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ANNEX TO THE ANALYSIS OF BELGRADE ENVIRONMENTAL ENDANGERMENT BY NITROGEN OXIDES FROM THE ENGINES IN THE ROAD TRANSPORT

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Abstract. *The base for an integral environmental management should comprise an estimate of the health influence, identification, evidence, registration and monitoring of the sources, types and levels of environmental pollution, an estimate of the population's exposure to the pollutants as well as the measures for the improvement of the actual situation. Increased concentrations of the nitrogen- oxides can have negative influences on the health of certain segments of population. The estimation of health influence assumes identification of the environmental health factors with great impact on health. Air pollution is an unavoidable result of the development of big cities.*
This analysis comprises the data about air pollution in Belgrade caused by the burning of the flammable liquids in the engines in the road transport. The measurement was done in the period from 2000 to 2004 along with the estimation of the environmental degradation. The obtained results of the research indicate that the traffic is the constant source of the air pollution caused by nitrogen oxides in Belgrade, the inner city zone being the most endangered one.

Key Words: *Nitrogen Oxides, Air Pollution, Environmental, Road Transport*

1. INTRODUCTION

The data of the World Health Organization (WHO) shows that the level of the air polluting in big cities (over 500 000) exceeds the values of the Air Quality Recommendations. Nitrogen oxides concentrations have a rising trend as a result of the traffic increase. In the big cities in Western Europe, almost 30 -50% of air pollution originates from traffic emission.

The number of the vehicles being used in traffic will be doubled as well as the production and processing of the oil. At the same time, the traffic air pollution and the possibilities for ecological accidents will increase.

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The Table 1.1 shows the data about the increasing of the number of vehicles registered on the territory of the Republic of Serbia in the period 1999 – 2004. The increase of the percentage of freight vehicles and cars is evident.

Table 1.1 Registered Road Vehicles and Hook Up Vehicles (without data for Kosovo and Metohija)

Year	Cars	Special cars	Busses	Freight vehicles	Special freight vehicles	Product-ion vehicles	Accessory vehicles	Tractors	Motor cycles
1999	1212656	20508	8907	76027	21003	2164	84280	216141	27711
2000	1273746	13592	8949	91918	19086	1320	91062	115305	13262
2001	1382396	16723	9287	99019	22143	1705	93300	117687	13097
2002	1343658	15548	8911	96890	22554	1352	94249	119031	12339
2003	1388109	16107	9144	101433	24713	1483	96509	121377	13287
2004	1449843	16462	9125	109292	27633	1620	91546	132711	14771

According to the current information about the total amounts of energy being used in Serbia and Montenegro, the percentage of energy consumption is following: freight road traffic 57,2%; traveling road traffic 23%; railway transport 6,5% and water transport 12,3%. Estimated percentages of the traffic pollution (without air and sea transport) are the following: Freight road traffic 70,4%; traveling road transport 19,5%; water transport 7,4% and railway transport 2,4%. Table 1.2 shows data for liquid fuels for the period 2000 -2004.

Table 1.2 Fuel Consumption of Enterprises in the Sector of Warehousing and Connections (10^3 t) (without data for Kosovo and Metohija)

Consumption type	Year				
	2000	2001	2002	2003	2004
Road traffic	64	70	72	68	67
City traffic	53	60	64	67	67
Total for all transport types	242	236	247	257	256

Road traffic vehicles function by internal broach combustion of fuel in adequate engine. Chemical composition of the fuel represents a mixture of carbon hydrate in solid, liquid and gassy form with small percentage of nitrogen, oxygen and sulfur. The burning process depends on fuel composition, level of burning and evaporation of fuel. Qualitative and especially quantitative characteristics of the emission of the burning gases depend on the type of the fuel, driving regime, vehicle loading and the altitude. Due to low speed in the winter period the vehicle engine does not reach the working temperature, so that the oxidation emission contains less NO_x relating to the higher speed and maximal engine power utility.

Considering the results on the air pollution, diesel engines are different from gasoline engines. Internal broach combustion in diesel engines is being processed with the extra quantity of the air so that very small quantities of the fuel remain unburned.

Table 1.3 shows the content of NO_x in burning gases of the engine depending of the utility regime.

Table 1.3 Content of NOx in the Oxidation Gases of Engines
(hour/10^6 marks pollutants relating million parts of the air)
D - diesel engines, O - gasoline engines

Pollutant	Engine working regime							
	Waiting		Acceleration		Driving		Reducing speed	
NO_x	D	O	D	O	D	O	D	O
(hour/10^6)	50-60	15-45	849	1347	237	653	30	18

During the internal broach combustion process in the engine approximately 200 different non-oxidated carbohydrates are being produced, depending on the type of the car and type of the engine. Processes being performed in the engines with the internal broach combustion are very compound and the composition of the resulted gases cannot be clearly determined. Oxidation type determines the type of the burning products.

Table 1.4 Quantities of the Polluting Substances in the Air Emitted by the Functioning of the Internal Broach Combustion Engines.

Table 1.4 Composition of the Substances Produced from Engines

Type of emission	mg per 100 dm^3 expended fuel	
	Gasoline engine	Diesel engine
Aldehides (HCHO)	0,5	1,2
Carbon monoxide (CO)	300	7,5
Carbon hydrates	25	16
Nitrogen oxides (NO_2)	14	28
Sulfur oxides (SO_2)	1	5
Organic acids (acetate)	0,5	4
Particles	1,5	15

2. Geographic and Climate Characteristics of Belgrade

Belgrade is the capital of the Republic of Serbia, with approx. 1,6 million inhabitants (15,8% of total population of Serbia).

Belgrade and its vicinity are characterized by a moderate continental climate with average temperature per year 11,7 ^oC, average fall of 666,9 l/m^2, average humidity 69,5% with approximately 67 clear days, 111 cloudy days and 2096 sunny hours.

Radiation and water level also have an influence on the climate characteristics. Belgrade is surrounded on three sides with the river flows, having almost 200 km of the river banks. Beside the strong air warming, Belgrade has significant changes of elements – fog, wind, smog. Topography of Belgrade affects different types of smog and fog in certain zones of the city also having an impact upon the space distribution of the air- pollution.

The "rose of the winds" has the shape that is characteristic for the whole area liable to a specific local wind or *košava* as the wind typical for this region of Serbia. It is typical in two directions, namely, as a south – east wind, it is *košava* and as a west- northwest one, it is *gornjak*. Average speed of *košava* is 25 - 43 km/h, especially in autumn and winter in 2-3 days intervals.

The research done at the height of 10 meters based on the methodology of the "European Wind Atlas" shows that the energy of the wind is greater on the trace of the water. Accumulation created on the river Danube for the needs of the hydroelectric plant "Djerdap" causes the rising of the water level around Belgrade which affects the atmosphere stability and distribution of the air pollution.

3. The Objective and the Results of the Research

The aim of the Belgrade environmental endangerment research project is to determine the air pollution caused by the engines from the road transport and the influence of this kind of the pollution on the human health.

Determination of the risk for environment should be done considering the nature and the volume of the effects emerging in the populated area. The quantity and the quality of the potential changes in the physical, biological and human domains have direct effects on the environmental resources.

The influence on the environment is different and often unpredictable with long lasting effects. The load with dangerous substances represents a special danger and an environmental threat.

Polluting gas substances determined by the Program of the Air Quality Control for environmental air include nitrogen oxides. Polluted air has various negative effects on the health of the population, materials and eco-systems. The level of the health degradation, vegetation devastation as well as historical monuments depends on the existence and concentration of pollutants in the air. Air pollution is a continual process.

Today, there are approximately 2,500 freight vehicles with carrying capacity over 5 tones. Traffic, tourist and other enterprises use about 1 500 buses, almost 1090 of them being used in public city traffic. Two bus stations (BAS, Lasta) have daily frequency of over 1400 buses. Fuel supply is done through 135 public fuel stations and almost the same number of the internal stations (within the enterprises). Apart from these data, Belgrade has also intensive transit traffic.

The most intensive type of traffic is the road one. The development of the road traffic can be analyzed from the data about last 50 years.

Table 3.1 Development of the Traffic in the City of Belgrade for the Period 1953 – 2003

Year	Number of inhabitants	Number of vehicles	Number of streets	Length of road network (km)
1953	457 000	5 728	1 500	524
1977	1 400 000	300 000	1 800	900
2003	2 000 000	800 000	4 000	2 000

The basis for environment quality control is systematic measuring. The network of measuring points is determined by:

– population density
– emission sources
– urban situation
– heating methods
– space purposes.

Occasional measurements are being done with the purpose of completing the data.

The measuring methods are in accordance with the Rules about extreme values, methods for emission measuring, criteria for determining measuring points and data evidence ("Sl. glasnik RS", No. 54/92). Nitrogen oxides are being measured every day (24 hours) all the year round and they are being expressed in weight measures per m^3 of the air. Concentration of the nitrogen oxides is determined by the modified Gris - Saltzman method according to the Standard ISO 6768.

For determining the air pollution level, measuring data have been used from the City Institute for Health Care, the Republic Hydro-meteorological Institute and the Institute for Health Care of Serbia.

Air quality in Belgrade has been analyzed by the following indicators:

– average value per year
– total number of days over GVI (maximal values of the emission)
– series of days over GVI
– maximal concentrations.

The analyzed statistic data show that the concentrations of the NO_2 and other polluters in the air have been lowered during the sanctions from 1992 - 1994. After the sanctions, in 1995 the city and the transit traffic have become more intensive. These and other polluters have caused the rising of the level of the analyzed substances as well as an increase of the days over GVI.

The measured concentrations of the NO_2 are not scientifically different in winter and summer periods; this leads us to conclude that the traffic is the main air polluter in the air in Belgrade.

Concentrations of nitrogen oxide are maximal after the morning traffic rush. They react with OH radicals and sun light creating aldehides and ozone. Concentrations of nitrogen dioxides measured in summertime are higher than the ones measured in wintertime. The reason for this can be complete and faster transformation of nitrogen monoxide into nitrogen dioxide.

On the basis of the measured data and by their detailed analysis it is possible to make detailed quantification of the air pollution in Belgrade. A negative trend can be shown by increasing the average number of days with concentrations of NO_2 over maximal values of emission (85 $\mu g/m^3$) per measuring point for the period 2001-2004 (6,27 -9,27) which represents an increase of 47,8%.

Emission of polluting materials from mobile sources depends on the combustion of the fuel in engines, the level of traffic intensity, the fluctuation of the roads and the meteorological situation. Data of Direction for Traffic Police in the Ministry for Internal Affairs of the Republic of Serbia show that the number of vehicles has increased for ten percent in 2003 considering 2002. At the most frequent crossroads about 6000 vehicles pass. The inner city zone has little traffic permeability, and the average age of the vehicles is advanced, so that all the above-mentioned facts show that the air pollution in Belgrade coming from the mobile sources represents a big environmental problem.

Table 3.2 Nitrogen Dioxide and Its Frequency in the Air
(World Health Organization recommends that the number of days above GVI shouldn't be bigger than 36 (10%)

Year	Average values per year µg/m³			Maximal measured concentrations µg/m³	Number of days above GVI per measuring point	Series of days above GVI
	Year	Winter	Summer			
2004	28,56	30	33	491	9,27	13
2003	32,35	35,1	32,4	192	8,58	15
2002	30,5	32	32	258	7,83	8
2001	21,19	22	26	241	6,27	2
2000	29	17,5	22,6	222	9	0

Systematic measurements of the polluting substances coming out the vehicles engines (done by Institute for Health Care > Dr. Milan Jovanovic Batut) show that the values exceed the maximal ones thus influencing the air pollution of Belgrade. The pollution factor above 3 has been present for many years at the crossings of Streets Decanska-Nusiceva (tunnel) and Boulevard of King Alexander -Prince Milos (Assembly).

Table 3.3 Average Concentrations of Nitrogen Dioxide in Belgrade at the Crossroads
(average per year 60 µg/m³)

Cross road	2001		2002		2003		2004		2005	
	Average concen tration (µg/m³)	Pollution factor	Average concen tration (µg/m³)	Pollution factor	Average concen tration (µg/m³)	Pollution factor	Average concen tration (µg/m³)	Pollution factor	Average concen tration (µg/m³)	Pollution factor
Slavija	-	-	140,0	2,33	148,2	2,47	132,0	2,20	146,2	2,44
Vukov spomenik	-	-	182,9	3,05	162,9	2,72	165,5	2,76	152,5	2,54
London	223,7	3,73	194,3	3,24	173,1	2,88	179,9	3,00	172,2	2,87
Tunel	208,2	3,47	224,7	3,74	188,6	3,14	192,3	3,21	183,4	3,05
Skupština	-	-	203,8	3,40	195,0	3,25	182,0	3,03	185,0	3,08
Cvijićeva	170,0	2,83	152,7	2,55	150,0	2,50	157,8	2,63	158,1	2,64
Batutova/D.Tucovića	105,2	1,75	90,8	1,51	139,0	2,32	138,3	2,30	147,2	2,45
Zemun	-	-	137,3	2,29	132,5	2,21	153,5	2,56	162,3	2,70
Novi Beograd	116,1	1,94	102,0	1,70	102,5	1,71	105,3	1,76	119,7	1,99
Karaburma	-	-	100,3	1,67	109,3	1,82	122,5	2,04	122,2	2,04

Table 3.4 Monthly report - number of days over GVI NO_2

Month	2001	2002	2003	2004	2005
January	10	16	11	15	7
February	2	17	16	19	14
March	2	4	18	18	5
April	4	2	2	2	0
May	0	3	4	3	1
June	1	13	13	3	0
July	5	6	17	1	1
August	4	12	27	3	5
September	12	7	15	2	0
October	11	10	9	14	0
November	10	1	9	21	3
December	8	3	12	1	0

Analyzing the data and considering the number of days over GVI, in winter, the most polluted months are January, February while, in the summertime, the most endangered month is August. April and May are the months with the smallest number of over GVI days.

Table 3.5 Maximal Daily Concentrations of NO_2 ($\mu g/m^3$)

Month	2001	2002	2003	2004	2005
January	158	131	169	174	116
February	128	195	192	241	140
March	105	93	134	142	119
April	112	99	110	115	84
May	81	159	144	100	116
June	131	157	115	181	84
July	127	104	121	107	189
August	241	152	156	116	106
September	172	156	130	88	80
October	131	109	126	243	80
November	149	101	129	491	173
December	137	258	184	116	64

The biggest individual concentrations of nitrogen oxides are 351,0 $\mu g/m^3$ (2,34 times more than allowed) at the Tunnel point in January. The most endangered is the inner city (Tunnel, London, Assembly), city zone (Slavija, Vukov spomenik, Cvijiceva), and the greater city zone (Batutova, Karaburma). All median values per year have higher levels on every measuring point than the permitted median values per year for nitrogen dioxide (60 $\mu g/m^3$).

4. The Health Risk for Respiratory System of Belgrade Inhabitants

The polluting materials in the environment have unhealthy influence on the health of people, causing certain diseases and having a bad influence on chronic diseases.

Nitrogen dioxide has a toxic influence on the respiratory system (Bronchial asthma…). Diagnoses in primary health care (the period 1997-2001) show following frequency of groups:

1. Pharyngitis acuta et tonsillitis acuta
2. Infectiones tractus respiratorii superioris multiplices acutae loci non specificatis
3. Bronchitis acuta et bronchiolitis acuta
4. Emphysema and other obstructive respiratory diseases
5. Asthma bronchiole

Comparison of diagnoses from primary health care in later period (2000-2004 of pre schooling group) show that the most frequent disease is Pharyngitis acuta and tonsillitis acuta. Tables 4.1, 4.2, 4.3 show the levels of respiratory diseases frequency of certain population groups and level of frequency of some respiratory diseases.

Table 4.1 Respiratory Diseases in the Period 2000-2004

Year	Respiratory diseases (per 1000)			
	Children of pre schooling age	Pupils	Grown up	Working population
2004	3571,2	1540,1	235,0	98,9
2003	3536,8	1638,1	237,3	103,8
2002	3565,7	1587,9	228,6	111,8
2001	4896,6	2053,9	209,2	153,5
2000	3607,9	1179,9	236,2	124,5

Table 4.2 Level of Respiratory Diseases in the Period 2000-2004
A- pre-school age, B- pupils, C- grown ups, D- working population

Year	Level of respiratory diseases (per 1000)											
	Pharyngitis acuta et tonsillitis acuta				Infectiones tractus respiratorii superioris multiplices acutae loci non specificatis				Bronchitis acuta et bronchiolitis acuta			
	A	B	C	D	A	B	C	D	A	B	C	D
2004	2097,5	872,4	105,4	47,1	871,1	470,7	45,3	13,0	249,8	74,3	24,4	13,5
2003	2175,0	885,9	97,9	43,8	761,6	468,2	44,3	15,8	222,2	81,3	24,9	14,8
2002	2279,2	912,2	98,4	48,1	701,9	449,2	36,6	16,8	202,0	77,8	26,4	14,5
2001	3070,8	1184,0	91,8	59,2	1076,4	525,4	30,8	20,4	314,0	108,0	26,1	15,2
2000	2515,7	752,7	89,8	53,8	589,8	302,3	35,2	16,4	200,8	47,9	29,6	16,6

Table 4.3 Levels of Respiratory Diseases of Belgrade Inhabitants for the Period 2003-2004

Municipality	Area km^2	Density of population per km^2	Diseased in		Level of disease %	
			2004	2003	2004	2003
Barajevo	213,12	117	6 401	5 505	25,60	22,02
Voždovac	148,64	1123	87 641	97 600	52,48	58,44
Vračar	2,92	23860	55 568	54 421	79,75	78,10
Grocka	289,23	260	53 692	57 757	71,15	76,53
Zvezdara	31,65	4739	75 712	87 464	50,47	58,30
Zemun	438,72	436	121 284	129 698	79,29	84,79
Lazarevac	383,51	161	50 418	51 690	81,31	83,37
Mladenovac	339,00	166	37 563	41 113	66,61	72,90
Novi Beograd	40,77	5790	152 721	142 770	70,12	60,49
Obrenovac	409,95	185	25 696	24 143	33,83	31,78
Palilula	446,61	400	82 226	66 792	45,68	37,10
Rakovica	30,36	3219	44 806	48 008	45,83	49,11
Savski venac	14,00	3405	33 100	33 454	69,41	70,16
Sopot	270,75	75	13 182	14 054	64,21	68,46
Stari grad	6,98	10000	29 566	33 200	42,23	47,42
Čukarica	156,50	1022	124 425	119 272	77,76	74,54

An analysis of the data given in Table 4.3 leads to the conclusion that the most endangered by air pollution are inhabitants of the Municipalities of Lazarevac, Vracar, Zemun, Cukarica and Grocka where the percent of deceased persons is above 70%. Density of the population has a big influence on the level of disease. The lowest level of respiratory diseases is in the Municipality of Barajevo where there is no intensive traffic which, in its turn, leads us to conclude that traffic is the dominant source of respiratory diseases.

5. Conclusion

The present concentrations of nitrogen oxides, created by combustion of flammable liquid substances/fuels in engines of the road transport during the period 2000-2004 in the area of Belgrade and on several measuring points significantly exceed the maximal values of emission. The most endangered is the inner city zone because of little permeability of the streets, the great number and age of the vehicles. The maximal concentrations of nitrogen dioxide are during February, January, August and October. The measured concentrations during the day are the highest after the morning and afternoon traffic rush. The present concentrations of NO_2 have a negative influence on the health of the people causing many different respiratory diseases and worsening the chronic diseases. The most endangered segment of population is children of pre-school age in the Municipalities of Lazarevac, Vracar, Zemun, Cukarica and Grocka.

The tendency to further traffic increase will cause further air pollution by nitrogen oxide resulting in undesirable consequences.

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PRILOG ANALIZI UGROŽENOSTI ŽIVOTNE SREDINE BEOGRADA AZOTNIM OKSIDIMA NASTALIH U MOTORIMA DRUMSKOG TRANSPORTA

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Polazna osnova integralnog upravljanja životnom sredinom uključuje identifikaciju, evidenciju, registraciju i praćenje izvora, vrste i stepena zagađenosti sredine, procenu obima izloženosti populacije štetnom delovanju polutanata, kao i preduzimanje mera radi unapređenja postojećeg stanja. Povišene koncentracije azotnih oksida u životnoj sredini mogu dovesti do porasta negativnih uticaja na zdravlje pojedinih grupa u populaciji. Procena uticaja na zdravlje je identifikacija zdravstvenih faktora životne sredine značajne na zdravlje. Aerozagađenje je neminovan pratilac razvoja velikih gradova. Zagađujuće materije prisutne u vazduhu dovode do promene kvaliteta vazduha koji je najneophodniji prirodni izvor života.

U radu je, na osnovu podataka izvršenih merenja i ispitivanja za period 2000-2004. godina, data kvantifikacija zagađenja vazduha Beograda azotnim oksidima nastalih sagorevanjem zapaljivih tečnih materija u motorima drumskog transporta, kao i ugroženost životne sredine.

Dobijeni rezultati istraživanja ukazuju da je saobraćaj stalni i dominantni izvor zagađenja vazduha azotnim oksidima u Beogradu sa centralnom zonom kao najugroženijom.

Ključne reči: *azotni oksid, zagađenje vazduha, životna sredina, drumski transport*