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SANITARY-EPIDEMIOLOGICAL ASSESSMENT OF QUALITY OF ATMOSPHERIC AIR IN MOSCOW

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The results of the comparative assessment of the sanitary and epidemiological quality of the ambient air in Moscow and the Russian Federation, that demonstrate a decrease of the air pollution level in 2014 in comparison with 2012, both in Moscow and in the Russian Federation, are presented in this study. It has been noted that most of the excess of hygienic air quality standards in the areas of Russian cities are recorded on stationary observation stations situated close to the motorway, located in residential areas, and in Moscow – in the zones of industrial enterprises' impact. It has been revealed that the tendency to the reduction of the negative impact from industrial enterprises on air pollution is registered in the whole of the Russian Federation and in Moscow. It is demonstrated that the high-priority contaminating agents, the content of which for the year 2014 in the Russian Federation exceeded the hygienic daily average standards in 5 and more times, are mainly: benzo (a) pyrene, suspended substances, sulfur dioxide, benzene, formaldehyde, nitrogen dioxide, hydrogen sulfide, etc. To assess the quality of the ambient air in Moscow, the method of "inverse distance" and inter- and extrapolation of the data obtained from the observation stations on the whole territory of Moscow has been used. The study shows that the air quality of the individual administrative districts of Moscow varies considerably, and is determined by the traffic load level as well as by the volume of emissions of the industrial enterprises and the wind rose. As high-priority contaminating agents affecting the air quality, nitrogen dioxide, ammonia, benzene, suspended substances, ozone and formaldehyde are distinguished. It is noted that close to the highway near Moscow there is an excessive concentration of nitrogen dioxide, formaldehyde, phenol, and carbon monoxide, and in areas close to industrial zones – nitrogen dioxide, phenol formaldehyde and benzo (a) pyrene.

***Key words**: ambient air quality, sanitary-epidemiologic evaluation, exceeding of the hygienic standards, approximation, interpolation, extrapolation, the method of «Inverse Distance», observation stations, monitoring, high-priority contaminating agents.*

According to the World Health Organization (WHO), air pollution affects more than 80% of urban population [14]. Air pollution is a major cause of morbidity and mortality. The risk of stroke, heart diseases, lung cancer, acute and chronic respiratory diseases, including asthma, increases with air deterioration [16-20].

This problem is particularly true for Moscow, the largest city in the Russian Federation, where air quality affects health of more than 12 million people (more than 8.4% of the total population). Thus, according to the WHO experts [4], $PM_{2.5}$ particles content in the air of Moscow, with its composition of sulfates, nitrates, carbon black and other chemicals present, is about 2-2.5 times higher than the average threshold concentration (10 $\mu g/m^3$) established by the WHO. As for life expectancy of the population (according to The Economist

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Intelligence Unit), the city of Moscow in 2015 is only the 13th of 20 cities included in the rating of the world cities with a population of over 10 million inhabitants.

According to epidemiological and sanitary studies [1–3,8,9,11–13,15], in Moscow there are risks of assident mortality and morbidity associated with exposure to environmental factors, especially air and drinking water. The leading environment that makes risks to health is the air.

To reduce population morbidity and mortality associated with air pollution, relevant actions of both the municipal and regional, as well as federal authorities, are needed.

Requirements to the air quality and hygiene criteria for its public health safety are established by federal regulations, i.e. the laws "On the sanitary-epidemiological welfare of population" and "On air protection", as well as the sanitary rules and standards "Hygienic requirements for air quality of inhabited localities".

The target of the present study was the comparative hygienic assessment of the ambient air quality in Moscow and the Russian Federation, as well as the evaluation of the air quality in the administrative districts of Moscow.

Materials and methods. As infosources for the comparative sanitary assessment of the ambient air quality in Moscow and Russia, we used data form No: 18 "Information on the sanitary condition of the Federal Subject of Russia" approved by the Order of the Federal State Statistics Service No.673, ddt. 20.11.2014.

In order to assess air quality per administrative districts of Moscow, we used data on the content of pollutants in the ambient air for 2012-2014, obtained by "Hygiene and Epidemiology Center in Moscow" as part of the environment and health monitoring, as well as the data of the State Agency on Environment Protection "Mosekomonitoring" and "Moscow Center of hydrometeorology and monitoring of environment".

An assessment of ambient air quality in a comparative aspect with the Russian Federation and in the context of the administrative districts was carried out by the over-limits share of maximum permissible concentration (MPC) in sampling points at fixed stations, highways in the area of residential development, in the industrial enterprises affected areas (129288 samples by 25 indices).

To obtain info on the level of the mean-year concentrations, the electronic map of the city was marked with the system of calculation points as a regular grid of 3240 km^2 total area, 54×60 km size and grid points step of 200×200 m. The approximation was performed by an "inverse distance" method [10].

Upon the approximation procedure, we calculated mean indices of all the calculation points located within the borders of each administrative district.

A comparative analysis of the chemical substances concentrations (maximum of one-time and daily average) in the air of Moscow and the Russian Federation was carried out taking into account the requirements of SanPiN 2.1.6.1032-01, and *Hygienic Standards* 2.1.6.1338-03 and *Hygienic Standards* 2.1.6.2309-07.

Study results. According to the Federal Service for Surveillance over Consumer Rights Protection and Human Well-being [6], urban settlements air quality on the territory of the Russian Federation has improved. So, the share of the ambient air samples in 2014 in the cities of the Russian Federation exceeding $MPC_{o.t.}$ amounted to 1.06 ± 0.02%, which is 0.3% less than in 2012 (1.37 ± 0.02%). A similar dynamics is observed in Moscow. The proportion of air samples, incompliant with hygienic standards, decreased 2 times: from 0.43 ± 0.06% in 2012 to 0.22 ± 0.04% in 2014. It should be noted that the level of air pollution in Moscow (transient increases in concentrations) is approx. 3-5 times lower than in the RF cities on the whole.

Most often an exceedance of the air quality hygienic standards in the urban territories of the Russian Federation is being recorded at the fixed monitoring stations and close to the highways located in residential areas and in Moscow, i.e. in the affected areas of indus-

trial enterprises. However, there's a tendency of decreasing the negative effect of industrial enterprises on air pollution both in the Russian Federation on the whole, and in Moscow.

According to FSBI "Central Federal State Budget Institution" in 2014 the level of air pollution near the highways and industrial areas can be characterized as the "higher", in residential areas of the city as "low".

Priority chemicals polluting the ambient air in the Russian Federation, according to the State Report [6], include phenol, suspended particles, formaldehyde, benzo(a)pyrene, carbon monoxide. Substances that determine health situation in Moscow [5,7] are hydrogen sulfide, nitrogen dioxide, ammonia and aliphatic saturated hydrocarbons.

According to the State Report [6], in 2014 in the Russian Federation on the whole, the average daily concentrations of pollutants in the ambient air in 99.18% of samples comply with hygienic standards. Only 0.82% of samples taken in the territory of the Russian Federation in 2014 showed chemical impurities pollution in the air exceeding $MPC_{d.a.}$ (as in 2013). The exceedance of 1.1 to 2.0 $MPC_{d.a.}$ was observed in 0.71% of samples, from 2.1 to 5.0 $MPC_{d.a.}$: in 0.08% of samples, and more than 5.1 $MPC_{d.a}$:. in 0.02% of air samples.

In 2014, a 5-times or higher exceedance of the daily average hygiene standards was observed in the Russian Federation in terms of benzo(a)pyrene, suspended solids, sulfur dioxide, benzene, formaldehyde, nitrogen dioxide, hydrogen sulfide and other pollutants content in the atmosphere.

For comparative assessment of the ambient air quality in all the administrative districts of Moscow, we converted the mean-year data of the field measurements for 2012-2014 in a single array made by FSBI[1] "Moscow Central Hydrometeorological Service", branches of FSBI[1] "Moscow Center of hydrometeorology and monitoring of environment" and the State Agency on Environment Protection "Mosekomonitoring".

The ambient air quality monitoring in Moscow is done by FSBI "Moscow Central Hydrometeorological Service" at 16 fixed stations located in all districts of the city, except the Southwestern Administrative District and the Prefecture of Troitsky and Novomoskovsky Administrative Districts, branches of FSBI[1] "Moscow Center of hydrometeorology and monitoring of environment" at the route sites and departmental monitoring stations (see Figure . 1) and by the State Agency on Environment Protection "Mosekomonitoring" at 52 automatic air pollution monitoring stations (AAPMS) [5].

In 2014, the number of route sites increased to 45 (39 sites in 2012), and the departmental – reduced to 4 (5 in 2012) [5].

At FSBI1 "Moscow Center of hydrometeorology and monitoring of environment" fixed stations daily monitoring is in place, 2-4 times a day, within the timelines established by GOST 17.2.3.01-86. The fixed stations monitoring program includes 25 pollutants: suspended solids, sulfur dioxide, carbon monoxide, nitrogen oxide and nitrogen dioxide, hydrogen sulfide, phenol, hydrogen chloride, ammonia, formaldehyde, gasoline fraction hydrocarbons, benzene, xylene, toluene, acetone, benzo(a)pyrene, iron, cadmium, cobalt, manganese, copper, nickel, lead, chromium and zinc.

At the automatic air pollution monitoring stations (AAPMS) the atmospheric air is under monitoring twenty-four-seven, in real time, measuring the content of 26 substances in the ambient air which are typical for anthropogenic emissions sources in Moscow, including SPMs (PM10 and PM2.5), organic compounds, carbon dioxide and oxygen. The program also includes studies of carbon monoxide, nitrogen oxide and dioxide, the amount of hydrocarbons, ozone, sulfur dioxide, hydrogen sulfide, ammonia, formaldehyde, phenol, benzene, toluene, styrene, ethylbenzene and other substances.

The chemical substances for which the information was obtained from less than 7 monitoring stations, or all the values thereof are zero, were excluded from the analysis. To obtain comparable data on the ambient air quality in each of the administrative districts we used the method of "inverse distance".

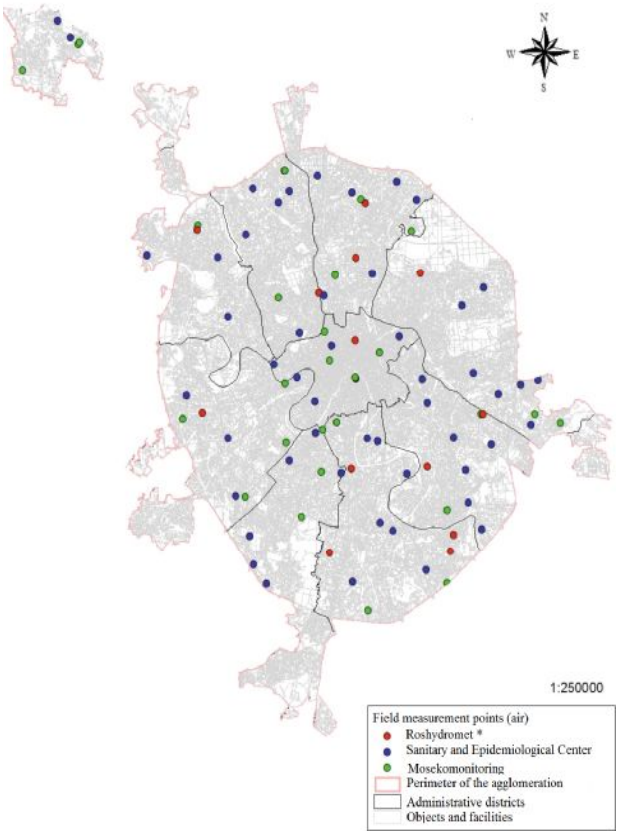


Fig. 1. Location of the monitoring stations for the ambient air quality in the city of Moscow in 2012-14
**Federal Service for Hydrometeorology and Environmental Monitoring of Russia*

The method of "inverse distance" is based on determining the "center of gravity" for a network of monitoring stations, a point whose coordinates are the arithmetic mean of the corresponding coordinates of the monitoring stations and the data interpolation within a circle of a radius 1.1R, where R is the distance between the "center of gravity" and the most remote station, in the formula (1):

$$C_{x,y} = \frac{\sum C_k / r_k}{\sum 1/r_k},$$

where C_k is the measured concentrations at the *k*-th monitoring station and at the point under consideration (regular grid point) for the respective speed scalar and wind direction; r_k is the distance from the point under consideration (x, y) to the *k*-th station.

The extrapolation outside the circle is done by the formula *(2)*:

$$C_{x,y} = \frac{\sum C_k / r_k}{\sum 1/r_k^0} + c\left(1 - 1{,}1\frac{R}{r^0}\right),$$

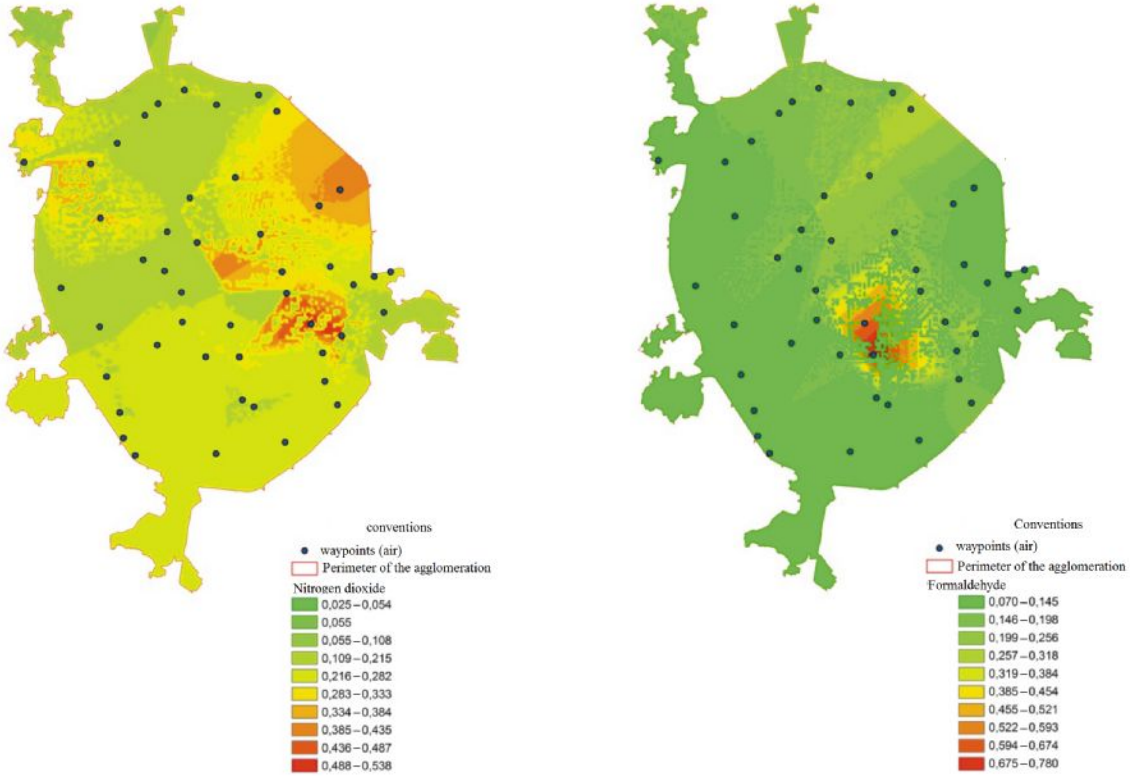
where r_k^0 is the distance from the *k*-th station to the intersection point of the circle and the straight line that connects the point under consideration with the center of gravity; r^0 is the distance from the point under consideration to the center of gravity; c is "suburban background".

The data analysis of the spatial distribution of the year-average concentrations obtained in view of data approximation procedures, allowed prioritize the administrative districts of Moscow depending on the level of pollution with certain substances, including nitrogen dioxide and formaldehyde (Fig. 2).

The mean concentrations of priority pollutants in the ambient air of Moscow administrative districts analyzed for 2012-2014 showed systematic exceedance of hygienic standards for the content of nitrogen dioxide, ammonia, benzene, suspended matters, ozone and formaldehyde.

The highest concentrations of nitrogen dioxide observed in the Northwestern, Central and Southern Administrative Districts (from 1.46 to 1.52 MPCd.a.), and the lowest – in Zelenogradsky and the Northeastern Administrative Districts (from 0.65 to 0.90 MPCd.a.). In the areas of the Eastern, Western, Northern, Southwestern and the Southern Administrative Districts there is an exceedance of the hygienic standards registered for nitrogen dioxide at the level of 1.11 to 1.34 MPCd.a.

The highest mean concentrations of ammonia are in the areas of Zelenogradsky, the Central and Northwestern Administrative Districts (from 1.2 to 1.25 MPCd.a.) lower concentrations – in the Eastern, Southwestern and the Central Administrative Districts (0.52, 0.63 and 0.71 MPCd.a., respectively).



a) nitrogen dioxide b) formaldehyde

Fig. 2. Concentrations of certain pollutants in the air, obtained by data approximation from all the monitoring stations

The mean concentrations of ammonia at about 1 MPCd.a. are registered in the air of the Northeastern, Southwestern and the Southern Administrative Districts.

The most petrol-polluted air is in the Western Administrative District (1.10 MPCd.a.), polluted with suspended solids – in Zelenogradsky Administrative District (1.07 MPCd.a.).

Ozone concentrations at the level of or exceeding the MPC for the ambient air are registered consistently in the territory of Zelenogradsky, the Northern, Northwestern, Central, Southwestern and the Southern Administrative Districts (from 1.00 to 1.36 MPCd.a.).

The most of formaldehyde is in the ambient air of the Eastern, Northeastern, Central and Southeastern Administrative Districts (from 1.03 to 1.34 MPCd.a.). In other administrative districts of Moscow the mean concentrations of formaldehyde for 2012-14 were observed at the level of 0.61 - 0.84 MPCd.a..

Conclusions. Thus, the study showed that:

1. Subject to hygienic criteria, the quality of the ambient air in Moscow is improving. The share of ambient air samples incompliant with hygienic standards, decreased 2 times (from 0.43 ± 0.06% in 2012 to 0.22 ± 0.04% in 2014).

2. The air quality of the administrative districts in Moscow greatly varies and is dependent upon the traffic, the volume of emissions from industrial enterprises and the wind pattern.

3. The priority pollutants affecting the air quality are nitrogen dioxide, ammonia, benzene, particulate matters, ozone and formaldehyde.

4. Near the highways there are observed the excess concentrations of nitrogen dioxide, formaldehyde, phenol and carbon monoxide.

5. In the proximity to industrial zones: nitrogen dioxide, formaldehyde, phenol, and benzo(a)pyrene.

References

1. Avaliani S.L., Mishina A.L. O garmonizacii podhodov k upravleniju kachestvom atmosfernogo vozduha [Harmonization of approaches to management of air quality]. *Zdorov'e naselenija i sreda obitanija*, 2011, no. 3, pp. 44–48 (in Russian).

2. Bobkova T.S. Zonirovanie territorii perspektivnoj zastrojki s primeneniem metodologii ocenki riska zdorov'ju naselenija [Future built-up area zoning by applying the methodology for assessing the population health risk]. *Gigiena i sanitarija*, 2009, no. 6, pp. 38–41 (in Russian).

3. Filatov N.N., Glinenko V.M., Fokin S.G., Efimov M.V., Muratov V.V., Balakireva A.S. Vlijanie himicheskogo zagrjaznenija atmosfernogo vozduha Moskvy na zdorov'e naselenija [Impact of chemical ambient air pollution in Moscow on its population's health]. *Gigiena i sanitarija*, 2009, no. 6, pp. 82–84 (in Russian).

4. VOZ: 80 % zhitelej gorodov mira dyshat "plohim" vozduhom [WHO: 80 % of the city residents take “bad” air]. Setevoe izdanie «RIA Novosti». Available at: https: //ria.ru/science/20160512/1431949885.html (25.10.2016) (in Russian).

5. O sostojanii okruzhajushhej sredy v gorode Moskve v 2014 godu: Doklad [On the state of environment in Moscow in 2014: report]. In: A.O. Kul'bachevskogo ed. Moscow, DPiOOS Publ.; NIA-Priroda Publ., 2015, 384 p. (in Russian).

6. O sostojanii sanitarno-jepidemiologicheskogo blagopoluchija naselenija v Rossijskoj Federacii v 2014 godu: Gosudarstvennyj doklad [On the state of the sanitary and epidemiological welfare of the Russian Federation population in 2014: State Report]. Moscow, Federal'naja sluzhba po nadzoru v sfere zashhity prav potrebitelej i blagopoluchija cheloveka, 2015, 219 p. (in Russian).

7. O sostojanii sanitarno-jepidemiologicheskogo blagopoluchija naselenija v gorode Moskve v 2014 godu: Gosudarstvennyj doklad [On the state of the sanitary and epidemiological welfare of the Russian Federation population in 2014: State Report]. Moscow, Upravlenie Rospotrebnadzora po g. Moskva, 2015, 233 p. (in Russian).

8. Novikov S.M., Ivanenko A.V., Volkova I.F., Kornienko A.P., Skvorcova N.S. Ocenka ushherba zdorov'ju naselenija Moskvy ot vozdejstvija vzveshennyh veshhestv v atmosfernom vozduhe [Assessment of Moscow population health risk from exposure to ambient air suspended matter]. *Gigiena i sanitarija*, 2009, no. 6, pp. 41–44 (in Russian).

9. Avaliani S.L., Novikov S.M., Shashina T.A., Dodina N.S., Kislicin V.A., Mishina A.L. Problemy sovershenstvovanija sistemy upravlenija kachestvom okruzhajushhej sredy na osnove analiza riska zdorov'ju naselenija [The urgent problems of the improvement of the environment management system based on the analysis of health risk assessment]. *Gigiena i sanitarija*, 2014, vol. 93, no. 6, pp. 5–8 (in Russian).

10. RD 52.04.186-89. Rukovodstvo po kontrolju zagrjaznenija atmosfery [РД 52.04.186-89. Atmosphere pollution control manual]. utv. Goskomgidrometom SSSR 01.06.1989, Glavnym gosudarstvennym sanitarnym vrachom SSSR 16.05.1989. [approved by the National committee of hydrometeorology of the USSR dd. 01.06.1989, by the Chief State Sanitary Inspector of the USSR dd. 16.05.1989]. Moscow, 1991, 641 p. Available at: http: //ohranatruda.ru/ot_biblio//normativ/data_normativ/44/44486/index.php (20.10.2016) (in Russian).

11. Ivanenko A.V., Volkova I.F., Kornienko A.P., Sudakova E.V., Bestuzheva E.V. Sostojanie zdorov'ja detskogo naselenija v Moskve po dannym social'no-gigienicheskogo monitoringa [Pediatric population's health in Moscow according to the data of sociohygienic monitoring]. *Gigiena i sanitarija*, 2009, no. 6, pp. 64–65 (in Russian).

12. Sudakova E.V. Mnogosredovoj kancerogennyj risk zdorov'ju naselenija goroda Moskvy [Multimedia carcinogenic health risk for the population of Moscow]. *Zdorov'e naselenija i sreda obitanija*, 2015, vol. 267, no. 6, pp. 13–16 (in Russian).

13. Izmerov N.F., Buhtijarov I.V., Prokopenko L.V., Izmerova N.I., Kuz'mina L.P. Trud i zdorov'e [Labor and healthe]. Moscow, LitTerra Publ., 2014, 416 p. (in Russian).

14. Urovni zagrjaznenija vozduha povyshajutsja vo mnogih samyh bednyh gorodah mira [Air pollution levels rising in many of the world’s poorest cities]. *World Health Organization*. Available at: http: //www.who.int/
mediacentre/news/releases/2016/air-pollution-rising/ru/ (25.10.2016) (in Russian).

15. Fokin S.G. Ocenka riska zdorov'ju naselenija pri proektirovanii transportnyh potokov Moskvy [Population health risk assessment on designing the transport streams of Moscow]. *Gigiena i sanitarija*, 2009, no. 6, pp. 36–38 (in Russian).

16. Ashmore M. R., Dimitroulopoulou C. Personal exposure of children to air pollution. *Atmospheric Environment*, 2009, vol. 43, pp. 128–141.

17. EPA-454/B-13-003. QA Handbook for Air Pollution Measurement Systems. *Ambient Air Quality Monitoring Program*, 2013, May, vol. II, 348 p. Available at: https: //www3.epa.gov/ttnamti1/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf (20.10.2016).

18. EPA-454/R-13-007a. National Monitoring Programs Annual Report (UATMP, NATTS, CSATAM). Eastern Research Group, Inc. Morrisville, NC 27560, 2013, August, vol. 1: Main, 1203 p. Available at: https: //www3.epa.gov/ ttn/amtic/files/ambient/airtox/2011nmpreport.pdf (20.10.2016).

19. Potoglou D., Kanaroglou P. S. Carbon monoxide emissions from passenger vehicles: predictive mapping with an application to Hamilton, Canada. *Transportation Research Part D*, 2005, vol. 10, pp. 97–109.

20. Michelle L. Bell [et. al]. Quantifying the human health benefits of air pollution policies: Review of recent studies and new directions in accountability research. *Environmental science & policy*, 2011, vol. 14, pp. 357–368.

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