FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 2, N° 4, 2004, pp. 235 - 242

QUALITY MARK OF AIR IN CITY OF NISH, BASED ON MEASURED CONCENTRATION OF SO_2 AND SOOT BETWEEN 1980 AND 2001

UDC 504.06.677.014.05

Nenad Živković[1], Amelija Djordjević[1], Žarko Janković[1], Dragana Nikić[2]

[1]University of Niš, Faculty of Occupational Safety
[2]University of Niš, Faculty of Medicine

Abstract. *A qualitative and quantity mark of air quality is obtained by applying the air index quality. For calculating the air index quality, based on the presence of sulphur-(IV)oxide (SO_2) and soot we use the information on daily concentration of SO_2 and soot in the air, but also we can use information of 98 percentile of all middleday values of SO_2 concentration and soot measured during one year (C_{98}). Measured index of air quality by applying the concentration C_{98} of sulphur-IVoxide and soot for the area of Nish shows us distinctively moderate air quality for the period of 1980-2001.*

Key Words: *Sulphur-(IV)oxide, Soot, Category of Air Quality, Air Index Quality*

INTRODUCTION

In the second half of the 20th century, it happened that the concentration of pollutants in the environment increased. As a consequence of increased concentration of pollutants the living quality also degraded. We observed especially the increasing concentration of pollutants in the atmosphere. Everyday a large quantity of industrial substances and those from energetic installations and traffic are emitted. Pollutants registered in the atmosphere of urban areas are of different chemical structure, and thus of different percentage of toxic.

In this paper we analyzed the air index quality in Nish, as an indicator of the environment protection.

The evaluation of air pollution in our country is performed by the book of regulations on the highest values, measuring methods of emission, criteria for establishing of measuring places and gathering the data ("Sluzbeni glasnik Republike Srbije", br. 54/92). The qualitative measuring of air quality is not regulated by the book of regulations. Yet,

Received August 30, 2003
Project N0: MNT.2.14.0084.Б; MIS.3.07.0149.A/1.

the literature offers a method for quality evaluation of air based on the calculating of "air pollution indicator" ("index of air pollution") which represents the relation between statistically processed measured concentrations of pollutants and GVI.

Qualitative and quantitative evaluation of air quality in Nish, in this paper, is presented on the basis of calculating the index of air quality. Calculating the index of air quality is performed as originally based on the concentration of C_{98}, SO_2 and soot, applying the directive, US, EPA, EPA 451/K-94-001 because both the GVI for daily concentration and SO_2 and soot are the same with high concentration of C_{98}. [2].

INDEX OF AIR QUALITY

Index of air quality represents the relation between daily concentration of standard polluting substances and their influence on general public health. Based on level of daily concentration of air pollutants and their influence on public health, we created a graphic measure index in which we determine the quality of air in urban areas (Fig. 1).

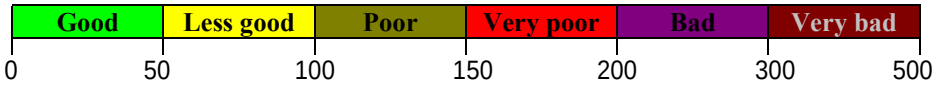

Fig. 1 Scale of Air Index Quality

In this graph of air index quality, number 100 is correspondent to the limit value of polluting substance emission, which is obtained on the basis of document EPA 451/K-94-001.

Different levels of daily concentrations of air pollutants have different effects on people and their health. We defined the interval of scale, table 1, based on the level of air pollutants and their effect on the public health.

Table 1 Daily Level Concentration of Standard Polluting Substances and Interval Index of Air Quality

Level concentration of polluting substances	Concentration of polluting substances							Interval index
	O_3 1-hour. (ppm)	O_3 8-hour.	particles 24-hour.	soot 24-hour.	CO 24-hour.	SO_2 24-hour.	NO_2 24-hour.	
I	-	0-0,064	0,0-15,4	0-54	0,0-4,4	0-0,034	**	0-50
II	-	0,065-0,084	15,5-40,4	55-154	4,5-9,4	0,035-0,144	**	51-100
III	0,125-0,164	0,085-0,104	40,5-65,4	155-254	9,5-12,4	0,145-0,224	**	101-150
IV	0,165-0,204	0,105-0,124	65,5-150,4	255-354	12,5-15,4	0,225-0,304	**	151-200
V	0,205-0,404	0,125-0,374	15,5-250,4	355-424	15,5-30,4	0,305-0,604	0,65-1,1,24	201-300
VI	0,405-0,504		250,5-350,4	425-504	30,5-40,4	0,605-0,804	1,25-1,64	301-400
VII	0,505-0,604		350,5-500,4	505-604	40,5-50,4	0,805-1,004	1,65-2,04	401-500

** Quotation level does not have negative influence on people health

Table 2 presents the graphic index of air quality, category of the air quality and its effect on public health.

Table 2 Graphic Measuring Index of Air Quality and Its Effects on People's Health

Scale of air index quality	Air quality	Effect on people health
0 do 50	Good	Air quality is considered satisfactory and air pollution poses little or no risk.
51 do 100	Less good	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of individuals. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.
101 do 150	Poor	Certain groups of people are particularly sensitive to the harmful effects of certain air pollutants. This means they are likely to be affected at lower levels than the general public. For example, children and adults who are active outdoors and people with respiratory disease are at greater risk from Exposure to ozone, while people with heart disease are at greater risk from carbon monoxide. Some people may be sensitive to more than one pollutant. When AQI values are between 101 and 150, members of sensitive groups may experience health effects.
151 do 200	Very poor	Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects.
201 do 300	Bad	AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.
301 do 500	Very bad	The entire population is more likely to be affected.

Air index quality could be defined as:

$$I_p = \frac{I_{GI} - I_{DI}}{C_{GI} - C_{DI}} \cdot (C_P - C_{DI}) + I_{DI} \tag{1}$$

where is: I_p - Air index quality for correspondent pollutant;
C_p - Measured concentration of emission of correspondent pollutant;
I_g - Upper limit of graphic index of air quality correspondent to the level of concentration of pollutant in which we find concentration of pollution substance C_p (Table 1);
I_d - Lower limit of graphic index of air quality correspondent to the level of concentration of pollutant in which we find concentration of pollution substance C_p (Table 1);
C_{gi} - Upper limit of pollutant concentration level in which we find concentration of pollution substance (Table 1);
C_{di} - Lower limit of pollutant concentration level in which we find concentration of pollution substance (Table 1).

The goal of calculating the index of air quality is obtaining the information on:
- daily levels of pollutant substances air concentration,
- the effect of air quality on public health,
- undertaking the necessary measures to protect the air.

Considering that the GVI for daily concentrations of SO_2 and soot towards directives of EPA 451/K-94-001 are similar with GVI of high concentrations of C_{98}, according to the book of regulations of the Republic of Serbia No. 70/93 calculating the index of

annual air quality can be done according to equation 1. Calculating the index of air quality by using C_{98} makes possible for us to give qualitative-quantity evaluations of air quality for the period of one year.

AIR QUALITY IN THE AREA OF CITY OF NISH IN RELATION WITH THE LEVEL OF CONCENTRATION OF SO_2 AND SOOT

According to the equation 1 we calculated the index of air quality on the basis of 98 percentile of all middleday measured concentrations of SO_2 and soot between years 1980 and 2001 in the following measuring places: 1 – Square Kralja Aleksandra, 2 – Hospital, 3 – Ambulance "Zeleznicar", 4 – Factor "Mlekara Nis", 5 – elementary school "Dositej Obradovic" (Obilicev Venac), 6 – Factor "Blok signal", 7 - elementary school "Cele Kula", 8 – elementary school "Cegar", 9 – Fire station, 10 – Editors' Office of the "Narodne novine", 11 – Medical School, 12 – Niska Banja, 13 – Marketing EI Nis, 14 – Part of city "Bubanj", 15 – elementary school "Sreten Mladenovic Mika" and 16 – Part of city "Obilicev Venac".

Due to the lack of necessary data for calculating the index of air quality in this paper we did not give the index for 1988, 1989 and 1992. Measured values for index of air quality for measuring places in which we monitor the concentration of SO_2 and soot are given in Table 3, and the disposition of measuring places is showed in Figure 5.

In all analyzed years, in most of the measuring places the value of index of air quality is 50 to 100 which corresponds to the category of air quality – moderately good. In the first year we analyzed – 1980 – the value of index over 100 is calculated in the measuring places No. 1, 2,3,5 and 10 (Table 3). According to the calculated value of index from our measuring places we can conclude that the air was of a bad quality related to the concentrations of SO_2 and soot. Calculated index in other measuring places in the year of 1980 had a value from 59 to 91, which shows us that the air quality was moderately good. In the following years, up to 1987 in most of measuring places there was a decrease of values of air quality index and improvement of air quality. Between 1981 and 1987 only in the measuring places 11 and 12 we calculated the value of air quality index of over 100, and in the measuring place 8 under 50.

In the measuring place 12 the value of index over 100 was in years 1982, 1983 and 1984. In the measuring place 11 in the year 1985 the quality of air for the area which covered this measuring place was negative.

In the year of 1984 in the measuring place 8 air quality was good.

Height value index (108) was calculated in 1987 on measured place No. 1. On the rest measured places in that year value of index was from 19 to 99. Next year, 1988, on all measured places calculated value index was- air quality- moderate good.

In 1999, calculated value was 46 on the measured place No. 12 (air quality – good), and on the other measured places between 50 and 100(air quality- moderate- good)

In the year of 1993 there came to an increase of index value in the measuring place 10. Calculated value of index for the measuring place 10 is 153, and the area, which covered it, was characterized by the air quality – expressively negative.

Increased values of index air quality are calculated for the bigger number of measuring places in year 1994, in the measuring place no 5 (index 117) and measuring place no 7 (index 117) and measuring place no 10 (index 139).

Number of measuring places in 1995 dropped to 6. In all of 6 measuring places in 1995,1996 and 1997 the calculated value of air quality index corresponds the second interval of the scale of air quality index (Fig. 1). Quality of air in Nish area, in these years is of moderately good quality.

In five measuring places, in which we monitored concentration of SO_2 and soot in 1998 the index value is under 50, the quality of air-good.

In 1997 we monitored concentration of sulphur-(IV) oxide and soot again in the measuring places No. 6 and 14 in which the quality of air was categorized as good. In rest of measuring places (7, 8, 10 and 15) calculated quality index is also categorized as "good" (Table 3).

In 2000 and 2001 in all the measuring places the calculated value indices of air quality were in the interval of scale index of air quality to 50 and the air quality is good. In we analyze the calculated index values of air quality in those 16 measuring places in period between 1980 and 2001 we observe the highest variability of air quality index on the measuring place No. 12. The value of index in the measuring place No. 12 is from 12 (calculated for 2001) up to 148 (calculated for 1982), Table 3. The area, which covers measuring place No. 12, should regularly be characterized as "good" air quality because this area belongs to health and recreation. However, air quality was in a category of "good" only in 1987, 1991 and last four years of the analyzed period. In all the years this quality in the measuring place No. 12 was not satisfactory for the sensitive population.

In 1982, 1983 and 1984 the calculated index value of air quality was even higher than 100. In rest of the measuring places values of index were not significantly different in period of monitoring air quality. Highest index values were calculated for measuring places No. 1, 2, 3, 10 and 15. In the measuring place No. 1 the highest index values (over 100) were calculated for 1980 and 1987. Also, in 1980 high index values were calculated in the measuring place No. 2, 3, 5 and 10.

The least oscillations in index value are in measuring place No. 4, 9, 13 and 14. In these places up until 1998 the calculated index values were always in the second interval of scale index. Air quality in those measuring places was regularly of a moderate good quality. In the measuring place No. 5, the index value of air quality over 100 was calculated for 1980 and 1994. During the rest analyzed years in the measuring place No. 5 the index value of air quality was from 51 (1982) to 98 (1991). Therefore, in the measuring place No. 5 in 1980 and 1994 the air quality was negative and in other years of analyzed period moderately good.

Air quality in the measuring place No. 6 was continually monitored until 1994. The air quality in measuring place No. 6 was in 1994 in the category -negative-, calculated index value of air quality was 113. In rest of the years of monitoring air quality in measuring place No. 6 calculated index value of air quality is less than 100 (air quality moderately good).

In measuring place No. 7 in 1994 air quality was negative, and from 1998 the air quality was "good". The rest of the years of the monitored period in the measuring place No. 7 the air quality was moderately good. For the analyzed period of years the air quality in the measuring place No. 8 was mainly of moderately good quality. In this measuring place the calculated index value of quality was less than 50 in 1983, 1998, 1999 and 2000, when the air quality was "good".

During the monitored period from 1980 to 2001, there was variability of air quality in the measuring place No. 10. In 1980 and 1994 the calculated index value was over 100 (air quality moderately good) and in 1993 it was over 150 (air quality bad). We calculated less index value of air quality of 50 in 1998 (air quality good). In all the rest years of monitoring the air quality was between the interval of 50 and 100.

In measuring place No. 11 we monitored the air quality until 1987. Between the years 1980 and 1987 in the measuring place No. 11 only the year of 1985 had negative air quality. During the rest monitored years the air quality was moderately good. Short period of monitored years in the measuring place No. 15 shows us the variability of air quality. Air quality in the measuring place No. 15 was negative in 1993, and in 1994 expressively negative. Considerable improvement of air quality in the measuring place No. 15 dated from 1998, when the calculated index values of air quality were less than 50 (air quality good). From Table 3 we can see that in most of the measuring places in the analyzed period of years the index value of air quality is from 50 to 100 (air quality moderately good).

Based on 98 percentile of middleday measured concentrations of SO_2 and soot in all the measuring places during the interval 1980-2001 the calculated index of air quality is shown on a diagram in Fig. 2. In the observed period negative air quality in the city area of Nich was in 1989 and 1994. High index values of air quality in these years are not a consequence of changing the emission of SO_2 and soot, but probably the effect of meteorological parameters on the deposition and transmission of SO_2 and soot.

The course of development of calculated index values of air quality corresponds to the course of development of midyear concentration of SO_2 until 1998. This can be explained by the presence of bigger concentration of SO_2 than soot in air, and in this interval the bigger effect on the index value of air quality had SO_2. In the last analyzed years, namely, from 1999 to 2001, there came an increase of soot concentration in relation to SO_2 concentration. The course of midyear SO_2 concentration and calculated index values of air quality is shown in Figs. 2 and 3.

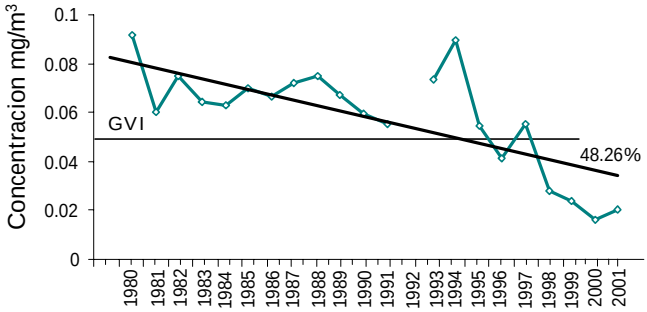

Fig. 2. Mean concentration of SO_2 for the period 1980-2001, and its trend line

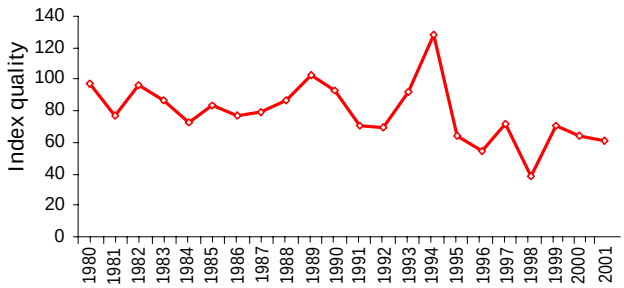

Fig. 4. Air index quality in Nish for the period 1980-2001

Table 3. Air index quality vs. concentration of SO_2;
calculated value in the period 1980-2001

Period	Measured places														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	V A L U E A I R I N D E X Q U A L I T Y														
1980	115	101	117	73	107	71	91	66	87	105	75	59	-	-	-
1981	85	82	95	60	74	71	69	53	70	86	67	56	-	-	-
1982	77	94	73	51	51	55	78	52	70	73	65	148	-	-	-
1983	85	73	80	55	80	80	83	73	78	73	72	141	-	-	-
1984	77	69	70	66	55	60	63	46	69	65	74	102	-	-	-
1985	84	95	85	83	83	86	86	58	77	83	103	76	-	-	-
1986	100	88	63	52	76	60	79	63	80	82	90	56	-	-	-
1987	108	99	74	57	57	54	75	65	54	84	97	19	-	-	-
1988	93	96	81	57	57	59	92	60	-	74	-	65	63	74	-
1989															
1990															
1991	64	63	61	54	98	76	68	57		63	-	46	60	58	60
1992															
1993	63	65	72	-	89	70	70	59	-	153	-	66	66	80	110
1994	76	69	95	-	101	113	117	90	-	139	-	73	89		245
1995	-	-	-	-	65	-	58	57	-	74	-	53	-		56
1996	-	-	-	-	56	-	53	54	-	54	-	54	-		53
1997	-	-	-	-	76	-	75	53	-	62	-	79	-		73
1998	-	-	-	-	59	-	30	32	-	49	-	25	-		41
1999						14	31	24		53		15		23	31
2000					63		56	7		61		10		16	17
2001	94	45			52		51			59		12			24

Fig. 5. Measuring places, marked in the plan of the City of Niš - period 1980-2001

CONCLUSION

Based on the results of the analyses of SO_2 and soot presence in the area of Nish for period 1980-2001 the following can be concluded:

1. In most measuring places in which we monitored SO_2 and soot concentration the air quality is moderately good. Calculated index values of air quality based on the concentration of C_{98} SO_2 and soot are in the second interval of the index value scale.
2. Negative air quality in most of the measuring places was in 1980 (measuring places 1,2,3,5 and 10) and 1994 (measuring places 5,6,7 and 10).
3. Expressively negative air quality was in 1993 in the measuring places No. 15.
4. Great variability of air quality index in monitored period is registered in the measuring places No. 12 and 15. Index value of air quality in the measuring place No. 12 is in the ranges of 25 to 148 and in the measuring places No. 15 from 41 to 245.
5. The course of development of air quality index calculated based on 98 percentile of all midday SO_2 concentrations, measured during 1980-1998 corresponds to the course of development of middle-year SO_2 concentrations in monitored period. This confirms the possibility of quantity evaluation of air quality by doing the calculation of air quality index for longer period of time.
6. Area of Nish is characterized by moderately good air quality.

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OCENA KVALITETA VAZDUHA GRADA NIŠA NA OSNOVU IZMERENIH KONCENTRACIJA SO_2 I ČAĐI U PERIODU 1980-2001. GOD.

Nenad Živković, Amelija Djordjević, Žarko Janković, Dragana Nikić

Kvalitativna i kvantitativna ocena kvaliteta vazduha donosi se primenom indeksa kvaliteta vazduha. Za izračunavanje indeksa kvaliteta vazduha, na osnovu prisustva sumpor-(IV)oksida (SO_2) i čađi koriste se informacije o dnevnim koncentracijama SO_2 i čađi u vazduhu, ali se mogu koristiti i informacije o 98 percentil svih srednjednevnih vrednosti koncentracije SO_2 i čađi izmerenih tokom godine (C_{98}). Izračunat indeks kvaliteta vazduha primenom koncentracije C_{98} sumpor-(IV)oksida i čađi za područie grada Niša pokazuje da je za period 1980-2001. godina karakterističan umereno dobar kvalitet vazduha.

Ključne reči: *Sumpor-(IV) oksid, čađ, kategorija kvalitet vazduha, indeks kvaliteta vazduha*