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Gas-phase oxidation processes: air pollution and human health

IMPACT OF AIR QUALITY IN BELGRADE ON HUMAN HEALTH AND SAFE ENVIRONMENT

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ABSTRACT

Air quality on a global level, as well as in Serbia and its capital and largest city Belgrade, is a serious problem. Considering that different measurements show that residents of Belgrade breathe in air which is considered harmful to health, this paper presents the monitoring of air pollution in the city considering the circumstances that exposure to outdoor air pollution is associated with a large number of acute and chronic health conditions. In this paper are also present the most important international and EU regulations in the field of air pollution as one specific issue within environmental protection. The synergy of the legislative and the actual state of pollution of ambient air was studied on the basis of exact parameters due to the territory of the capital of the Republic of Serbia, assessing the quality of legal provisions and their applicability, pointing to possible failures in legislation and in implementing these provisions. It is also pointed out the necessity for full harmonisation of national legislation with the European Union and the implementation of legal provisions in practice. Besides, the consistent application of regulations in practice is necessary, improvement of air quality monitoring and prevents transparency and accessibility of information.

Keywords: safe environment, quality of air, traffic, human health, legislation.

AIMS AND BACKGROUND

Environment protection and its improvement is one of the most important problems which contemporary society faces. Accelerated scientific and technological development, application of new energy sources, building of a large number of industrial facilities, creation of large urban areas, especially in the last few decades, have led to a distinctive level of pollution of basic natural resources of living world, to perturba-

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tion of harmony between man and environment, to rather serious threat to natural conditions, necessary for the preservation of environment, which in the end questions also the bare survival of mankind. This is what led to considerable pollution of air and atmosphere especially in urban areas (to deforestation, to thermal pollution of water and air heated by various industrial solutions), etc.

Air is a mixture of gases, containing mainly nitrogen and oxygen. Within air, there are also small amounts of argon, carbon dioxide and other rare gases (krypton, xenon, neon, helium, ozone, radon, etc.).

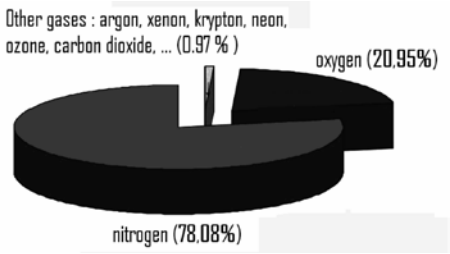

Fig 1. Air composition[1]

In Fig. 1, one can notice that in total volume of air there are 99% of nitrogen and oxygen, 0.9% of argon and 0.03% of carbon dioxide. Sources of environmental pollution are location-specific and spatially limited points, lines and surface sources of pollutants and energy into the environment. The level of pollutants is the concentration of pollutants in the environment, expressing the quality of the environment at a given time and space. Sources of air pollution can be classified into two groups. The first group consists of: sources of pollution in rural areas related to agriculture, mining, etc.; sources of pollution related to industry and industrial areas, chemical industry, metal and non-metal industry, production of electricity, etc; sources of pollution in communal areas such as heating, waste incineration, etc.[2] The second group consists of the so-called mobile sources of pollution which involve any form of motor vehicles with internal combustion (vehicles that use gasoline, diesel fuel, etc.). Thus, presence of various substances and gases in the air that are health-hazardous, pollute the air. Although, generally speaking, air pollutants are numerous and complex, we will present the key ones: nitrogen oxides, sulphur dioxide, carbon dioxide, solids particles, volatile organic compounds and toxic substances such as mercury. It is worth mentioning that combination of nitrogen oxides and volatile organic compounds in the air, in presence of ozone, are main ingredients of smog.

Some air pollutants cause changes in the ecosystem, such as acid rains and climate change. According to climate scientists, if the concentration of carbon dioxide increases, the planet will become warmer and that will affect human health and the environment. Climate changes are accelerating and our planet is constantly being heated. Residents of the northern hemisphere experienced the warmest winter in the past 125 years. One of the main Earth warming causes is rapid industrial development

which brought remarkable increased emissions of the so-called greenhouse gases[3]. Global warming will be dynamically accelerated unless something is urgently done about reducing the emission of harmful gases. If the average temperature rise continues at its current rate, billions of people on the planet will have to face with lack of food and water. In a new British scientist study has been made a computer model of climate change, after the forecast prognosis of a scientist James Hansen, where the ocean level will increase by 2.3 mm every year[4]. According to data from 2000, the largest producer of carbon dioxide emissions are the USA with 20.60%, China with 14.80%, Russia with 5.7%, India with 5.5% and Japan with 4% (Ref. 5). In Europe, emission of this gas is about 11% of total world emission[6]. Consequences of air pollution on human health are two to three times higher than it was thought before. For every increase of 10 μg of fine particles in the air, risk of premature death increases from 11 to 17%. Studies have shown that number of heart attacks, strokes, lung cancer increases, and children who live near highways have higher risk of developing asthma[7]. The latest reports of global burden of diseases show that air pollution is one of the ten major global risk factors to health[8]. It is believed that about 7 million people worldwide died earlier due to pollution; In European Union (EU), 400 000 people suffer of premature death[9]. The OECD (the Organisation for Economic Co-operation and Development) predicts that by 2050 global air pollution will be the largest cause of death associated to environmental conditions[10]. In addition, air pollution is identified as the leading environmental cause of cancer[11]. The influence of air pollutants primarily affects the respiratory system[12]. Things that are noticeable are: increased respiratory symptoms, infections, increased airway reactivity, irritation, lung inflammation, increased respiratory mortality and hospital visits, hospitalisations, decreased lung function, aggravated asthma, worsening of chronic obstructive pulmonary disease, increased risk of lung cancer. Cardiovascular system is exposed to: changes in cardiac autonomic function, myocardial infarction, angina pectoris, increased blood pressure, arteriosclerosis, increased cerebrovascular ischemia. Noticeable things at nervous and cerebrovascular systems are: neurodevelopment disorders, inflammation of the nervous tissue, oxidative stress, changes in the blood-brain barrier, headache, anxiety, stroke, the Alzheimer disease, the Parkinson disease... Also, what is especially threatening, is the impact of air pollution on reproductive capacity and children health. These negative effects include: endangered sperm quality, fragmentation of DNA, low weight at birth, premature birth, birth at low gestational age[13].

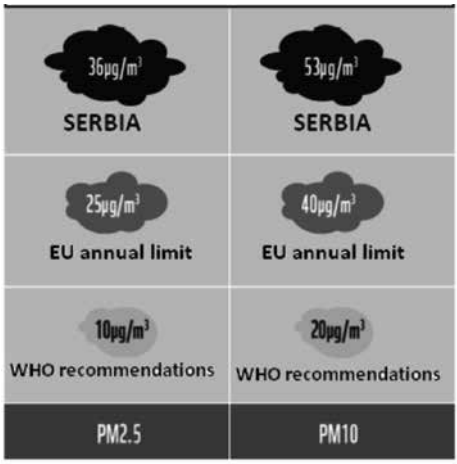

Fig. 2. Concentration of suspended particles in Serbia exceeding the EU and WHO standards[14]

In Fig. 2 presented data show that air quality in Serbia is a cause for great concern: the measurements show that citizens across the country breathe in air that is considered harmful to health. For example, the concentration of PM 2.5 and PM 10 are much larger than those that the European Union and the World Health Organisation (WHO) set up to protect health. Serbian report on air quality in 2013 states that in the course of a year, the annual limit value from PM 10 of 40 mg/m^3 at most locations was exceeded. In agglomerations Belgrade, Bor, Uzice and Smederevo in 2013 the air was of III category, which means that it was excessively polluted. In 2013, 73% of the population in urban and non-urban industrial agglomerations were potentionally exposed to concentrations of pollutants above the reference level[15]. The latest reports on air quality in Serbia and Belgrade confirm the data on exceeding limit values for air pollutants[16]. Regarding legislation, Republic of Serbia implements dynamic legislative activity in this area. The Assembly of the Republic of Serbia has rendered the Law on amendments to the Law on Environment Protection[17], which has improved the Law on Environment Protection[18], and also the Law on Fund for Environment Protection[19], the Law on Waste Management[20], the Law on Protection of Nature[21], a number of laws as well as several of by-laws directed towards the environment protection. The EU regulations, especially Directive 2008/50, which regulates air quality, have been taken over and incorporated in national regulations by adoption of Law on Air Protection of Republic of Serbia[22]. That way harmonisation of domestic legislation and practice with legislation and practice of the EU has been secured. The Directive on Cleaner Air for Europe (2008/50/EC) establishes harmonized health standards for polluting substances in air which arouse greater concern[23]. This Directive requires from governments to define air quality zones which cover the whole country. Boundaries between the zones are determined according to the density of population and criteria of exposure. If the standards are not satisfied, plans for air quality management have to be defined, and

by the authorities at the very level which are competent for particular zone, whose object is to reach the quality standard on the territory of the zone in the shortest time possible. Directive 96/61/EEC on Integrated Pollution Prevention and Control is being applied on industrial and other facilities and activities which are classified according to the level of pollution and the risk these activities might have for the health of people and the environment. General framework for regulations in the area of air quality is the Directive of the Council 96/62/EC on assessment and management of air quality which has been adopted by our law. By means of this directive a list of polluting substances among which there are SO_2, NO_2, CO, particles, lead, ozone, cadmium, arsenic, nickel, mercury, benzene is established and maximum allowed concentrations are further defined. Significant are the directives which refer to Air Quality and Daughter Directives (SO_2, NO_x, Pb) – 99/30/EEC, Volatile organic compounds – 99/13/EC, Quality of fuels – 98/70/EEC, Emissions of non-road mobile machinery – 97/68/EC, Carbon dioxide and other greenhouse gas emissions – 93/389/EEC, emission from motor vehicles – 70/220/EEC. Council Decision 97/101/EC establishing a reciprocal exchange of information and data from networks and individual stations measuring ambient air pollution within the European Union (Exchange on Information decision (EOI) on Air) held of 27 January 1997 (Ref. 24). A Community-wide procedure for the exchange of information and data on ambient air quality in the European Community is established by the Council Decision 97/101/EC. The decision introduces a reciprocal exchange of information and data relating to the networks and stations set up in the European Community to measure air pollution and the air quality measurements taken by those stations. The total emissions of sulphur oxides (SO_x) have been reduced by 78% compared to the level from 1990 in the EU-27. Reduction of sulphur oxides pollution (SO_x) in the European Union was achieved by implementation of EU legislation on limited pollution from large combustion plants and by implementation of standards of low sulphur content of the fuel for transportation[25].

RESULTS AND DISCUSSION

In the Republic of Serbia, as mentioned there is an ongoing process of harmonisation with the European Union regulations. Laws like that regulate air quality standards such also, as it is protected natural value of general interest. The Law on Air Protection regulates air quality management and determines the measures, mode of organisation and control and carrying out of air quality protection as well as improvement of quality of air which is protected natural value of general interest that is under special protection (Art. 1(1)). Complete compliance will be achieved by rendering subordinate regulations based on the Law[26]. The Republic of Serbia, autonomous province and units of local self-government, provide air quality monitoring within their competence. Conditions for air quality monitoring on the territory of the Republic of Serbia are set by the Government, upon the Ministry proposal. All the above legislation is a legal framework for treatment, and in this paper the authors based their research on

precise analysis of the ambient parameters of pollution measured in Belgrade, which is the capital and largest city in Serbia in correlation with the current legislation and mutual interaction.

The city lies at the confluence of the Sava and Danube in central Serbia, where the Pannonian Serbia meets the Balkan Peninsula. Population of Belgrade, according to the 2002 census was 1 576 124. It is the largest city in the territory of former Yugoslavia, and by population ranks fourth in Southeastern Europe after Istanbul, Athens and Bucharest. Belgrade covers more than 3.6% of the territory of the Republic of Serbia, and is home to 15.8% of total numbers of citizens and 31.2% of all employed people work here. The city covers an area of 3223 km^2. Belgrade has a complex morphological structure, both basic (natural), and socio-technological structure, appeared by complex transformations and development of inherited city tissue[27]. As a metropolis with the characteristics of the region, the city of Belgrade has its own specifities, especially if one considers the conditions of quality of environmental resources. Air pollution is continuously one of the main factors. The main sources of pollutant emission in the ambient air of Belgrade city (Fig. 3) are: energetic (heating plants, power plants, boiler rooms, individual heaters for about 200 000 individual chimneys); traffic (cars, public transport and transport traffic); small and medium manufacturing processes (bakeries, fast food preparation, barbecue, pizzas); some restored industrial buildings in the city (under the Republic jurisdiction) and agriculture (usage of protection means from earth and from the air); liquid and solid fossil fuels with higher sulphur content and with unknown content of chemical components are used for heating in heating processes; pollutant emissions from mobile sources are also conditioned by the quality of the fuel, the combustion process in engines with regard to the age of the vehicle, traffic density, road infrastructure and urban solutions; reliable data on emissions of air pollutants exist only in the energy sector and electricity generation, while data on the quantities of emissions from other sources (production processes in industry, use of solvents, road transport, agriculture, waste treatment and disposal, etc.) do not exist or are unreliable[28].

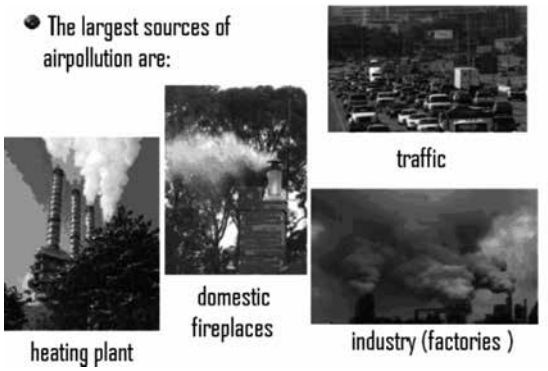

Fig. 3. Biggest sources of air pollution in Belgrade[29]

Laboratory of Environmental Institute for Physics in Belgrade has developed a method of active monitoring of heavy metals in the air using bags with moss. In contrast to the 'higher' plants, mosses have developed not only real roots, stem and leaf, but also analog parts that resemble to the aforementioned organs. In the absence of cuticle on the surface of leaves, moss absorbs water and nutrients from the air, and thus pollutants as well. Thanks to these morphological and physiological characteristics, moss is good bio-monitor for pollutants, especially heavy metals that are present in the ambient air (Fig. 4).

Fig. 4. Preparation of moss bags for exposure in the polluted environment[30]

Fig. 5. Active bio-monitoring in an urban environment using transplanted moss[31]

Figures 4 and 5 show the experimental methodology. During 2014, a project 'Bio-monitoring of heavy metals in the air/education on the impact of traffic on air quality' was implemented in order to obtain information on the content of heavy metals in

the air along the main roads of the city of Belgrade. Bags with moss were exposed to atmospheric deposition at 48 measuring sites including the city main intersections, junctions, roundabouts, traffic streets, and places with lower vehicle flow. Content of carcinogenic and toxic elements such as: As, Cd, Co, Cr, Cu, Ni, Pb, Pt, Sb and Zn, was measured in samples exposed to moss. At all measuring points were assessed total flow and flow of vehicles by categories in order to determine the relationship of the traffic intensity with the measured concentrations of heavy metals in moss, or in air. The results of this study clearly indicate that the biggest polluter in Belgrade is traffic. It is the city with frequent traffic collapses which can cause exceeding values of some pollutants, which originate mainly from fuel. Research has shown that changes in the content of heavy metals in moss reflect the load to measured sites by traffic. Results in this direction suggest that there are more frequent locations in the city with a turnover of more than 3500 vehicles per hour, where the air is heavily polluted; the air is polluted on several locations where traffic of vehicles per hour is 2000–3000; at locations with traffic of vehicles of 1000–2000 per hour, the air is moderately polluted; one-way streets and places where traffic of vehicles is less than 1000 per hour have slightly contaminated air[32].

Results of this project and other similar projects contribute to a better and more comprehensive consideration of air quality in Belgrade and can be used for the preparation of management plans relating to air quality and sustainable transport. Also, the TWINING project has enabled software monitoring of traffic impact on air quality; it has also enabled reacting in short-term measures to reducing of current pollution. This is particularly important in terms of health problems caused by air pollution. It is estimated that in 2010 more than 10 000 people prematurely died due to exposure to suspended particles and ozone. It is the second highest rate of premature deaths due to air pollution in Europe. Besides that, there were 2.5 million absences from work. It is assumed that due to pollution, over 1000 of Serbian population suffer from chronic bronchitis, 600 are being placed in the hospital because of respiratory or cardiovascular symptoms, and 2000 of them die every year due to air pollution[33]. Belgrade, as a specific urban-industrial area has a large population exposed to pollutant concentrations above the permitted level, which is one of the key factors of health risk. There is continuously increased number of people suffering from lung diseases, especially allergies with children. Systematic testing on increased concentration of sulphur dioxide, soot, nitrogen oxide and other air pollutants that affect human health have not been performed in Belgrade. The legislation does not oblige health centres and hospitals in those communities to monitor health changes in humans and notify the network of institutes for public health. Professionals who deal with this problem should only rely on the studies done abroad, as well as individual line of research in Serbia dealing with the harmful influence of air pollution on human health.

Further conciliation of regulations of the Republic of Serbia, in this area, with the EU regulations implies, according to the National Programme for Integration with the European Union (NPI): the adoption of subordinate regulations envisaged by the

Law on Air Protection which is or will be in compliance to the actual EU regulations. Adoption of subordinate regulations on the basis of the Law on Air Protection Republic of Serbia in order to accomplish full implementation of the NPI for the exclusion of CFC (Chlorofluorocarbon) from use since 2005, as well as the plan for the exclusion of HCFC which is being prepared, implement the Provision 1497/2007/EU and Provision 303/2008/EU. The adoption of the Law on Meteorological and Hydrological Activities which will be, in the part of air quality monitoring, conciliated with monitoring strategies Co-operative Programme for Monitoring and Evulation of the Long-range Transmission of Air Pollutansts in Europe (EMEP) and GAW, as well as subordinate regulations which will be conciliated with the Directive 2008/50/EU. Ratification of Protocol on Persistent Organic Pollutants, Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) and Protocol on Hard Metals alongside the Convention on Long-range Transboundary Air Pollution. The adoption of technical regulation which would transfer the Directive 1999/32 on restriction of sulphur in certain liquid fuels and amendment to the Directive 93/12/EEU and Directive 2003/17/EU – amendment to the Directive. Preparation and rendering of National programme for gradual restriction of maximum national emissions per year in accordance with the requirements of NEC Directive and National plan for the reduction of emissions from existing facilities for combustion in compliance with the requirements of Large Combustion Plants (LCP Directive) (Ref. 34).

CONCLUSIONS

Air pollution at a global level, and therefore in Serbia and Belgrade is constantly a topical problem, which seems to last and sustainable solution is not possible. The increase in registered vehicles is only one of the indicators that high-frequency traffic in Belgrade threatens with severe environmental pollution. Belgrade today is known for its traffic jams since there is no developed transport network towards its needs. In addition, we may say that Belgrade is the largest city in Europe without metro system, and the road network is insufficient. In the end, the city on two rivers needs new bridges and bypass around urban areas. Increase of amount of vehicles in the capital city has increased average annual values of all air openings which originate from car exhaust fumes. According to available data, the number of registered cars in Belgrade exceeds the figure of 500 000. Values of the toxins released are above permitted and consequently, the number of people who suffer from serious diseases of the respiratory and digestive organs rises daily. The most vulnerable part of the society is the elderly and children. Measures to prevent and reduce air pollution and improve air quality include the following activities[35]: prescribing emission limit values for pollutants from stationary sources of pollution; prescribing the limit values of pollutant emissions from mobile sources of pollution; determining the maximum national emission limits for individual pollutants; prescribing permitted amounts of certain pollutants in certain products, especially in liquid fuels, as well as in certain

paints and varnishes; reduction of emissions of greenhouse gases; gradual reduction of substances that deplete the ozone layer; measures of prevention and rehabilitation; introduction of work permits for installations that are not subject to integrated permissions and do not need impact assessment studies; work prohibition and clearly defined responsibilities for the operator. Bearing in mind the current economic situation in Serbia, it is really hard to take care of many activities, to prevent and reduce air pollution and improve air quality. These circumstances should not be an 'alibi' in the sense that we should make certain steps and progress towards the establishment of European standards, in order to enable the implementation of the same in the process of Serbia EU accession. Harmonisation with EU regulations is in progress in Republic of Serbia. On the grounds of adopted regulations in the fields of air pollution it can be concluded that these issues are regulated in detail, thoroughly and in accordance to modern European standards, as it is protected natural value of general interest. For instance, by adoption of Law on Air Protection in Republic of Serbia, primarily Directive 2008/50, which regulates quality of air, has been taken over and incorporated in national regulations. In this way, harmonisation of national and EU legislation and practice was secured. State and local network for control of quality ambient air system consists of automatic measuring stations and points where air quality control monitoring is conducted manually or by sampling and subsequent analysis in the laboratory. The number of these stations is large. But on the whole territory of Serbia it is necessary to increase the number of these measuring points. The key is in communication and informing – the state and local administration must inform publicity about possible problems related to air quality on their territory. At the same time, all these measures, as experience has proved, cannot be enough without the strict application of the provisions of the Convention on the protection of the environment through criminal law SE, which emphasizes the need to establish criminal liability in cases of 'serious pollution or endanger of the environment'. The necessity of taking legal measures in this area is based on an estimate that endangering the environment offenses even more serious problem which causes significant harm to the environment in Europe and worldwide.

REFERENCES

1. https://ucenicaemilijamarkovic.wordpress.com/ visited on 20.04.2015.
2. Z. BJELAJAC, M. DUKIC MIJATOVIC, M. JOVANOVIC: The Importance of Proper Management of Radioactive Waste Control from Aspect of Security Risks and Threats. Oxid Commun, **37** (1), 379 (2014).
3. S. BESERMENJI: Air Pollution in Serbia. Collection of Works, book 57, Geographical Institute 'Zoran Cvijic', Serbian Academy of Arts and Sciences, Belgrade, 2007, 495–501.
4. www.sloboda_za_životinje.org/ekologija/ visited on 25.04.2015.
5. www.planeta.org.yu/14/11globalno.htm/ visited on 2.05.2015.
6. www.astronomija.co.yu/suncsist/planete/zemlja/vazduh.htm/ visited on 12.05.2015.
7. www.topvita.info/clanak.asp?id=4 visited on 30.05.2015.
8. http://www.thelancet.com/themed/global-burden-of-disease/ visited on 1.06.2015.

9. http://ec.europa.eu/environment/air/index_en.htm/ visited on 2.06. 2015.
10. http://www.oecd.org/env/indicators-modelling-outlooks/oecdenvironmentaloutlookto2050theconsequencesofinaction.htm visited on 2.6.2015.
11. http://america.aljazeera.com/articles/2013/10/17/who-outdoor-air pollutionaleadingcauseofcancer.html visited on 2.06.2015.
12. Z. BJELAJAC, M. POCUCA, M. DUKIC MIJATOVIC, M. MARKOVIC: The Current State of Pollution of Water, Soil and Air in the Republic of Serbia with Overview to the Importance of Industrial Ecology. Oxid Commun, **35** (4), 1049 (2012).
13. Z. BJELAJAC, M. POCUCA, M. DUKIC MIJATOVIC: Uranium and Dioxin Consequences of Bombing of Yugoslavia in 1999 and its Impact on the Ecosystem and Human Health. J Environ Prot Ecol, **14** (2), 480 (2013).
14. European Environment Agency. Air Base: Public Air Quality Database-Air pollution, 2011.
15. http://www.sepa.gov.rs/download/VAZDUH2013.pdf/ visited on 3.07.2015.
16. www.zdravlje.org.rs visited on 5.07.2015.
17. The Law on Environment Protection: Official Gazette of Republic of Serbia, No 36/2009.
18. The Law on Environment Protection: Official Gazette of Republic of Serbia, No 36/09, 88/2010 and 91/2010.
19. The Law on Fund for Environment Protection: Official Gazette of Republic of Serbia, No 72/2009.
20. The Law on Waste Management: Official Gazette of Republic of Serbia, No 36/2009.
21. The Law on Protection of Nature: Official Gazette of Republic of Serbia, No 36/2009.
22. The Law on Air Protection of Republic of Serbia: Official Gazette of Republic of Serbia, No 36/2009 and 10/2013.
23. A. WOLF-NIEDERMAIER: Environmental Policy, Europe from A to Z. Guidebook to European Integrations. Konrad Adenauer Foundation, Belgrade, 2004, 61–62.
24. Council Decision 97/101/EC of 27 January 1997 Establishing a Reciprocal Exchange of Information and Data from Networks and Individual Stations Measuring Ambient Air Pollution within the Member States. 97/101/EC (OJ L 35, 5.2.1997, p. 14–22).
25. http://ec.europa.eu/environment/europeangreencapital/docs/about/cities%20of%20the%20future_web.pdf visited on 03.04. 2015.
26. www.beograd.rs visited on 17.07.2015.
27. Provision on Conditions for Monitoring and Requirements for Air Quality: Official Gazette of Republic of Serbia, No11/10 and 75/2010.
28. N. DJOKIC: European Week of Mobility – Air Quality – City of Belgrade. Secretariat for Environmental Protection of Belgrade, Belgrade, 2013, p. 8.
29. www.slideshare.net/ visited on 7.07.2015.
30. http://www.ekologija.rs/biomonitoring-kvaliteta-vazduha-pomocu-mahovina/ visited on 09.07.2015.
31. http://www.ekologija.rs/biomonitoring-kvaliteta-vazduha-pomocu-mahovina/ visited on 10.07.2015.
32. (EMRC (2014). Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package).
33. www.ekologija.rs/biomonitoring-kvaliteta-vazduha-pomocu-mahovina/ visited on 11.07. 2015.
34. HEAL (2013). The Unpaid Health Bill – How Coal Power Plants Make Us Sick?
35. http://arhideaserbia.co.rs/Zastita%20vazduha%20i%20atmosfere.html/ visited on 14.07.2015.

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