Evaluation of Air Pollution by NO_2, SO_2, PM10 in Bucharest

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In this paper is analysed the air quality in urban areas in Bucharest, the analysis was based on the monitoring of the average concentration of particulate matter PM 10, nitrogen oxides, NO_2, and sulfur dioxide, SO_2 in Bucharest between 2009-2015. The analysis refers to the maximum concentration of 24 h and the occurrence of overruns beyond the limit set. It also looked at the wind regime, air quality and temperature influence on air pollution in Bucharest between 2009-2015.

Keywords: urban, air pollution, NO_2, SO_2, PM 10

The environment is characterized by some natural activities, economic, social and political involve all participants equally and may include demographic data, lifestyle and economic cycles etc. Air pollution is of interest to monitor and analyze where one or more substances or mixture of pollutants are present in the atmosphere in quantities or for a period that can be dangerous to humans [1], animals or plants and contribute to endangering the business people [2-9]. Air quality is caused by air emissions from stationary and mobile sources and transport of pollutants over long distances [8].

Environmental pollutants are transported by air. The effects of pollution occurring due to weather changes of all of the main weather elements, decrease of solar radiation and temperature rise [10,11].

At European level, the institution that coordinates air quality is the European Environment Agency (E.E.A.). This institution correlates measurements that characterize air quality in 7500 a number of monitoring stations in Europe, a database Air Base [12].

Pollution atmosphere has the greatest impact on the environment due to the quantity and variety of pollutants and due to impairment of geographical areas, air pollution, represents a problem at global level, whose time scale is of the order emphasizing the greenhouse effect and the destruction of the ozone layer stratospheric [7, 26].

The legislation in environmental protection, aims at preventing and reducing pollution of any kind, conservation and preservation of the quality of the environment, management of natural resources and avoid over exploitation, ecological reconstruction of the affected areas of the pollution generated by human activity and natural [7]. It is useful to use environment-friendly materials to reduce pollution [25-28]. Considering atmospheric polution it is necessary to use in all areas of activity materials that have a low impact on the environment [29-40].

Experimental part

Materials and methods

Peculiarities research methodology consisted of analyzing pollutants NO_2, SO_2, particulate matter PM10 in Bucharest between 2009-2015 at four monitoring stations Lacul Morii, Drumul Taberei, Titan, Mihai Bravu [12].

The main source of air pollution with sulphur oxides is the power plants that burn coal and oil and whose emissions exceed 60% of the total emission of sulphur oxides, relative to SO_2. SO_2 discharged into the atmosphere at a rate of 1-2% reacts with oxygen under the action of ultraviolet radiation, generating SO_3. This gas reacts with water vapor to form sulfuric acid. The environmental impact is reflected by amplifying the effects of chronic respiratory diseases.

In low concentrations causes spasm and contraction of the muscles of the upper airways, in high concentrations causes burning respiratory and conjunctiva mucosa, impaired breathing, choking.

The main pollutants resulting from energy generation processes are SO_2, NO_2, they are pollutants that underlie the formation of acids, which are factors that influence climate [7]. The urban concentrations of 0.01-0.1 ppm SO_2 may have values (SO_2 at 25^0C and 1 atm presure), which may reach and even excede the maximum allowable daily emission, in large agglomerations SO_2 may form in the atmosphere, to aggressive chemical compounds. SO_2 entering the catalytic or photochemical reactions with other pollutants in the atmosphere forming sulphur trioxide (SO_3), sulfuric acid [6]. Oxidation of sulphur:

$$S + O_2 \rightarrow SO_2 \quad (1)$$

$$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3 \quad (2)$$

In terms of high humidity atmosphere , sulphuric acid is formed:

$$SO_2 + H_2O \rightarrow H_2SO_3 \quad (3)$$

$$2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4 \quad (4)$$

The latter reaction is a reaction of the oxide, which is changing rapidly in the presence of sulphates and chlorides of iron and magnesium, which served as a catalyst for the reaction. Such reactions assist in the formation of acid rain.

In Romania, the energy is produced mainly by burning fosil fuels, emissions discharged into the air due to the energy field can be seen in figure 1 [6].

Another pollutant is analyzed in this paper NO_2 due mobile sources, stationary as power plants, industrial

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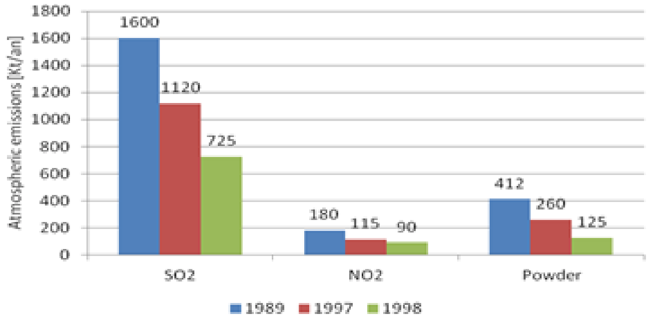

Fig. 1 Atmospheric emissions from energy in Romania [6]

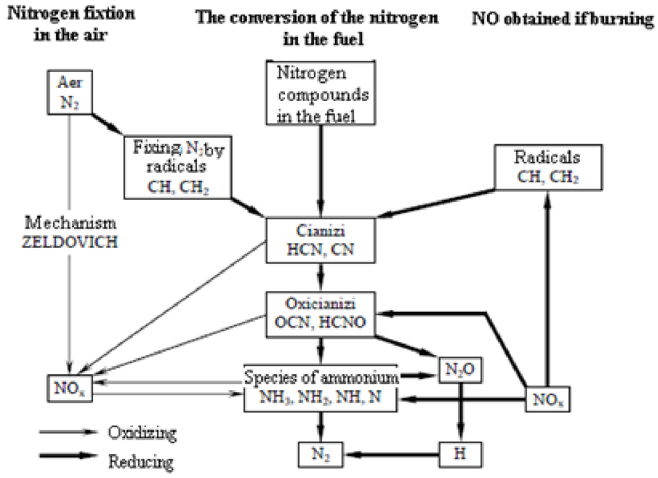

Fig. 2. The formation and reduction of nitrogen oxides in the combustion of fossil fuel plants [6]

enterprises, heating homes with their own sources. Nitric oxide is dangerous to humans, affects the mucous membranes, respiratory and transforms oxyhemoglobin in metahemoglobin, which can lead to paralysis.

Prolonged exposure to nitrogen oxides action weakens the body, leading to bacterial infections. NO_2 formed by reaction of nitric acid with H_2O, cause various types of corrosion that affect the construction and mounting, H_2NO_3 form nitrogen by the reaction with various cations present in the atmosphere.

They have a corrosive action on copper, brass, aluminum, nickel, destroying the electrical and telecommunication networks. These processes can take place at very low concentrations of nitrogen oxides in the atmosphere of air (0.08 ppm). Strongly oxidizing character of nitrogen oxides and nitrides and nitric acid is the main cause of destruction of plastics, paints and varnishes, used as coatings in industrial plants. The NO_2 adversely affect the ozone layer [7].

In the process of combustion, nitric oxide is formed by three mechanisms: thermal mechanism, the mechanisms of formation of nitrogen oxide or early NO formation mechanism of existing nitrogen in the fuel. The formation and reduction of nitrogen oxides to molecular nitrogen is shown in figure 2.

The oxidation reactions:

$$N + O_2 \rightarrow NO + O \quad (5)$$

$$2NO + O_2 \rightarrow 2NO_2 \quad (6)$$

The process of formation of NO in nitrogen present in the fuel is slower, and the slower mechanism is the formation of thermal NO. Techniques for controlling NOx emissions in the exhaust gases are shown in table 1. The sources of pollution with particulate matter are cement and asbestos, steel mills, metal foundries, thermal power

Table 1
CLASSIFICATION TECHNIQUES TO CONTROL NOx EMISSIONS [7]

Combustion method		Optimum sizing of the outbreak	
		Burning speed (the burners and / or the entire outbreak	
		Non-stoichiometric combustion of (for air flow control or fuel)	
		Recirculation of the combustion gas	
		Changing the operative parameters	
		Fluidized bed	
Methods afterburner	**Dry process**	Selective reduction of noncatalitică (Selection Non-Catalytic Reduction)	
		Catalytic reduction	Selective Catalytic Reduction
			Non-Selective Catalytic Reduction
		Adsorption on activated carbon or copper oxide *)	
		Reduction through accelerated electrons flow *)	
	Wet process	Oxidation - absorption - reduction	
		Oxidation - absorption	
		Absorption - Absorption reduction or oxidation	
*) The procedures are used simultaneously to control the emission of SO_2			

Pollutant	The maximum amount (µg/m³)	Duration of exposure (minutes/hours/years)
Sulphur dioxide (SO_2)	500 350 100-150 40-60	10 minutes 1 hour 20 hours 1 year
Nitrogen dioxide (NO_2)	400 150	1 hour 24 ore
Particles suspended in the black smoke	100-150*) 40-60*)	24 hours 1 year
The total amount of airborne particles	150-230 60-90 *)	24 hours 1 year
*) Approximate values for the case of simultaneous exposure to sulfur dioxide and particulates, these values can be applied to not only present when one of the two components.		

Table 2
MAXIMUM ALLOWABLE IMPOSED BY THE WORLD HEALTH ORGANIZATION FOR POLLUTANTS [7]

plants, which operate with solid fuels pulping cotton plants, diesel engines, construction sites. Powders, dust, and smoke aerosols can have adverse effects on the environment in the short term and long term. Health has the following effects: irritation of the eyes, throat and reduce resistance to infection. Particulates, from diesel engines can cause lung cancer [17]. Fly ash removed by the chimneys of the combustion plants, dust, fine ash entrained by the wind from the storage heaps and coal dust, arising from heaps of coal or from the transport and preparation thereof, have the effect of environmental pollution and long distance transport of hazardous gases, in relation to the emission site [7].

Results and discussions

Bucharest is located in the S-SE Romania, between 25°49’50” geographical coordinates and 26°27’15" east longitude and 44°44’30 “and 44°14’05" north latitude, being consists of two administrative units, Bucharest and Ilfov, representing 0.76% of the total area of Romania. The region is bounded by Prahova Bucharest (N), Ialomiþa (E, NE), Calaras (E-SE), Giurgiu (S-SV) and Damboviþa (fig. 3) [8].

Nitrogen dioxide, NO_2 concentrations in the air is evaluated by using the hourly limit value to protect human health (200µg/m³) allowed to exceed 18 times / year and an annual limit value to protect human health (40µg/m³). Annual average concentrations of nitrogen dioxide in the air surpassed the annual limit value for human health (40 mg/m³) in Bucharest at these stations that monitor pollution from traffic: in 2009 Lacul Morii (61 µg/m³) Titan (68µg/m³), Mihai Bravu (43.35 µg/m³) in 2010 Mihai Bravu (50 µg/m³) in 2011 at Drumul Taberei (41.96 µg/m³) in 2012 Mihai Bravu (59 µg/m³) and at Drumul Taberei (45 µg/m³) in 2013 Mihai Bravu (60 µg/m³) in 2014 Mihai Bravu (45 µg/m³) , 2015 all to Mihai Bravu (43 µg/m³) (fig. 4) [13].

It can be noted NO_2 emissions are highest in the transport sector come from heavy vehicles, followed by emissions from cars, followed by emissions from vehicles and traffic light rail (fig. 5). In this study were analyzed and

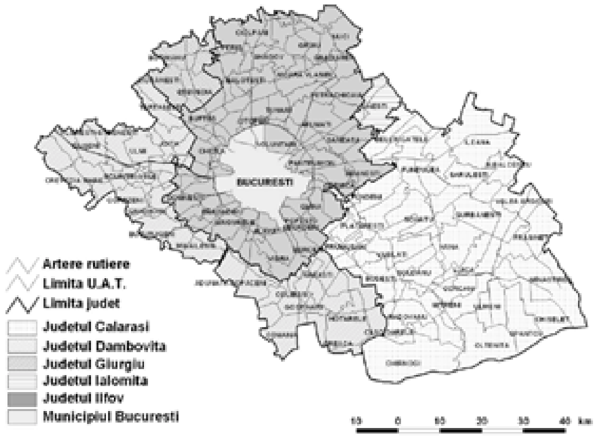

Fig. 3. Bucharest area [8]

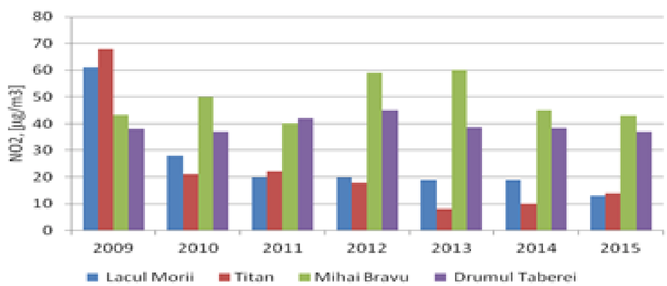

Fig. 4. Annual average NO_2 concentrations recorded in Bucharest in 2009-2015

emissions of particulate matter PM10 from air quality monitoring stations in Bucharest (Lacul Morii, Titan, Mihai Bravu, Drumul Taberei, Berceni) [13].

The concentrations of particulates with a diameter less than 10 microns - PM10 in ambient air is evaluated by using the daily limit value determined by gravimetry (50 µg/m³), which must not be exceeded more than 35 times / year, the annual limit value determined weight (40 µg/m³). The values of annual average concentrations of PM10 exceeded the annual limit value for human health

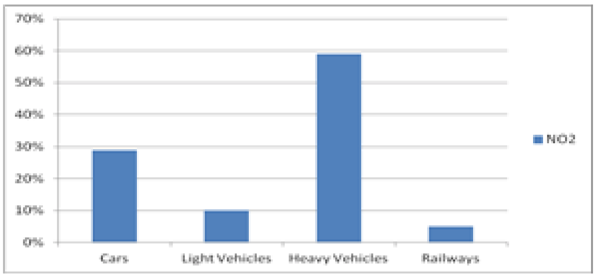

Fig. 5. Contribution types of vehicles to the emission of NO_2 effect of acidification and eutrophication of total national emissions in the transport sector

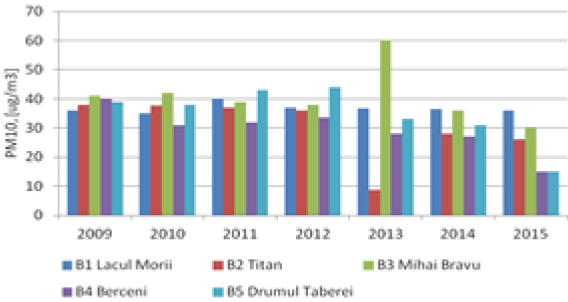

Fig. 6. Annual average concentrations of PM10 in 2009-2015

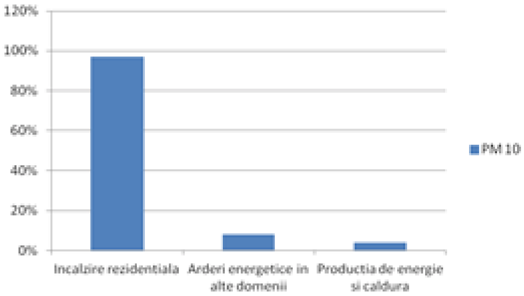

Fig. 7. Contributions of energy sectors nationally for emissions of particulate matter PM10

protection (40 µg/m^3) in 2009 (41 µg/m^3) in 2010 (42 µg/m^3), 2013 (60.12 µg/m^3) to Mihai Bravu traffic station that supports the influence of industrial pollutants in 2011 (43 µg/m^3) and in 2012 (44 µg/m^3) at station Drumul Taberei industrial type (fig. 6) [13,14].

Figure 7 shows the amount of particulate matter PM10 derived from residential heating (aprox. 90%), followed by energy consumption in other areas (aprox. 7%) and the heat and power production (aprox. 3%).

SO_2 concentrations in ambient air are evaluated using the hourly limit value for human health protection (350 µg/m^3) that must not be exceeded more than 24 times / year, and the daily limit value for human health protection (125 µg/m^3) not to be exceeded more than 3 times / year [23].

The analysis of data presented in figure 8 shows that for the period 2009-2015 for traffic stations in Bucharest for SO_2 pollutant, there is a general tendency to reduce annual average concentrations, which usually were below the limit values 40 µg/m^3.

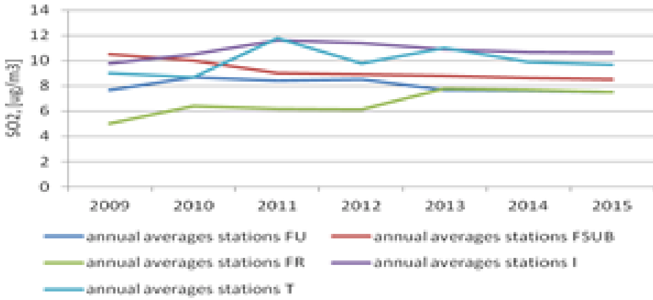

Fig. 8.Evolution of annual average concentrations of pollutants SO_2 stations recorded traffic in Bucharest in 2009-2015
Legend: FU = urban area, FSUB = suburban area; FR = rural area/ regional area, I = Industrial, T = transport

According to table 3, SO_2 emissions from large combustion plants are decreasing.

Note that the higher SO_2 emissions coming from the transport sector are due to cars (fig. 9).

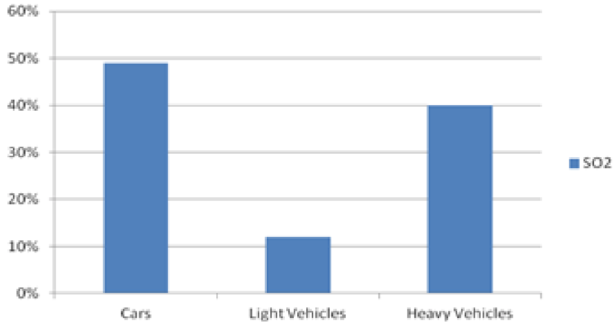

Fig. 9. Types of vehicles contribution to the emission of SO_2

Given that air pollution is influenced by weather conditions, the wind regime and temperature influence on air pollution was analyzed.

The wind plays an important role in the transport of pollutants [23]. It can enhance the action of pollution or clean the urban air. Wind direction can be favorable or unfavorable to air pollution depending on a number of natural and anthropogenic factors: shape, size, city location from sources of pollution, nature and intensity of emissions that contribute to spreading of pollutants at distances greater or smaller from source depending on the wind direction and speed, and in calm conditions, stationary pollutants near the source. The wind speed is also of special importance in the diffusion of pollutants, the concentration of which is inversely proportional to the wind speed.

Importance of winds for environmental quality is related to the location of air pollution sources to population centers. In Bucharest is an uneven distribution of the frequency of winds in central areas compared with peripheral, which constitutes a major restrictive factor for the location of a stationary source of air pollution (industrial plants, landfills etc.) urban areas being directly exposed during certain periods to pollutants emitted in nearby areas.

Years	2010	2011	2012	2013	2014
Emissions of SO_2 (tons / year)	300617,792	274246,46	212742,87	160416,57	134967,209

Table 3
SHARE Of SO_2 ACIDIFICATION EFFECT OF LARGE COMBUSTION PLANTS NATIONWIDE IN 2010-2014 [2]

Table 4
FREQUENCY OF MULTI-WIND DIRECTIONS IN BUCHAREST, 2009-2015 (m / s) (%)

2009-2015	NNE	NE	ENE	E	ESE	SE	SSE	S	SSV	SV	VSV	V	VNV	NV	NNV	N
m/s	1.3	1.4	1.9	2.3	2.3	1.7	1.4	1.2	1.0	1.0	1.4	1.5	1.6	1.6	1.2	1.2
%	3.9	3.8	7.7	11.9	8.9	4.9	4.9	4.3	3.5	4.1	8.5	5.0	4.1	5.2	7.4	11.7

Analyzing multi-frequency wind directions with the weather station at the University Politehnica Bucharest, Faculty of Biotechnical Systems Engineering, observed that the highest frequency have the E winds (11.9%) and N winds (11.7%). The low frequencies have the SSV winds (3.5%) (table 4).

In Bucharest, there are problems related to transporting pollutants from industrial units on the outskirts of the municipality (industrial platforms Pantelimon Branesti Dudesti-Policolor Sud, CET Vest etc.) or landfills (Glina, Chiajna) to inhabited districts (Pantelimon Pallady, Berceni, or Military) [8].

From figure 10 it is seen that the prevailing wind is a low intensity wind (1.5 - 5.5 m / s).

Figure 11 shows that maximum intensity wind comes from the N to the value of 6.8 m / s.

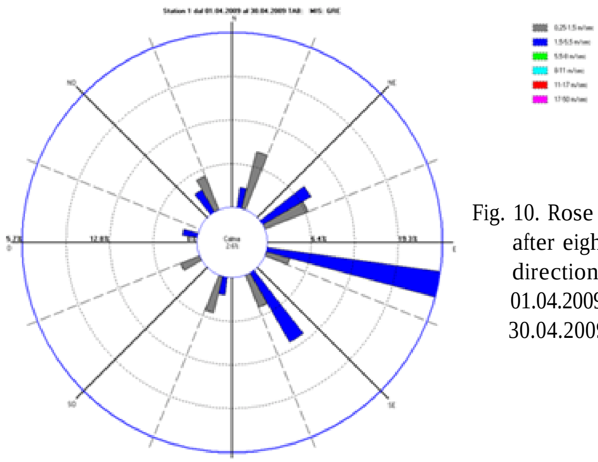

Fig. 10. Rose wind after eight directions 01.04.2009-30.04.2009

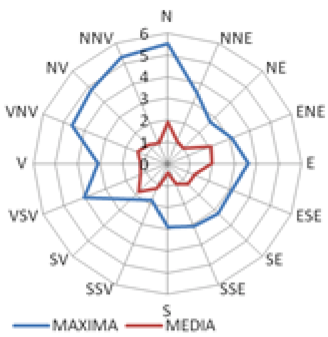

Fig. 11. Wind Rose spring 2011

The influence of air temperature on air pollution

The air temperature influences the vertical distribution of air pollution being responsible for the stable or unstable air masses [8]. The correspondence of classes of thermal stratification is based on the level of turbulence of the vertical gradient of temperature (which includes the radiative air-soil interaction) and the average wind speed, turbulence accompanying different intensities. Direct temperature stratification causes atmospheric instability and generate convective motions of air upward. Some of the pollutants emitted by different sources of anthropogenic and natural pollution of the earth's surface are engaged in free air, then being dispersed over long distances by currents circulation in the atmosphere [24]. Dispersal is influenced by the type, concentration and mass of the pollutants and the intensity of the convection movements and bottom thermoconvection. The thickness of the atmospheric layer where the mixture occurs by convective air volumes and the concentration of pollutants depend on the convection [14]. If the convective layer has a small height, the dispersion of pollutants is in a low volume of air, resulting in increased concentrations. If the thickness of the layer is greater, combined with the upflow velocity increase, it results in faster dispersion of the pollutants.

It shows a thermal stratification inversion atmospheric stability due to formation of currents, resulting in a substantial decrease in the thickness of the mixing layer, and the probability of rapid increase in the concentration of pollutants is considerable. At the earth's surface in association with moisture, particularly in industrial sites, this causes the stagnation phenomena of the pollutants in the soil.

Lateral and vertical diffusion of the pollutant plume stratification is dependent on the weather and the distance from the source of pollution and the height of the source [17,18]. As to spread out laterally and vertically with the removal of the source direction of the wind, the concentration of the wedge-axis distance will decrease continuously. The magnitude of this decrease varies depending on the thermal stratification and the size and scale of turbulence. Succession of atmospheric stability classes is an indicator of continuous variation of intensity of turbulence in the boundary layer of the atmosphere. This layer is in the immediate vicinity of the soil, where are mechanical and thermal interactions of the soil with the atmosphere, the local interaction is directly linked to the large-scale movements of the atmosphere. The urban environment can change the layers of low pressure (mixed layer between an altitude of 200m in winter, under anticyclones, up to 2000 m in the summer) to give rise to phenomena of heat islands that are favorable to accumulation of pollutants (bell shape).

Bucharest is also known as the urban heat island due to: fuels burned in the city, heating asphalt and brick surfaces, as well as the large number of people [15]. In Bucharest, most of the city is distributed horizontally and vertically is shaped like an urban bell (phenomenon horn), climbing in altitude up to several times the height of the buildings [7]. Urban heat island is seasonal and there are diurnal variations in the temperature and the ratio of the area affected [7]. In Bucharest, expansion of built areas (especially in the north of the city) at the expense of green areas (potential consumer of thermal energy) increases thermal values to the suburbs.

In the past 20 years the volume of traffic has increased resulting in heat island effects that are highest where the green areas have the lowest percentage. The air temperature may have an important role in the case of determining conversion of noxious chemicals in other species, more dangerous to human health than those from which they originated. In Bucharest, ozone values exceed the maximum allowable concentrations starting from March/April due to increased solar radiation, under which certain pollutants (especially nitrogen oxides, resulting from the activities of industry, traffic) react with atmospheric oxygen causing photochemical reactions in which ozone is obtained [16,19].

Air temperature was recorded daily by the weather station at the Faculty of Biotechnical Systems Engineering from University Politehnica Bucharest. During the period 2009-2015 and 1994-2008, respectively.

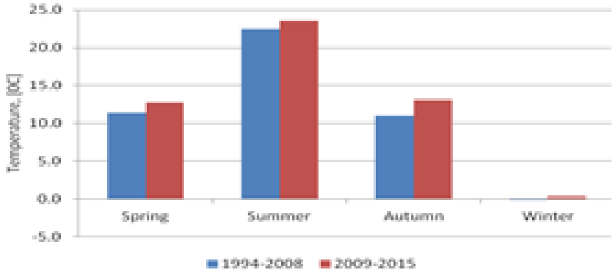

Fig. 12. Seasonal average temperatures in Bucharest 2009-2015 compared to the period 1994-2008

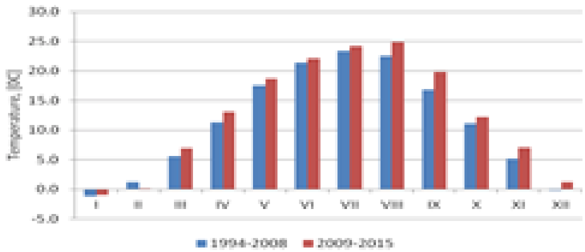

Fig. 13. Evolution of the monthly average temperature during the period 2009 to 2015 in Bucharest compared to the period 1994-2008

The spring season average temperature in Bucharest increased in the period 2009-2015 compared to 1961-1990 by 1.4^{0}C, summer average temperature has risen by 1.1^{0}C, fall average temperature has risen by 2.1^{0}C while winter average temperature has risen by 0.4^{0}C. The tendency is toward the increase of the average air temperature (fig. 12).

The average temperature during the period 2009-2015 in Bucharest compared with 1994-2008 increased by 1.2^{0}C. An important feature of the trend in the thermal regime in Bucharest is heating.

An increase in heat to the central area of the city was amplified in the last century with the development of built areas, the diversification of heating sources and increased heat pollution, the resulting thermal values are higher than towards the periphery by 2-3^{0}C [7].

Heat island effects are somewhat limited in the north and south of Bucharest by relatively large green areas (forests Herastrau parks, Youth, Carol).

Conclusions

Analyzing the pollutants such as PM10, NO_2, SO_2 was found that the amount of particulate matter PM10 largely comes from residential heating (aprox.90%), followed by burning energy in other areas (aprox.7%) and production of energy and heat (3%).

The highest SO_2 emissions from transport come from cars. SO_2 emissions due to large combustion plants are declining. Reduction of SO_2 in the energy sector is achieved mainly by removing the use of fuels with high sulphur content (coal or oil fuel) and the use of fuels with low sulphur content (natural gas). Energy is essential for economic and social welfare, however energy consumption and production cause environmental pressures, such as the contribution to climate change and ensuing environmental deterioration with adverse effects on human health.

Highest NO_2 emissions in the transport sector come from heavy vehicles/trucks, followed by emissions from cars.

The main measures to be taken are:

- maintaining traffic restrictions for trucks in downtown Bucharest;
- reducing traffic congestion by implementing a system of intelligent traffic control;
- increase the attractiveness of public transport and cycling;

The analyzes of data on the dispersion of pollutants into the atmosphere show that there are areas more exposed to increased risk of pollution, in particular those with a high density of buildings and traffic.

References

1. VOICU, G., BECHIR, A.M., ARCHIR, O.C., J. Environ. Prot. Ecol, 2012, 12, no. 3, p. 1357

2. ALLABY, M., Atmosphere: A Scientific History of Air, Weather and Climate, Facts on File Inc. PublishingHouse, New York, 2009

3.. CAPSA, D., BARSAN, N., FELEGEANU, D., STANILA, M., JOITA, I., ROTARU, M., URECHE, C., Environ. Eng. Manag. J., **15,** no. 3, 2016, p. 655-663

4.. CAPSA, D., NEDEFF, V., BARSAN, N., Academic Journal of Science, **3**, no. 2, 2014, p. 97–106

5. CAPSA, D., NEDEFF, V., VASILICA, M., LAZAR, G., PANAINTE, M., BARSAN, N., Present Environment and Sustainable, Development, **6**, no 2, 2012, p. 387-404

6. CAPSA, D., NEDEFF, V., Journal of Engineering Studies and Research, Univ. Bacau, 2016

7. ISTRATE, M., Technologies and equipment to reduce emissions, Ed Iasi, 2004

8. IOJA I., Methods and techniques for assessing the environmental quality of the area metropoliatanã Bucharest, 2009

9. CIULACHE S., 2004, Geogr.V, Bucharest University Press

10. BEAUMONT, L.J., HUGHES, L., POULSEN, M., Ecological Modelling, **186**, no. 2, 2005,
p. 251–270.

11. SONAL, S.V., BIRVA, D., Environmental Application & Science, **3**, no. 5, 2008, p. 358-367.

12. *** http://www.epa.gov/ncea/isa (19.07.2010)

13. *** http://www.anpm.ro/

14.*** Annual report on the state of the environment in Romania, Bucharest 2016

15. RUSANESCU, M., RUSANESCU, C. O., Hidraulica nr. 3, pp. 60-68, 2016

16. GUGIUMAN, I., COTRAU, M., Elements of urban climatology, RSR Academy Press, Bucharest 1975

17. RUSANESCU, C. O., STOICA, D., Metalurgia International, nr. 3, pp. 81-83, 2013

18. RUSANESCU C.O., POPESCU I. N., DAVID L., 3 rd International Conference on Environmental and geological science and Engineering (EG' 10), September 3-5,pp. 175-180, 2010

19. ITICESCU, C., GEORGESCU, L.P., TOPA, C., MURARIU, G., Journal of environmental protection and ecology, **15,** Issue: 1, Pages: 30-38, 2014

20. BUTU, I., M., BUTU, M., CONSTANTINESCU, I., MACOVEI, S., Rev. Chim. (Bucharest), **63,** no.3, 2012, p. 330

21.*** Order no. 592/2002 Normative order to approve the setting limit values, threshold values and the criteria and methods of evaluation of sulfur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter (PM10 and PM2.5), lead, benzene, carbon monoxide and ozone in the ambient air.

22. *** STAS 12574-87 - Air in protected areas. Terms of quality
23.DURBACA, I., Mat. Plast., **52**, no. 1 , 2015, p. 43

24. DULCEA, D., IONEL, I., PASCU, L.,F., Rev. Chim.(Bucharest), **66**, no. 8, 2015, p. 1232
25. SAFTA, V., Actual Tasks on Agricultural Engineering, **35**, 2007, 281-293
26. DURBACA, I., STEFANESCU M.FL., SPOREA, N., Buletinul Universitatii Petrol-Gaze din Ploiesti, Seria Tehnica, Vol. LXV, No.1/ 2013, p. 64-70.
27. POPESCU, I.N., ZAMFIR, S., ANGHELINA, V., F., RUSANESCU, C.O., Advanced Manufacturing Engineering, Quality and Production Systems, 2nd International Conference on Manufacturing Engineering, Quality and Production Systems, 2010.
28. DURBACÃ, I., POPA, N., VOICU, GH., DURBACA, A.C., Mat. Plast., **52**, no. 4 , 2015, p. 464
29. POPA, N., CARDEI, P., VOICU, GH., MINCIUNA, V.ªT., DONCEA, S.M., DINCÃ, M., DURBACA, I., Mat. Plast., **52**, no. 2,2015, p. 144
30. CARDEI, P., POPA, N., VOICU, GH., MINCIUNÃ, V.ST., DONCEA, S.M., DURBACA, A.C., DURBACA, I., DINCA, M.,Mat. Plast., **52**, no. 3, 2015, p. 345
31. ENESCU, M.C., POPESCU, I.N., ZAMFIR, R., MOLAGIC, A., BRATU, V., International Journal of Energy and Environment, **4** (4) (2010)122-130.
32. ENESCU, M.C., POPESCU, I.N., ZAMFIR, R., MOLAGIC, A., BRATU,V., Proc. 2nd International Conference on Manufacturing Engineering, Electrical and Computer Engineering (2010) 212-216.
33. RIZESCU, CR. Z., BACINSCHI, Z., STOIAN, EL. VA., POINESCU, A. A., Proceedings of the 4 th WSEAS International Conference on Waste Management , (WWAI 10), p.139-143, 2010,
34. POPESCU, I.N., ENESCU, M.C., BRATU, V., ZAMFIR, R.I., STOIAN, E.V., Advanced Materials Research, Trans Tech Publ. **1114** (2015), 239-244.
35. POPESCU, I.N., BRATU, V., ENESCU, M.C. , AEE '10: Proceedings of the 9th WSEAS Int. Conference on Applications of Electrical Engineering, Recent Advances in Electrical Engineering, (2010) 225-232.
36. STOIAN, E. V., RIZESCU, C. Z., CHIÞANU ELENA, ANGHELINA, V., POINESCU, A. A., EMESEG 2010, WORLDGEO 2010, p.130-135,
37. STOIAN, E. V., RIZESCU, C. Z., PINTEA, J., UNGUREANU, D. N., FLUIERARU, C. P., International Journal of Geology, Issue 3, **3** (2009), p.70-78,
38. PETRE, I., STOIAN, E.V., ENESCU M.C, Scientific Bulletin of Valahia University-Materials and Mechanics, 14 (2016), (**11**), 35-40, ISSN 2537-3161/ pp.35-40
39. STOIAN, E.V., BRATU, V., ANGHELINA, F. V., ENESCU, M.C., The Scientific Bulletin of Valahia University - Materials and Mechanics, 10 (13) 2015
40. STOIAN, E.V., BRATU, V., ENESCU, M.C., POPESCU, I.N., The Scientific Bulletin of Valahia University- Materials and Mechanics, 8 (**11**) 2013

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