a high or severe pollution. The evaluation according to the AQSI indicates a heavier atmospheric pollution compared with assessment by AQI.

The application of both of these approaches for air quality evaluation in Albania could provide a more versatile, reliable and comprehensive information on the long-term exposure to air pollutants of Albanian citizens, compared with current approach based simply on the comparison of measured concentration of pollutants with national air quality standards. To communicate the health risks caused by air pollution, these two evaluation methods have been utilized separately. However, we recommend that the application of the AQI allows a more realistic air quality assessment compared to interpretive evaluations according air quality sub-indices, because it takes into account the impact of all pollutants measured. The adoption of such an index to monitor air quality in all the cities of Albania will help mutual comparisons in a much more realistic and meaningful manner and could help in the development and the adaption of appropriate strategies and measures in order to reduce the air pollution.

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