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Estimating Summer Emissions from Land Transportation Vehicles Moving Along the Urban Roads

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Abstract: The industrial and transport effect on the environment is distinguished most significantly by the formation of technogeneous geochemical anomalies in the urban landscape. This study was conducted within the boundaries of urban agglomeration (Penza city) for two years (2014 and 2015) during the summer (June to August). To determine the effect that the distance from road and the amount of heavy metal emissions have, samples were extracted at a distance of 10, 20, 30, 40, 50 and 60 metres from the roadway. There were three sampling points at each sampling line, with a 3 to 4-metre space between them. The year-long measurements make up a number over 20.000. In Penza, the flow of traffic typically varies between 3 and 3943 cars per hour. When produced in significant amounts, heavy metal emissions from vehicles—exhaust emissions (Pb, Cu, Ni), particulate matter emissions (Cu, Ni, Zn), emissions from plastics and paint (Zn, Cd), and tirewear emissions (Zn)—accumulate in the roadside area, transform and further migrate along the food chains. All road categories show a significant elevation in the background and emission limit values for all heavy metals studied. The most dramatic rise was recorded for Cu and it was 5.09- to 19.11-fold. The concentration of Ni, Zn and Pb exceeds the acceptable rate 1.17- 8.79-fold. The concentration of carbon monoxide decreases with distance from the road. Street ranking by car hazard shows that all main urban streets with regulated traffic are category 1 hazard sources of emission, mainly due to lead compounds (%). Between spring and summer, the traffic flow increases 1.3- to 2-fold and the hazard category of roads rises (under 1.5-fold). Significant changes in the traffic infrastructure and vehicle replacement compensate for the negative impact of vehicles on air quality in Penza, which was initially caused by the increase in the number of vehicles on the road and by the subsequent overload of the transport network. The increase in the queue length and time did not entail the emission growth. On the contrary, since 2014, Penza has been showing a decreasing trend and since 2015, the total amount of emissions from motor vehicles has been remaining at a stabilized point.

Key words: Highways, heavy metals, exhausts, emission limit value.

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Introduction

Road transport in the Russian Federation, as well as throughout the world, continues to be one of the major air pollutants (Gariazzo et al., 2007; Buekers et al., 2014; Casals and García, 2015). In large cities, its contribution to total emissions can reach 90%.

Traffic jams on highways, accidents, pollution of the environment by transport bring annual losses, are estimated at trillions of dollars (Pataki et al., 2006). None of the measures taken practically did not have any significant effect on their decline. On the contrary, losses are only increasing, despite the increasing costs of road workers (Pismakov, 2017).

The main feature of industrial and transport impact on the environment is manifested in the formation of technogenic geochemical anomalies in various components of the urban landscape (Dzikuć and Adamczyk, 2015). Their contrast and spatial location depend on the combination of the functional structure of the city, determine the nature and degree of impact on the environment and landscape-geochemical conditions, differentiate this influence (Dzikuć, 2013).

Today, large cities are experiencing an increase in emissions of harmful substances into the atmosphere (King et al., 2014). The reasons for this are various: violation of design technological regimes, obsolescence of equipment, and an increase in the volume of road transport. Therefore, despite the significant decline in production, which has been observed recently, the environmental problems associated with industrial pollution of the environment continue to remain quite acute.

The development of measures for the improvement of atmospheric air is impossible without a clear understanding of the spatial and temporal distribution of impurities. This issue is of particular importance for urbanized areas exposed to multicomponent and changing emissions, most of which are dispersed in the surface layer of the atmosphere (Dzikuć, 2015).

Asphalt concrete in pavement is exposed to: (a) mechanical static and dynamic loads causing normal compressive, tensile and tangential (shear) stresses in asphalt concrete; (b) high summer and low winter negative temperatures; (c) water and liquid corrosive media; (d) variable moisture - drying and freezing - thawing; and (e) solar irradiation and solar radiation, light, heat and oxygen.

Many of these factors act simultaneously (Pataki et al., 2006). The unfavourable combination of them leads to many types of destruction of asphalt concrete. The combination of multiple loads and high summer temperatures (in countries with hot climates, where the road surface can heat up to +55 °C) converts the bituminous binder in the composition of asphalt from a solid to a viscous-plastic state. In hot seasons, asphalt concrete with excessive bitumen and low residual porosity may form oily stains, as bitumen increases in volume and is squeezed to the surface with increasing temperature, which leads to the development of plastic deformation on this site and the risk of traffic accidents surfaces in places of "sweating" of bitumen.

Aging processes lead to the transition of oils into resins, and resins into asphaltenes, which results in an increase in the hardness of bitumen (its penetration increases) up to a brittle state and a decrease in its deformability over time. In this study, a comprehensive account was taken of emissions of heavy metals, as well as evaporation of binding hydrocarbons from asphalt concrete (due to a local temperature increase in the case of heavy traffic, due to local abrasion, etc.), also from lubricants that did not form in cold seasons would vapour.

Materials and Methods

This study has been conducted for two years (2014 and 2015) during the summer (June to August). In the course of conducting research related to the assessment of the state of the atmospheric air of the city of Penza, areas and zones were identified that contribute to the movement and redistribution of air mass:

- The main air passage zone: the main highways of the city are attributed to, which cross the territory, both in the latitudinal and in the meridian direction. The air mass transports harmful substances (including emissions containing heavy metals) outside the city limits, helping to cleanse impurities; a so-called circulation type of movement is created.
- Most of the city is occupied by wind corridors. All highways are related to them when orienteering on the terrain in the latitudinal direction. Such zones contribute to the free movement and redistribution of wind flow through the territory; this is the so-called citywide type of movement. Street canyons—areas with buildings built along street highways—the so-called inner urban type of movement.
- According to the intensity of the movement the following features are highlighted: the maximum congestion of roads is observed in the morning and evening hours. The number of cars is growing in the morning when driving from the residential zone

to the central part of the city and in the evening in the opposite direction.

Sampling to determine the effect of distance from the road and the amount of emissions was made on both sides of the road at a distance of 10, 20, 30, 40, 50 and 60 m from the roadway. At each of the distances, three sampling points were determined, located at a distance of 3–4 m between them. The samples were subjected to qualitative (on the composition of chemical compounds) and quantitative (content of each of the substances, 100% – all substances in the sample, % – the proportion of a particular substance) analysis in laboratory conditions. The analyses were carried out on the basis of the Laboratory of Analytical Chemistry of the Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences.

There are several automatic pollution control stations in Penza, which are located near highways and meet the stated requirements. Data on the content of pollutants in the air are recorded year-round, usually every twenty seconds. The total number of measurements during the year exceeds 20,000. At the same time, the station records the concentrations of various chemical compounds, including heavy metals, in the form of specific values, in different columns of the text file. The file data is then available to statistical processing for any desired time interval. The summer period was chosen because at this time, due to the high positive rates of air temperature and heated asphalt cloth, the maximum emission of harmful substances contained in motor vehicle exhausts and in the melting roadway occurs. Moreover, the difference in temperature between the roadbed and the air can be very significant (up to +20 °C), which ensures the formation of air flow and separation to the side of the road chemical compounds, including heavy metals. At the same time, for comparative analysis, data from other seasons of the year were used.

The intensity of traffic on the roads of the city is very diverse. Depending on the measured average intensity of the movement of vehicles, all the runs in the city of Penza can be divided into five categories (Table 1).

Most of the hauls in the territory of the city of Penza belong to V, IV, and III categories, i.e. to hauls with extremely low, low and moderate traffic intensity. They account for about 84% of the total number of hauls. These sections are usually located within the regions and as part of the transport flows passing through them, there are no transit vehicles. Only 16% are hauls with high and extremely high traffic, which represent the greatest risk to the environment. These sections belong to the roads of republican and regional significance; in addition, the streets consisting of sections I and II are located in the industrial and administrative districts and the city centre. Sampling was also carried out directly from the road bed, in particular in places where bitumen spots appear in the summer under the influence of high temperatures. Subsequently, samples were analyzed for the qualitative composition of substances.

Results

Emission of gases and other substances were contained in the exhaust gases of motor vehicles on the city roads of Penza. For the city of Penza, the intensity of motor vehicles varies from 3 to 3943 cars/h, depending on the location and destination of the stretches that make up the city's motorway. On a significant part of the hauls, the traffic intensity was up to 1294 cars/h and only for 1/6 of all the hauls was noted a high and extremely high traffic intensity with variation from 1311 to 3943 cars/h.

Significant emissions of HM (heavy metals) from vehicles [Pb, Cu, Ni (exhaust gases); Cu, Ni, Zn (particles of abrasive parts of machines); Zn, Cd (plastics and paint); Zn (tires)] in the soil, lead to their accumulation in the roadside zone, transformation and further migration along food chains.

For all categories of hauls, a significant excess of background values and TLV (The Threshold Limit Value) of the mobile form was established for all studied HMs (Table 2).

The highest TLV excess was recorded for Cu and it was 5.09–19.11 times. The concentration of Ni, Zn and Pb exceeds the permissible rate of 1.17–8.79 times. The

Table 1: Classification of hauls of Penza

Haul category	*The name of the haul intensity*	*Number of cars/hour*	*Number of hauls*
V	Extremely low	<50	2087
IV	Low	50-500	1871
III	Moderate	500-1300	1348
II	High	1300-2500	976
I	Extremely high	2500-4000	42

Table 2: The content of the mobile form of HM in the upper layer of the soil ground of the roadside zones (mg/kg)

Categories of hauls		*I*	*II*	*III*	*IV*	*V*	*Bc.*	*TLV*
Cu	B	239 ± 4	181 ± 3	166 ± 3	97 ± 2	77 ± 2	15–20	3
	M	57 ± 1	41 ± 1	35 ± 1	20 ± 2	15 ± 1		
	Cc	11.97	9.06	8.33	4.86	3.89		
Zn	B	519 ± 5	391 ± 4	349 ± 5	289 ± 4	276 ± 4	18–30	23
	M	136 ± 3	95 ± 2	79 ± 3	62 ± 3	61 ± 3		
	Cc	17.34	13.02	11.66	9.46	9.12		
Ni	B	135 ± 5	105 ± 5	82 ± 3	54 ± 4	23 ± 1	12–20	4
	M	35 ± 1	26 ± 1	20 ± 2	12 ± 1	5 ± 1		
	Cc	6.75	5.25	4.13	2.71	1.17		
Cd	B	4 ± 0.6	3 ± 0.4	2.5 ± 0.6	2 ± 0.4	1 ± 0.3	3–5	0.5
	M	1.3 ± 0.3	0.8 ± 0.2	0.5 ± 0.2	0.4 ± 0.2	0.2 ± 0.1		
	Cc	1.56	0.9	0.89	0.88	0.35		
Pb	B	65 ± 2	61 ± 1	52 ± 1	36 ± 1	27 ± 1	10–15	6
	M	20 ± 1	17 ± 1	14 ± 1	9 ± 1	6 ± 1		
	Cc	5.42	5.05	4.35	2.96	2.25		
Zc	39.04	29.28	25.36	16.87	12.78			

Notes: B – bulk form of HM; M – mobile form of HM; Cc – coefficient of HM concentration; T – a total indicator of HM concentration, Bc - background content of HM.

maximum permissible concentration of Cd on sections with high and extremely high traffic is 1.38–2.46 times. On the runs with the intensity of the movement of vehicles less than 1300 cars/h, the excess of the TLV of the mobile form for Cd was not recorded.

In accordance with SanR&R (Sanitary rules and regulations) 2.1.7.1287–03, for all the studied HMs, the soil contamination of the roadside zones refers to a moderate level of pollution. The only exception was the stage Dimitrovgrad highway at the entrance to the bridge over the river Penza. Gas stations are located on both sides of this haul, along the roadway there are sedimentation tanks for trucks, which are not allowed into the territory of the central part of the city during the daytime due to the high workload of highways and the high level of air pollution in the city. This transport stage is characterized by one of the highest values of the intensity of the movement of vehicles, which at peak hours reaches 3943 cars/h.

Because of the low capacity of the bridge to handle the traffic flow over the river in Penza, the traffic jams on the bridge are an ongoing issue. All these factors contribute to an increase in the man-made load on this stretch and lead to additional pollution on this section of the highway. This haul on pollution Cd refers to the average level of pollution.

In accordance with the indicative scale of the danger of soil contamination, runs with a traffic intensity of more than 1500 cars/h are classified as hazardous (32 < Z s < 128), moderately hazardous can be referred to as a stretch with an intensity of more than 180 cars/h, movements are characterized by an acceptable level of pollution (Zc < 16).

It is reliably established that the concentration of HM in the soil of the roadside zones depends on the category of the haul, i.e. on the intensity of the movement of vehicles. Conducting univariate analysis of variance made it possible to establish that the content of HM in the upper layer of soil and roadside zones depends on the season of the year.

The maximum values of concentrations for all HM are observed in the spring, which is explained by the increased mobility of HM in the upper soil layer due to a greater decrease in pH values. In the summer season, the content of HM is reduced due to their active absorption by plants and a slight decrease in anthropogenic load from the road geotechnical system. By the autumn, the concentration values of the mobile HM form increase again due to secondary pollution of the upper soil layer of the HM soil contained in leaf litter, changes in acidity due to precipitation in the form of rain and sleet, and an increase in the intensity of motor vehicles.

One of the most dangerous HM is Cd. Before deciding to prohibit the use of Cd in the production of tires, it got into the soil of roadside areas at their abrasion. Currently, Cd is not used for tire vulcanization, but the environmental situation for this metal in the city of Penza is still quite tense.

Despite the fact that Ni, Cu and Zn are contained in vehicle emissions in minimal quantities and their bulk enters the roadside ecosystem as a result of tire abrasion and wear and tear of various parts, it is their share of the main contribution to changes in the geochemical composition of the upper roadside soil layer zones.

A slight excess of TLVPb is associated with the ban on the use of leaded gasoline since the late 90s, which largely improved the ecological situation. A positive correlation was found between the concentration of HM in the soil of the roadside zones and the category of the transport stage, i.e. the intensity of the movement of vehicles and the mass emission of pollutants.

All other conditions being equal, the HM content in the soil depends on the magnitude of the technogenic load on the study area, the pH of the medium, the carbon content in it, and these characteristics, as was shown earlier, are subject to seasonal changes. Therefore, in the course of the study it was suggested that the concentrations of HM in the upper soil layer are also subject to seasonal variation. A comparative analysis of soil samples in different seasons of the year showed that the content of HM in the upper layer of the ground of the roadside zones is not the same and varies throughout the year (Figure 1).

The following relationship was found in the content of mobile forms of HM in the soil of roadside zones. The maximum concentration values for all HM are observed in the spring, which is explained by the increased mobility of the HM in the upper soil layer due to the high carbon content and lower pH values, caused by increased humidity during this period of the year. In the summer season, the content of HM is reduced due to their active absorption by plants and a slight decrease in anthropogenic load from the road geotechnical system.

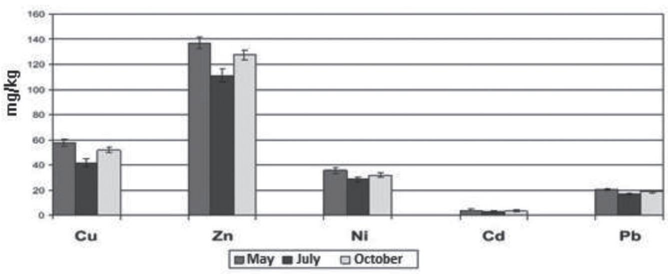

Figure 1: Dynamics of HM content by seasons.

By the autumn, the concentration values of the mobile form of HM increase again. The reasons for the increase in the content of HM are secondary pollution of the upper layer of HM soil, contained in leaf litter; changes in soil pH values due to precipitation in the form of rain and sleet characteristic of this period; and some increase in carbon content in the soil.

In addition, the reason for the increase in the content of HM in the soil and ground of the roadside zones is an increase in the intensity of traffic flows on the roads of the city of Penza in the autumn period. In the upper layer of soil, HM not only accumulates, having a negative impact on the growth and further development of vegetation, but also migrate, polluting large areas. For an objective assessment of contamination of the upper layer of soil, it is necessary not only to determine the total content of HM, but also to study the patterns of distribution of HM in the soil with distance from the source of pollution.

Sampling and analysis of soil samples at various distances from the road revealed some patterns in the migration of HM. It was found that the urban development of Penza are characterized by three options for the spread of HM with distance from the roadway (Figure 2).

The distribution of HM in variant I is typical for most of the city. In this embodiment, the direction and speed of the wind play a significant role in the spread of HM. Most of the pollutants from the road geotechnical system accumulate in the prevailing wind direction at a distance of 5–10 m from the edge of the road. The width of the roadway of these traffic sections varies from 8 to 15 m, which provides sufficient throughput, and the formation of congestion on them occurs only in certain areas at “peak hours”. Green plantings along them consist of trees aged 30–50 years, located at a distance of 3-4 m from each other. Mostly green spaces are completely absent.

Such conditions in the complex lead to the fact that a part of pollutants is delayed by green plantings at a distance of 1–5 m from the roadway, and the rest is freely distributed along the roadside zone. Urban development, located in these areas of the city at a distance of 40–80 m from the roads, is the second obstacle to the spread of HM in the urban area. At a distance of 50 m, there is a slight increase in the content of HM in the soil.

The central variant of the city is characterized by the second variant of the distribution of HM from a source of pollution. In contrast to variant I, HM accumulation in the upper layer of the soil does not depend on the

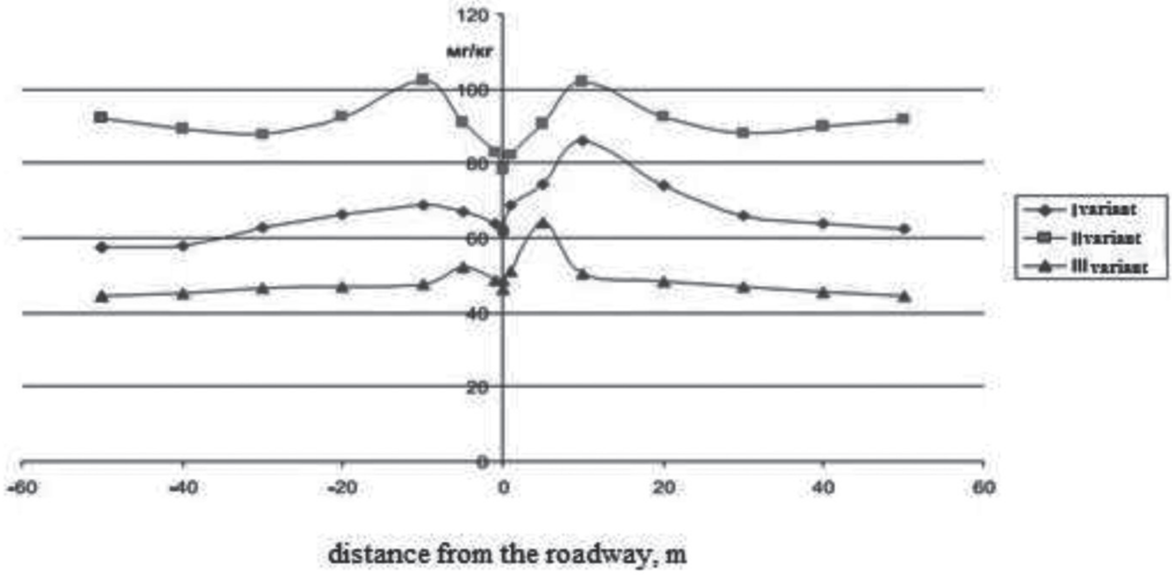

Figure 2: Options for the spread of HM from the road, taking into account urban development.

wind direction, the concentration of the studied HM increases 1.2–1.6 times and at a distance of 40 m there is a repeated significant increase in their content.

All these features in the distribution of HM are associated with the peculiarity of urban development (located at a distance of 1–20 m from the roadway) and the almost complete absence of green spaces along them. In addition, the width of the roadway is 5–10 m, which at high traffic intensity causes traffic jams on highways in the city centre.

In the area of the city, HM is distributed according to III variant, which differs significantly from the previous ones. Residential development in this area is located at a distance of 80–150 m from the road, the width of the roadway varies from 10 to 25 m, which increases the capacity of the roads and prevents them from forming traffic jams. Broad avenues and a rectangular scheme of the street-road network contribute to the free movement of air masses, which contributes to reducing the content of pollutants from vehicle emissions. Green areas along the main highways consist of tree and shrub vegetation, which is 10–30 years old, and the plants are planted fairly closely to each other, forming a protective barrier. As a result, there is a shift in the peak of accumulation of HM directly to the roadway, reducing the overall pollution of the roadside.

Effect of Various Gases and Non-volatile Substances on Public Health

The accumulation of gaseous impurities contribute to narrow streets and lanes. Such town-planning features are typical for central regions, mainly with low-rise buildings. The results obtained by computational and experimental methods for different distances from the roadway showed that the concentration of carbon monoxide decreases with increasing distance. This decrease is especially marked in the depth of residential development (Figure 3).

Residents of the first floors of residential buildings, which are influenced by negative factors from traffic flows, are at particular risk. Our data have convincingly shown that the main danger to human health and the environment is not the melting of bitumen on the asphalt road, but the emissions from road transport, including HM. There are a number of ways to reduce emissions. One of them, which is used in EU countries and in the USA, Japan, is an increase in the number of electric vehicles and a gradual replacement of the fleet (Buekers et al., 2014; Cucchiella et al., 2017). Another way is to reduce the number of cars older than 10 years and optimize the fleet with new cars, with gasoline or gas engines of a new generation, producing several times less emissions (Casals and García, 2015; Crippa et al., 2016). Optimization can also be achieved through the use of high-quality gasoline, with a high octane rating and lower lead content. These methods are widely used in the EU, in particular in Poland (Dzikuć and Adamczyk, 2015). The concentration of HM and other harmful substances in vehicle exhaust has a peak in the summer, as shown by the example of Arizona, USA (Georgescu et al., 2013). Therefore, this issue is very relevant, especially in terms of studying HM emissions in motor vehicle emissions in various countries of the world. Recently, mathematical modelling of pollution

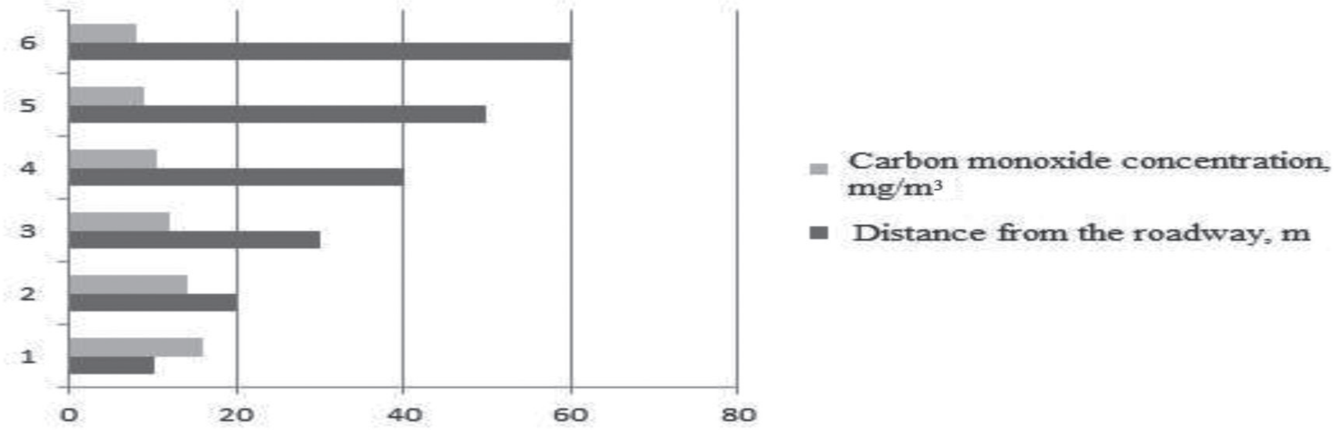

Figure 3: The concentration of carbon monoxide at different distances from the road.

processes and comparison of actual results with theoretical ones has become widespread (Gariazzo et al., 2007).

The ranking of the streets, conducted according to the category of danger of the car, showed that all main streets of citywide significance (MCS) with adjustable traffic belong to emission sources of the first hazard category, the main contribution to this value comes from lead compounds (%). Traffic intensity on such streets is equal to or exceeds 1000 cars/hour. The main streets of district significance (MDS) with traffic intensity above 1000 cars/hour also belong to the sources of emissions of the first danger category. Streets with lower traffic are classified as emission sources of the third hazard category. Local streets with asphalt pavement, located in the central part of the city, depending on traffic intensity, are sources of emissions of the second hazard category. Local streets with temporary coverage (LSTC) belong to the emission sources of the fourth hazard category. As can be seen from the data in the tables, in the spring-summer period, with an increase in the intensity of traffic flow 1.3-2 times their danger category increases (up to 1.5 times).

Human health is determined by the interaction of a number of factors (Georgescu et al., 2013): environmental quality, lifestyle, heredity, bad habits, socio-economic and psychological well-being, and access to medical care. In the structure of factors that form a risk to health, the first place is occupied by air (66.7%), the second by food products (13.5%) and the third by noise load (12.6%) (Crippa et al., 2016; Cucchiella et al., 2017). The most significant object for a person is the atmospheric air of populated areas, its qualitative composition. For example, at least 10 million tons of emissions of chemicals in the structure of which the largest proportion are: sulfur dioxide (up to 35%), carbon monoxide (up to 30%), hydrocarbons (1.2%), and nitrogen oxides enter the atmosphere of Ukraine annually (1%) and up to 2% of specific pollutants (Pismakov, 2017). HMs are categorized as specific substances and their influence is thus local and manifests itself in soil pollution and direct effects on biota within 50-100 m from the roadway, depending on its thickness, expressed in the number of cars per unit of time. These data are confirmed by our research, which showed the width of the HM contamination band.

One of the negative manifestations of the influence of harmful environmental factors on human health is the growth of autoimmune diseases, including skin diseases. According to WHO, currently 2/3 of all people suffer from skin diseases, including those of an allergic nature, due to the effect of various environmental factors (Ahlstroma and Kirchera, 2017).

Carbon monoxide is one of the most common anthropogenic pollutants of the air basin (hazard class 4) (Kotthaus and Grimmond, 2018). In the cities, the main sources of this pollutant in the air are motor vehicles, thermal power facilities and industry.

The accumulation of carbon oxides in the air leads to dysfunction of the surfactant in the lungs, enzymes in the tissues of the respiratory organs (Aggarwal and Jain, 2016). This leads to lipid oxidation, the formation of free radicals (National Center for Emission Management, 2017). Thus, the functions of cell membranes and their receptor proteins are disturbed, accumulation of various endogenous toxins occurs, autoallergic states develop (bronchial asthma, respiratory allergies) (Ioanans and Amelitta, 2015; Björkegren and Grimmond, 2018).

With regard to the effect on human health of non-volatile substances released during the melting of bitumen on asphalt cloth, as a result of laboratory studies performed by the Center for International Cancer Research under the auspices of the World Health Organization, it was concluded that bitumen (group 3) is not carcinogenic to humans; extracts, steam cracking and oxidized bitumens (group 2) may be carcinogenic to humans; and coal tar (group 1) is dangerously human carcinogenic (Burchart-Korol et al., 2016).

Recommendations

To compare the ratios of concentrations of any substances in the atmosphere in the main areas and the ratios of emissions of these substances by motor transport, several conditions must be met, namely:

- The presence of reliable and long-term series of observations of concentrations in the air of compared pairs of substances; this condition seems mandatory, according to some authors (Kotthaus and Grimmond, 2018).
- Knowledge of the values of the background concentrations of these substances characteristic of the city.
- Confidence in the fact that it is motor vehicle emissions that form concentrations of the substances in question in the air in the main areas.

It is known (Zaitsev and Kulagin, 2005; Giniyatullin et al., 2018; Urazgil'din et al., 2018) that conifers of woody plants are sufficiently resistant to the action of toxicants (including heavy metals). Therefore, the creation along protective highways of trees with coniferous trees helps reduce the impact of motor vehicle emissions on adjacent territories and prevent heavy metals from entering along with residential areas.

Conclusions

The calculations confirm that significant changes in the structure of traffic flows according to environmental classes of cars, a significant rejuvenation of the car park compensated for the negative impact of vehicles on air quality in Penza, caused by the increase in the number of the fleet and the overload of the city's transport network. The increase in the length and duration of traffic congestion has not led to an increase in emissions of harmful substances in the atmosphere. On the contrary, since 2014 Penza has a tendency to decrease, and since 2015 - to stabilize the total amount of emissions of these substances by motor transport.

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Calendar of Events

International Conference on Sustainable Water Treatment Technologies and Environment
14th to 16th October 2019
BouIsmail, Tipaza, Algeria
Website: http://udes.cder.dz/sustwater2019/index.html
Contact person: Mohamed Abbas
Organized by: Unite de Developpement des Equipements Solaires

The 2nd International Symposium on Water Pollution and Treatment
17th and 18th October 2019
Bangkok, Thailand
Website: http://www.iswpt.org
Contact person: Lisa

International Conference on Resources and Environmental Research (ICRER 2019)
25th to 27th October 2019
Qingdao, China
Website: http://www.icrer18.org/
Contact person: Ms Emma Chen
Organized by: ICRER

Challenges in Environmental Science and Engineering (CESE-2019)
3rd to 7th November 2019
Kaohsiung, Taiwan
Website: http://cese-conference.org/T2.htm
Contact person: Dr. Li Shu
Organized by: CESE 2019

4th Asia Conference on Environment and Sustainable Development (ACESD 2019)
9th to 11th November 2019
Yokohama, Japan
Website: http://www.acesd.org/
Contact person: Nancy Liu
Organized by: Yokohama National University

17th JOHANNESBURG International Conference on Science, Engineering, Technology and Waste Management (SETWM-19)
18th to 19th November 2019
Johannesburg, South Africa
Website: https://www.earet.org/conference.php?slug=SETWM-19&sid=1&catDid=167
Contact person: Prof. Frans Waanders Pr Eng. Pr Sci. Nat and Prof. Dr. Elvis Fosso-Kankeu
Organized by: North West University (NWU), Potchefstroom, South Africa and EAP

Small Water and Wastewater Conference 2019
1st to 5th December 2019
Perth, WA, Australia
Website: http://www.swws2019.com
Contact person: David Goodfield
Organized by: Murdoch University

4th International Conference on Water Pollution Control Engineering
5th to 7th December 2019
Xiamen, China
Website: http://www.wpce.org/
Contact person: Ms. Coral Lu
Organized by: APISE