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## OVERVIEW OF AIR QUALITY LEGISLATION AND MONITORING OF MEASUREMENT ZONE SERBIA

**Abstract:** Air pollution, in general, has a great impact on life quality and ecosystem condition. Main way to control and minimize that influence is to conduct regular air pollution sampling throughout the year and to tight existing or impose new air quality legislations throughout time. Proscribed measures adopted by governments depend on health and environmental recommendations and level of industrial and technological development of the country. Comparison of air quality legislations referring to proscribed limit values of annual and daily concentrations of pollutants such as SO<sub>2</sub>, NO<sub>2</sub> and black soot of Republic of Serbia, EU and neighboring non EU ex-Yugoslav Republics have been analyzed in this paper. Also, comparison of air quality referring to mentioned parameters in the cities of measurement zone Serbia, defined by article 5 of Law on Air Protection, Regulation of zoning and agglomerations in the Republic of Serbia, for the year 2013 have been analyzed.

**Keywords:** Air pollution, immission, air quality monitoring, air quality legislation

### 1. INTRODUCTION

Everyday human activities, especially those following industrial development of life standard increasing society cause emission of various chemical agents, gases, aerosols and other pollutants in the air. Air quality is determined by the presence and concentration of these pollutants and they can affect air microflora [1], forest [2], frost [3], and human environment and health in cities in which about 75% of European population lives [4]. More over centers of industrial development are the most exposed to the negative of bad air quality. According to the World Health Organization burden of disease, globally 7 million deaths were attributable to the household (HAP) and ambient air pollution (AAP) in 2012 [5]. According to Susana Ferreira et al. [6] every increase in SO<sub>2</sub> concentrations is associated with a reduction in life satisfaction. Therefore controlling and limitation of air immission have significant importance for environmental and health protection and life quality.

Since air quality is a regional problem, compatibility among neighboring countries legislations plays an important role for the regional environment. Although the pollution

and physical effects of pollution can be difficult to confine, some differences appear within a certain region, depending on the concentration of industrial facilities and other sources of pollution [7]. Comparison of Serbian, and neighboring ex-Yugoslav non EU countries legislation parameters, referring to black soot and SO<sub>2</sub>, NO<sub>2</sub> limit values, margins of tolerances and time by which margin should meet or already met the limit value, have been shown in Tables 1 and 2 respectively.

As candidates for EU membership ex-Yugoslav republics equiponderate, among the others, its environmental air legislation with EU DIRECTIVE 2008/50/EC [8]. Since rapid change of parameters such as upper threshold values of air immission could have negative impact on industrial development, governments of the mentioned countries accepted EU limit values for SO<sub>2</sub> and NO<sub>2</sub> immission and soot concentration and adopt programs to gradually minimize its current immission values by minimizing margins of tolerance until they reach proscribed limit values.

Table 1 show differences among legislations of the republics related to black soot air concentration.

**Table 1.** Differences among black soot limit values in the region

Country/Region	Averaging period	Limit value		
		24h	Calendar year	Winter time
EU		40 - 60	80	130
Serbia		50		50
Montenegro				<sup>1</sup>
FYR of Macedonia				<sup>1</sup>
Bosnia and Herzegovina	Republic of Srpska	125		50
	Federation of B&H			30

Limit values for black soot immission among Serbia [9], Republic of Srpska [10] and Federation of Bosnia and Herzegovina [11] have been already equiponderated with European [12]. Republic of Montenegro [13] and FYR of Macedonia [14] do not have proscribed limit values.

Governments of FYR of Macedonia and Montenegro already put in force SO<sub>2</sub> and NO<sub>2</sub> immission limit values proscribed by DIRECTIVE 2008/50/EC [8] by canceling margins of tolerance in 2012. Governments of

other republics, except Federation of Bosnia and Herzegovina, have been conducting the plan for minimizing margins of tolerances so they can meet limit values by 2021 or earlier (Table 2).

Main aim of this paper was to determine and compare certain indicators of air quality in 14 cities of a measurement zone in Serbia based on annual air quality immission reports for the year 2013 (Fig 1).

**Table 2.** Comparison of limit values and Margins of tolerance of EU and ex-Yugoslav countries

Country/Region	Pollutant	Sulfur dioxide (SO <sub>2</sub> )			Nitrogen dioxide (NO <sub>2</sub> )			
		Averaging period	1h	24h	Cal. year	1h	24h	Cal. year
EU	Limit value	350	125		200		40	
	Margin of tolerance	-	-		-		-	
	Date by which limit value was met	2005			2010			
Serbia	Limit value	350	125	50	150	85	40	
	Margin of tolerance	90	-	-	60	32	16	
	Date by which limit value should be met	2016			2021			
Montenegro	Limit value	350	125	-	200	-	40	
	Margin of tolerance	-	-		-		-	
	Date by which limit value was met	2012						
Bosnia and Herzegovina	Republic of Srpska	Limit value	350	125	50	150	85	40
		Margin of tolerance	150	-	-	75	40	20
		Date by which limit value should be met	2021					
	Federation of Bosnia & Herzegovina	Limit value	500	240	90	300	140	60
		Margin of tolerance	-	-	-	-	-	-
		Date by which limit value should be met	-					
FYR of Macedonia	Limit value	300	125		200	40	30	
	Margin of tolerance	-	-		-	-	-	
	Date by which limit value was met	2012						

<sup>1</sup>The legislation does not have proscribed limit values for the concentration of smoke and soot.



**Figure 1** - Cities of measure zone Serbia

Measure places will be labeled with corresponding numbers in the further work

(Table 3).

## 2. RESULTS AND DISCUSSION

Immission results of manual measurement collected in 14 cities and 32 measuring locations (Table 3) [15 - 27] are sorted and statistically processed so definition of average annual values such as average annual concentration, median of concentration, number of days above the limit and tolerant values can be obtained. Index of air quality SAQI<sub>11</sub> has been determined for all places that have provided the results of average day immission.

### 2.1. Sulfur dioxide (SO<sub>2</sub>)

Average annual concentration of sulfur dioxide, minimal and maximal daily value, median annual value, number of days beyond limit and tolerant values, as well as index of air quality SAQI<sub>11</sub>, has been determined for every measurement location possible (Table 4).

**Table 3.** Locations of measurement places

City	#	Measurement place location
Šabac	1	Casarne Šabac
Šabac	2	JKP „Stari grad“ –Vojvode Janka Veselinovica
Šabac	3	Heating plant , Benska bara – Đure Jakšića 1
Valjevo	1	Day nursery „Zvončić“ – Vlade Danilovića (city center)
Valjevo	2	Day nursery „Pčelica“ – V Puk
Valjevo	3	Day nursery „Kolibri“ – Novo Valjevo
Kruševac	1	Central pharmacy – Moše Pijađe 4
Požarevac	2	Bradarac, Post office – Jovana Šerbanovića 3
Požarevac	3	Elementary School „Kralj Aleksandar“ – Sime Simića 3
Požarevac	4	Train Station – Knez Milosev Venac bb
Kragujevac	1	Elementary school „Mirko Jovanović“ – Neznalog Junaka 8
Kragujevac	2	Kindergarten „Čuperak“, Iličevo – 19. Oktobar bb
Kragujevac	3	Institute for Public Health – Nikole Pašića 1
Kragujevac	4	Pivara – Infirmary No. 3 – Cara Dušana 16
Kragujevac	5	JKP „Čistoća“ – Industrijska 12
Kragujevac	6	„Energetika“ DOO – Kosovska 4A
Čuprija	1	Institute for Public Health Čuprija „Pomoravlje“ - M. Novakovića 7
Jagodina	1	City Hall, Kralja Petra I, 6
Čačak	1	City center – Koste Novakovića
Čačak	2	Traffic zone – Streets
Ivanjica	1	Infirmary – 13. Septembra
Ivanjica	2	Technical school – Branislava Nušića
Kraljevo	1	Institute for Public Health Kraljevo – Slobodana Penezića 16
Kraljevo	2	Pljakin Šanac
Kraljevo	3	City Hall Kraljevo – Cara Lazara 63
Kraljevo	4	Ribnica, Infirmary – Izletnička bb
Kruševac	1	Trg Mladih - Kosančićeva 36
Kruševac	2	Veterinary Station Kruševac, Bivolje, Mićuna Pavlovića 23
Zaječar	1	„Elektrotimok“ – Generala Gambete 84
Pirot	1	Industry zone
Leskovac	1	Faculty of Technology – Bulevar Oslobođenja 124
Vranje	1	Institute for Public Health – Lenjinova 1

Table 4. Air quality of measurement zone Serbia referring to sulfur dioxide air concentration

Unit:		[ $\mu\text{g}/\text{m}^3$ ]	[ $\mu\text{g}/\text{m}^3$ ]	[-]	[ $\mu\text{g}/\text{m}^3$ ]	[ $\mu\text{g}/\text{m}^3$ ]	[-]	[-]	Frequency of air quality class [%] referring to average daily concentration of pollutant [ $\mu\text{g}/\text{m}^3$ ]				
Pollutant:		Number of measuring days	Average annual concentration	Median concentration (C50)	Maximal measured value	Minimal measured value	Days beyond limit value	Days beyond tolerant value	Excellent	Good	Acceptable	Polluted	Very polluted
City	#								0 – 50	50,1 - 75	75,1 - 125	125,1 – 187.5	> 187.5
Šabac	1	340	24	23	71	5.6	7	7	-	-	-	-	-
Šabac	2	315	25	24	60	6.6	6	6	-	-	-	-	-
Šabac	3	310	23	21	58	5.8	1	1	-	-	-	-	-
Valjevo	1	255	15.57	13	64	11	0	0	98.43	1.57	0	0	0
Valjevo	2	263	14.95	11	59	11	0	0	99.24	0.76	0	0	0
Valjevo	3	290	14.9	11	89	8	0	0	98.97	0.34	0.69	0	0
Požarevac	1	356	22.61	15	116	5	0	0	91.58	6.74	1.68	0	0
Požarevac	2	364	26.26	21.5	135	6	1	1	92.31	6.32	1.1	0.27	0
Požarevac	3	365	25.21	20	97	6	0	0	90.96	6.3	2.74	0	0
Požarevac	4	365	22.43	17	110	6	0	0	92.06	6.57	1.37	0	0
Kragujevac	1	365	5.74	4	61	1	0	0	98.9	1.1	0	0	0
Kragujevac	2	359	4.17	2	50	1	0	0	100	0	0	0	0
Kragujevac	3	365	5.2	4	57	1	0	0	99.18	0.82	0	0	0
Kragujevac	4	365	4	3	25	1	0	0	100	0	0	0	0
Kragujevac	5	365	3.4	2	23	1	0	0	100	0	0	0	0
Kragujevac	6	353	5.75	3	48	1	0	0	100	0	0	0	0
Čuprija	1	318	11.27	10	135.5	10	1	1	97.18	0.94	1.57	0.31	0
Jagodina	1	327	13.04	10	143.3	8.33	2	2	96.33	1.53	1.53	0.61	0
Čačak	1	330	2.85	2	24	1	0	0	100	0	0	0	0
Čačak	2	358	2.82	2	16	1	0	0	100	0	0	0	0
Ivanjica	1	365	3.77	3	19	1	0	0	100	0	0	0	0
Ivanjica	2	365	4.16	3	22	1	0	0	100	0	0	0	0
Kraljevo	1	365	3.62	4.77	5.14	0.17	0	0	100	0	0	0	0
Kraljevo	2	365	4.12	5	5.9	0.47	0	0	100	0	0	0	0
Kraljevo	3	365	3.93	5	0.87	0.6	0	0	100	0	0	0	0
Kraljevo	4	365	3.98	5	5.65	0.6	0	0	100	0	0	0	0
Kruševac	1	333	10	7.7	65.9	2	0	0	99.07	0.3	0	0	0
Kruševac	2	335	10.5	8.5	44.2	2	0	0	100	0	0	0	0
Zaječar	1	338	14.09	3	140.6	0.46	1	1	97.05	1.77	0.89	0.29	0
Pirot	1	330	4.36	4	12.5	4	0	0	100	0	0	0	0
Leskovac	1	340	4.3	2.5	21.3	0.8	0	0	100	0	0	0	0
Vranje	1	365	5.6	4.6	25.9	2.8	0	0	100	0	0	0	0

Daily limit and tolerant value for sulfur dioxide immission is 125  $\mu\text{g}/\text{m}^3$  [9]. The most transgressions above the limit and tolerant daily values (7 and 6) have been recorded in Šabac, on the measurement locations 1 and 2 [16]. The biggest annual average concentration has been recorded in Požarevac (2), 26,26  $\mu\text{g}/\text{m}^3$  [18], and the lowest in Kraljevo (1) 0,13  $\mu\text{g}/\text{m}^3$  [22]. The maximum daily concentration was measured in December 19<sup>th</sup> in Jagodina (1) 143,33  $\mu\text{g}/\text{m}^3$  [20] and minimum in Leskovac (1) 0,83  $\mu\text{g}/\text{m}^3$  on 21 and 22 of January [26]. According to the index of air quality SAQI\_11 the highest quality of air was recorded in the cities of Čačak, Ivanjica, Pirot, Leskovac and Vranje where it had been graded as excellent during all year.

Cities with high average concentration of pollutants and transgressions of limit and tolerant daily values have relatively strong developed industrial sector. The city of Šabac is known by relatively strong chemical industry and Požarevac by coal powered plant electricity production (Kostolac powerplants). Cities with relatively weak industries and altitudes higher then average have had excellent air quality during the monitored period. Annual limit and tolerant value of sulfur dioxide immission is 50  $\mu\text{g}/\text{m}^3$  [9] and it was not exceeded in any measurement place.

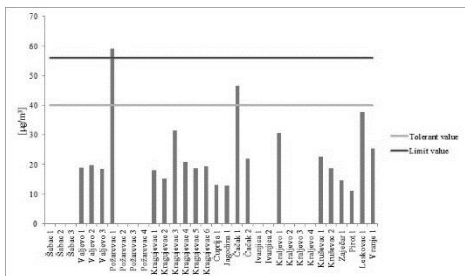


Figure 2 - Average daily concentration of NO<sub>2</sub> in measurement zone Serbia

## 2.2. Nitrogen dioxide (NO<sub>2</sub>)

Average annual concentration of nitrogen dioxide, minimal and maximal daily value, median annual value, number of days beyond limit and tolerant values, as well as index of air quality SAQI\_11, have been determines for every possible measuring location. Average annual concentration of NO<sub>2</sub> in the air of monitored zone Serbia for the year 2013 is shown in Figure2.

Daily limit value for nitrogen dioxide

immission is 85  $\mu\text{g}/\text{m}^3$  and tolerant value 117  $\mu\text{g}/\text{m}^3$  [9]. The most transgressions above the limit and tolerant daily values, 54 and 11 respectively, have been recorded at the location Požarevac (1) [18] and Čačak (1) [21], and on the same location tolerant values have been exceeded too, 13 and 2 times respectively. The maximum daily concentration was measured on December 23 in Požarevac (1) 201  $\mu\text{g}/\text{m}^3$  [18]. According to the index of air quality SAQI\_11 the highest quality of air was recorded in the the city of Pirot where 99,71% of measuring days has been graded as excellent. Annual limit value for nitrogen dioxide immission is 40  $\mu\text{g}/\text{m}^3$  and tolerant value is 56  $\mu\text{g}/\text{m}^3$  [9].

Annual limit and tolerant values were exceeded in Požarevac (1) (59,2  $\mu\text{g}/\text{m}^3$ ) [18] and tolerant value was exceeded on the measure location Čačak (1) (46,5 $\mu\text{g}/\text{m}^3$ ) [21]. Main reason of relatively high nitrogen dioxide air concentration in the city of Požarevac have been coal power plant electricity production and in the city of Čačak transit traffic routs combined with specific geographical position that prevents effective airing.

Measurement of nitrogen dioxide on the measurement locations Šabac (1,2,3) [16], Požarevac (2,3,4) [18], Ivanjica (1,2) [21] and Kraljevo (2, 3, 4) [22] has not been considered due to absence of data in those places.

## 2.3. Soot

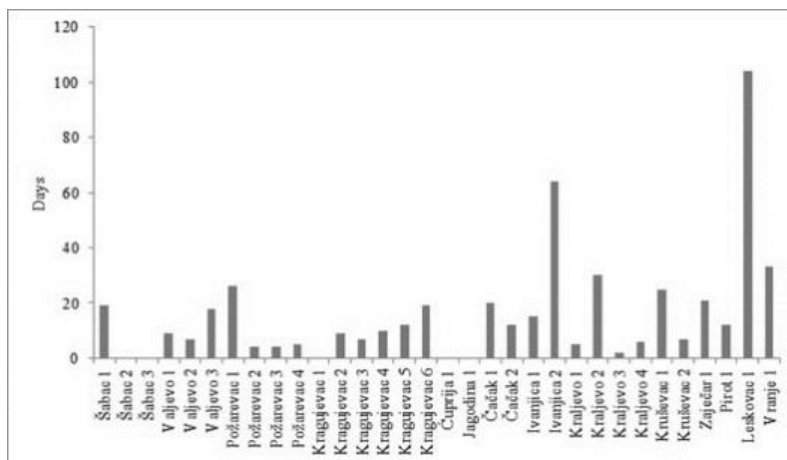
Average annual concentration of soot, minimal and maximal daily value, median annual value, number of days beyond limit and tolerant values, as well as index of air quality SAQI\_11, has been determined for every measuring place possible. Number of days with air concentration of soot beyond proscribed limit values for monitored zone of Serbia are shown in Figure3.

Daily limit value for soot immission is 50  $\mu\text{g}/\text{m}^3$  and tolerant value 75 $\mu\text{g}/\text{m}^3$  [9]. The most transgressions above the limit daily values have been recorded in Leskovac (1) 104  $\mu\text{g}/\text{m}^3$  [26], and Ivanjica (1) 64  $\mu\text{g}/\text{m}^3$  [21], while in the cities of Šabac (2,3) [16], Kragujevac (1) [19], Jagodina (1) [20] and Čuprija (1) [20] there were no exceedances (Fig 3).

The most transgressions above the tolerant daily values have been recorded in Leskovac (1) 48 [26], while in Šabac (1,2,3) [16], Požarevac (1) [18], Kragujevac (1,4) [19], Čuprija (1) [20], Jagodina (1) [20] and Pirot (1) [25], there was no exceedances. The maximum

daily concentration was measured on January 28 in Leskovac (1) ( $236 \mu\text{g}/\text{m}^3$ ) [26]. According to the index of air quality SAQI\_11 the highest

quality of air was recorded in at location Kragujevac (1) where 98,36% of measuring days has been graded as excellent.



**Figure 3** - Number of days with air concentration of black soot beyond proscribed limit values for monitored zone of Serbia

All transgressions in the city of Leskovac have been measured in the days of heating season as a consequence of insufficient treatment of smoke in central heating plant that burns coal and specific geographical position that prevents effective airing. Annual limit value for soot immission is  $50 \mu\text{g}/\text{m}^3$  and tolerant value  $75 \mu\text{g}/\text{m}^3$  [9]. There was no exceedances of neither the one of the annual values.

### 3. CONCLUSION

In this work terms of air quality legislation of Republic of Serbia and neighboring ex-Yugoslav republics were compared with corresponding EU legislation. Assessment based on the average daily data available, obtained by using manual air quality monitoring in the area of measurement zone Serbia for the year 2013, was carried out also.

Annual limit value of nitrogen dioxide has

been exceeded at one measurement location in the monitored zone. Proscribed annual limit and tolerant values for sulfur dioxide and black soot air concentration haven't been exceeded although a lot of daily limits have been, especially those referring to black soot. There had been measured 623 exceedances of limit values in the whole monitored zone, 505 referring to black soot, 99 referring to nitrogen dioxide and 19 referring to sulfur dioxide.

All transgressions of black soot limit and margin of tolerance were recorded in heating season period. From the analyzed it can be concluded that the central heating plants of the monitored zone together with coal power plants represents the main source of air pollution of the zone. Tightening of current air legislation by gradual decrease of margins of tolerances by 2021, and modernization of heating and power plants referring to smoke treatment or transition to the other types of fuel could have positive influence on air quality of the measurement zone Serbia.

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