Modern Applied Science; Vol. 9, No. 4; 2015
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

Pollution of the Air Basin in the Cities by Motor Transport and the Industrial Enterprises, Quality Assessment of Atmospheric Air with the Use of Calculation Methods and Instrumental Control

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Received: October 30, 2014 Accepted: November 6, 2014 Online Published: December 10, 2014

doi:10.5539/mas.v9n4p12 URL: http://dx.doi.org/10.5539/mas.v9n4p12

Abstract

Within this work, field observations of structure and intensity of motor transport streams were conducted, the information about the operating sources of atmosphere pollution from the enterprises in the city of Naberezhnye Chelny, their qualitative and quantitative structure, physical parameters were collected, processed and systematized. On the basis of the obtained data a summary calculation of emissions of the industrial enterprises and motor transport was carried out, the list of the priority polluting substances was defined, the complex index of pollution of the atmosphere was calculated, highways with the greatest transport loading were defined. On the basis of instrumental control the measurements of quality of atmospheric air near highways were carried out, actions for optimization of transport streams and decrease in negative impact were offered.

Keywords: atmospheric air, the polluting substances, dispersion calculation, permissible exposure limit, cards of dispersion, stationary sources, and mobile sources

1. Introduction

Nowadays the problem of studying of ecological state of the cities gains the increasing concern. Actuality of this kind of research is dictated by a need of protection and rational use of environment and preservation of a favorable ecological situation. Industrial production having concentrated enormous stocks of different types of energy, harmful substances and materials, became a constant source of technogenic danger. Except stationary sources, the big loss to environmental state is caused by emissions of the motor transport.

Continuous growth of automobilization and number of industrial facilities is followed by a number of the negative phenomena among which it should be noted, first of all, an excessive congestion in the atmosphere of various gas and dustlike pollution that brings in the industrial cities irreversible destructions of a surrounding landscape and the biosphere in general. So, in the cities with the developed industry the share of a contribution of automobile exhaust gases makes about 50-70% of cumulative emissions of the polluting substances. At the same time, if emissions of the industrial enterprises are the subject to rationing, the organization of transport streams is generally reduced providing the greatest capacity of the city highways and thus the set of ecological factors aren't considered.

The situation connected with pollution of the air basin in the cities by emissions of motor transport is aggravated with conditions of aeration of the occupied places which define the process of dispersion of impurity, significantly different from dispersion of emissions of stationary sources. Emission of harmful substances from motor transport in the lower layer of the atmosphere causes the high level of their ground concentration: the maximum content of emissions is fixed at the height of 50-200 cm from an earth's surface that means it is in a zone of a person's breath. The level of concentration of nitrogen oxides, carbon and other harmful ingredients in the streets of the Russian cities at 10-20 times exceeds maximum concentration limit (Milyaev, et al., 2010; Europe's polluters, 1989; Review of National Strategies, 1990).

Naberezhnye Chelny is the largest city of the Zakamsky region of the Republic of Tatarstan where more than half a million people live. The city is characterized by a high level of industrial development and transport networks. Nowadays there is generally a rectangular grid of the streets in the city. The heaviest traffic of

transport is carried out on the main highways of the city: Naberezhnochelninsky Ave., Musa Dzhalil Ave., Mira Ave., Highway No. 1, Sarmanovsky path, Hassan Tufan Ave. Vakhitov Ave., Academician Korolev St.

The specified main streets pass through all the city and connect the city center with residential areas of the city and an industrial zone, thereby carrying out functions of intercity distribution of streams of mass passenger and freight vehicles, service the nearby areas and deliver workers to their work places.

Total length of a street road network with dark-coloured pavement of Naberezhnye Chelny makes 568 km, the extent of the main streets of the city and a regional value makes 358 km.

Construction and design of the existing system of transport infrastructure of Naberezhnye Chelny were put in the 80th. Taking into account the development of the city, with the increase of amount of the manufacturing sites and growth of the motor transport the existing street road network gradually started glitching; as a result, the capacity of roads worsened that in its turn led to emergence of jams in rush hours.

2. Method

2.1 Calculation Methods

To estimate air pollution of the city the information about the operating sources of atmosphere pollution, their physical parameters and volumes of issue, qualitative and quantitative structure of the thrown-out polluting substances provided by the enterprises of the city was collected, processed and systematized (Suleimanov, 2013; Khabibullin, et al., 2013; Khabibullin, et al, 2014).

The research was made over those characteristics of a moving transport stream on highways; the protocol of inspection of structure and intensity of a moving motor transport stream of highways for each site of the thoroughfare was made. Measurements of intensity of automobile streams at each intersection were carried out in six and eight directions of the roads, at different daytime (7:00; 12:00; 16:30). The received results were fixed in the field note.

On the basis of the obtained information and with the use of the unified program of calculation of dispersion of the polluting substances the calculations of distribution air pollution were carried out.

On the basis of the analysis of dispersion results, 5 priority polluting substances are defined: manganese and its connections, carbon oxide, nitrogen dioxide, xylol, mineral petrolic oil. The calculated complex index of atmosphere pollution is determined by these substances. The calculated complex index of atmosphere pollution is determined by the following formula:

$$CCIAP_5 = \sum_{i=1}^{5} \left(Cc / MAC \right)^{\beta_i}$$

where i – impurity;

β_i – a constant for various classes of danger on reduction to the degree of dioxide sulfur harm;

C_c – calculated concentration of i-impurity.

Table 1. The level of air pollution which depends on levels of the air quality indicators

level of air pollution	$CCIAP_5$
low	0–4
rather high	5–6
high	7–13
very high	≥14

2.2 Instrumental Methods

According to studies of the scheme of a street road network of Naberezhnye Chelny, and also due to the information on transport loading of highways, according to the analysis about the purpose of roads were chosen 5 areas for carrying out tool measurements of air pollution within a sanitary rupture of highways.

Tool measurements of the content of the polluting substances in atmospheric air within a sanitary rupture of highways of Naberezhnye Chelny are executed. Measurements are taken for 5 chosen roads (Table 1) at various traffic intensity, not less than 30 times on each highway on the following substances: oxide carbon, nitrogen

oxide, nitrogen dioxide, sulfur dioxide, ammonia, and the weighed substances.

Sampling of air was carried out according to environment indices standards 17 2.3.01-86, RD 52.04.186-89, and also according to the requirements described in measurement techniques of the chosen indicators (Table 2). In the course of measurement the carrying out sampling data given about terms were fixed.

Table 2. Methods of measurement performance

Name of substance	Method of measurement performance	Method
nitrogen dioxide	END F 13.1:2:3.19-98	ion chromatography
nitrogen oxide	END F 13.1:2:3.19-98	ion chromatography
ammonia	RD 52.04.186-89, art. 5.2.1.1	photometrical
suspended substances	RD 52.04.186-89, art. 5.2.6	gravimetric
sulfur dioxide	END F 13.1:2:3.19-98	ion chromatography
carbon monoxide	END F 13.1:2:3.27-99	gas chromatography

Devices and equipment for sampling and measurement of the maintenance of polluting substances:

1. PU-4E aspirator, No. 5162, certificate No. 5021020, good through 07.05.2014.

2. PU-4E aspirator, No. 3918, certificate No. 5021024 good through 07.05.2014.

3. Automatic sample container OP-422 TC, No. 266-4-02, certificate No. 5021030 good through 07.05.2014.

4. Automatic sample container OP-422 TC, No. 422-4-03, certificate No. 5021028 good through 07.05.2014.

5. Sampling device PU-3E, No. 1011, certificate No. 5020880, good through 07.05.2014.

6. Meteometer MES-2, No. 12532, certificate No. 5021665, good through 13.05.2014.

7. Mechanical stopwatch SOPPR-2a, No. 3006, certificate No. 5027491, good through 10.06.2014.

8. Electronic scales of high-class accuracy RV-512, No. 8727336958, certificate No. 9213356, good through 05.04.2014.

9. Electronic scales of high-class accuracy RV-214, № 131123/11040614, certificate No. 9213355, good through 05.04.2014.

10. The ionic chromatograph "Stayer" with the conductivity sensor, No. 0612, certificate No. 9216184, good through 06.06.2014.

11. Gas chromatograph "Kristallyuks-4000", No. 172, certificate No. 9112467, good through 15.06.2014.

12. Photometer photo-electric KFK-3-01, No. 0200259, certificate No. 9216188, good through 06.06.2014.

Tests of atmospheric air were selected in direct proximity to highways mainly in a lee side in the morning and evening rush hours.

The weighed substances were selected on AFA-VP filters using the sampling device PU-3E. Ammonia, sulfur dioxide, oxides of nitrogen was selected on absorbers by means of aspirators PU-4E, OP-422 TC followed by the research of samples in ALCI by means of ionic chromatography and photometry. Concentration of carbon monoxide was determined by means of gas chromatography with preliminary sampling in gas pipettes and special packages made from tedlar. Measurement of temperature, pressure, speed of a wind was carried out with the use of a meteometer "MES-2".

In each point at least 2 parallel tests were selected, thus, all 600 tests were selected, for the analysis of the polluting substances on ion chromatograph and a photometer 600 initial workers of solution and 300 single solutions were prepared, according to the analysis of tests on the content of carbon oxide were received and processed more than 300 chromatogramms.

3. Results

3.1 Evaluation of Traffic Flows

In order to estimate the atmospheric air of the city and define the places of the greatest concentration of the polluting substances according to the methods (Milyaev, et al., 2000; Recommendations, 2002; Settlement instructions (methods), 2008; Suleymanov, Mavrin, & Harlyamov, 2011a; Suleymanov, Mavrin, & Harlyamov, 2011b; Suleymanov, Mavrin, & Harlyamov, 2011c; Suleymanov, et al., 2013; Suleymanov, G., Mavrin, & Mavrin, V., 2014; Suleymanov, Mavrin, & Harlyamov, 2012; Suleymanov, Mavrin, & Makarova, 2013) calculations of emissions of mobile sources were made. At calculations were used the data obtained by the results of monitoring of structure and intensity of a transport stream on highways during 2013.

The analysis of these protocols of inspection of structure and intensity of transport streams on the main highways of Naberezhnye Chelny showed that on the city highways located in lands allotted for settlement, the main contribution to total intensity of the movement is made by cars (85-95%), the contribution of cargo transport doesn't exceed 3-4%.

For an industrial zone, roads of federal and republican value, it is the contribution of cargo transport to total intensity of the movement that can make 10-20% because of the purpose of these objects. Respectively, the contribution of automobile transport to total intensity of the movement makes 60-80%.

The analysis of the results of natural investigations of structure and intensity of a moving transport stream of Naberezhnye Chelny showed that the highways of the city are characterized by various loading that is the greatest intensity of the movement on various highways is observed at different day times.

For an industrial zone the greatest transport stream was observed from 6:30 till 8:00 o'clock and from 16:30 till 18:00, respectively, before work of the enterprises and after the termination of the working day, in the rest of the time loading of highways is insignificant. For the highways leading in an industrial zone (Vakhitovsky Avenue, Avtozavodskoy Avenue, Avenue of Druzhby narodov, Koroleva St.) the maximum stream is observed also in the same time.

The main thoroughfares of the city (Mira Avenue, Moskovsky Avenue, Naberezhnochelninsky Avenue, etc.) the greatest transport loading falls on day time and for the period from 17:00 till 18:30. For Kazansky Avenue, Mashinostroitelnaya St. and the Menzelinsky path (the highway of federal value M7 passing through the city and its industrial zone) are characterized by the day loading as at this period of time passes the main stream of in transit transport.

3.2 Calculation of the Dispersion of Pollutant Emissions

On the basis of the obtained data, the summary calculation of dispersion of 143 polluting substances including those that form 28 groups of a summation is executed. When performing calculations, influences of meteoconditions and a land relief of distribution of impurity were considered (Amann, et al., 2000 a; Gourbayet, et al., 2002; Gram, & Gronskey, 1980; Kajino, 2003; Klaassen, et al., 2004). The carried-out calculations allowed receiving a picture of distribution of the level of air pollution across all the territory of Naberezhnye Chelny. (In Figure 1 there is represented the card of nitrogen dioxide dispersion).

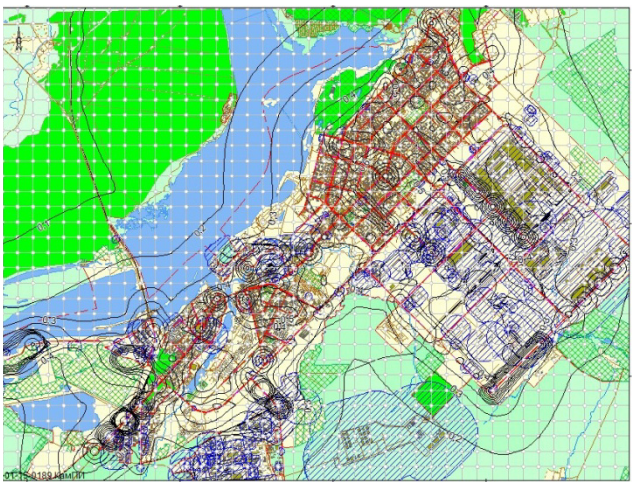

Figure 1. Card of nitrogen dioxide dispersion

Following the results of calculation of dispersion of the polluting substances, the excess of concentration of carbon oxide, dioxide of nitrogen and the groups of summation formed by these substances in a residential zone of the city is predicted. A zone of carbon oxide with the meanings of the maximum ground concentration more than 1 maximum concentration limit is observed along the large automobile highways and outcomes. Excess of maximum concentration limit of dioxide nitrogen is expected more than for 70% of the territory of Naberezhnye Chelny. For PS that are in emissions of the enterprises of the city, excess of maximum concentration limit on border with lands allotted for settlement isn't supposed. The greatest concentration in shares of maximum concentration limit are predicted on the following substances and groups of summation: manganese and its connections of 0.66 maximum concentration limits; I rubbed caustic of 0.6 maximum concentration limits; carbon (soot) of 0.31 maximum concentration limits; dimethylbenzene (xylol) of 0.7 maximum concentration limits; butane-1 of 0.35 maximum concentration limits; phenol of 0.26 maximum concentration limits; butyl acetate of 0.6 maximum concentration limits; acetone of 0.2 maximum concentration limits; trietanolamine of 0.22 maximum concentration limits; petroleum base mineral oil of 0.8 maximum concentration limits; solvent naphtha of 0.6 maximum concentration limits; abrasive dust of 0.2 maximum concentration limits; group of a summation 6015 (acetone, furfural, formaldehyde and phenol) of 0.55 maximum concentration limits; group of a summation 6017 (aerosols of pentoxide of vanadium and oxides of manganese) of 0.65 maximum concentration limits; group of a summation 6038 (sulphur dioxide and phenol) of 0.35 maximum concentration limits; group of a summation 6052 (acetic acid, phenol and ethyl acetate) of 0.3 maximum concentration limits.

3.3 Determining the Complex Index of Air Pollution

On the basis of the analysis of dispersion results were defined 5 priority polluting substances: manganese and its connections, carbon oxide, nitrogen dioxide, xylol, petroleum base mineral oil. The calculated complex index of the atmosphere pollution is determined by these substances. Spatial distribution of the calculated index of pollution of the atmosphere is shown in Figure 2.

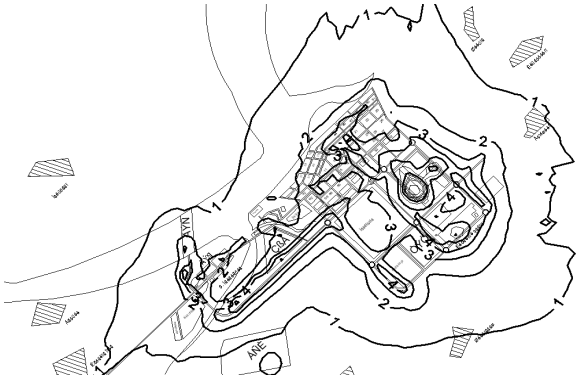

Figure 2. Card of spatial distribution of a calculated complex index of atmosphere pollution

Meanings of a calculated complex index of pollution of the atmosphere for 80% of the territory of a residential zone of the city are predicted within 4 (low level of pollution), for 20% – within 6 (high level of pollution).

High level of pollution of the atmosphere is predicted in the inhabited residential districts located in close proximity to an industrial zone and also in areas with high traffic intensity.

3.4 Assessment of Ambient Air Quality with the Use of Computational Methods

Five areas were chosen (Figure No. 3) for carrying out tool measurements of air pollution within a sanitary rupture of highways on the basis of studying of a street road network scheme of Naberezhnye Chelny, and also according the information on transport loading of highways, the analysis of purpose of roads. The list of roads includes:

1) Oryol ring (part of the federal highway M-7, point No. 1).

2) Naberezhnochelninsky Avenue (at Academician Korolev Street, a point No. 2).

3) Mira Avenue (at Vakhitov Avenue, a point No. 3).

4) Adel Cutuya Street (residential district Yashlek, point No. 4).

5) G. Tukaya Embankment (opposite to the house 10/64, a point No. 5)

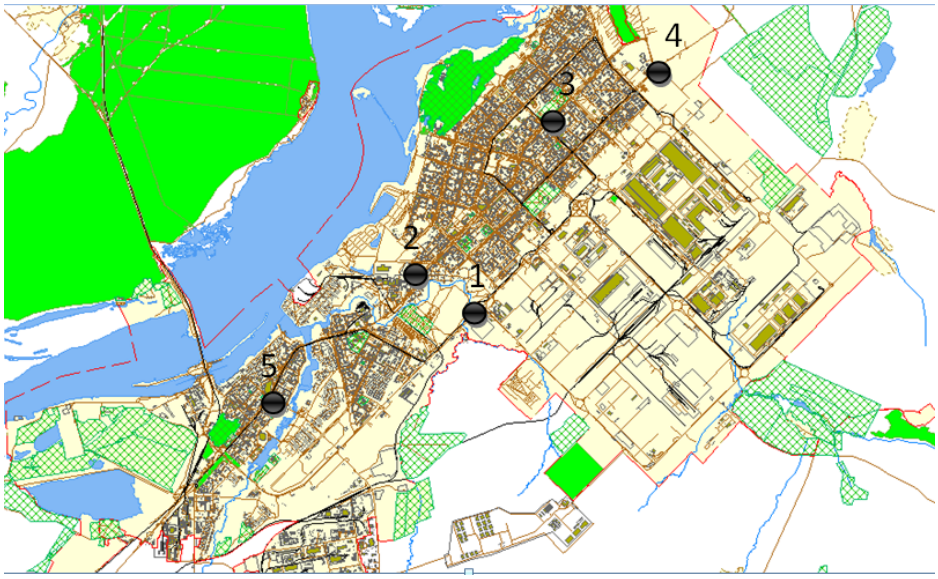

Figure 3. The plan of control points of atmospheric air arrangement in sanitary rupture limits of highways of Naberezhnye Chelny

Point No. 1. The Oryol ring is crossing of the federal highway M-7 and the city highway No. 1. Functional problems of the Oryol ring as traffic intersection are as follows: distribution of transport streams from the federal highway M-7 in the direction of the highway No. 1 and the federal highway M-7 and vice versa. In this regard, this area is characterized by the greatest intensity and a variety of transport streams which includes also transit transport. Also throughout all the route, since Nizhnekamsy hydroelectric power station and to the Oryol ring, in the adjacent territory there are gas stations, car washes, vehicle service station, parking for heavy trucks and trucks that create additional anthropogenic loading .

Point No. 2. Naberezhnochelninsky Avenue (at Academician Korolev Street) is the main transport corridor of the city, connecting old part of the city with the New city. This prospectus is characterized by the highest intensity of the movement of technical means, including passenger motor transport, also in rush hours this area is characterized by the traffic jams.

Point No. 3. Mira Avenue is the highway with the greatest intensity of the movement of passenger cars in the New city. First of all it is connected with the capital repairs which were carried out in 2010. The area of Mira Avenue at Vakhitov Avenue has two turns, because of the high intensity of traffic there can be traffic jams in rush hours.

Point No. 4. Adel Cutuya Street (the residential district Yashlek) is characterized as the area of the highway with the minimum intensity of car movement which generally consists of passenger cars.

Point No. 5. G. Tukaya Embankment (opposite to the house 10/64) is characterized as the area of the highway with average intensity of car movement which generally consists of passenger cars.

There were no cases of exceeding of maximum permissible concentration in atmospheric air according to the studied connections. According to the level of nitrogen dioxide, the average level of maximum permissible concentration coefficient for Oryol ring made 0.36, the maximum level – 0.68, the minimum level – 0.19; for Naberezhnochelninsky Avenue – an average – 0.19; the maximum – 0.39, minimum – 0.11; for Mira Avenue – 0.15, 0.23, 0.09; for Adel Cutuya St. – 0.10, 0.14, 0.06; for G. Tukaya Embankment – 0.09, 0.18, 0.07; the level of nitrogen oxide for the Oryol ring – 0.03, 0.05, 0.02; the level of ammonia for the Oryol ring – 0.20, 0.36, 0.08; for Naberezhnochelninsky Avenue – 0.11, 0.30, 0.06; for Mira Avenue – 0.11, 0.18, 0.06; for Adel Cutuya St. – 0.11, 0.19, 0.06; for G. Tukaya Embankment – 0.07, 0.16, 0.04; the level of the weighed substances for the Oryol ring – 0.28, 0.65, 0.11; for Naberezhnochelninsky Avenue – 0.17, 0.29, 0.06; for Mira Avenue – 0.16, 0.34, 0.08; for st. Adel Cutuya – 0.12, 0.31, 0.04; for G. Tukaya Embankment – 0.12, 0.49, 0.04; the level of sulfur dioxide for the Oryol ring – 0.04, 0.07, 0.02; the level of carbon oxide for the Oryol ring – 0.33, 0.71, 0.14; for Naberezhnochelninsky Avenue – 0.12, 0.26, 0.08; for Mira Avenue – 0.11, 0.16, 0.07; for Adel Cutuya St. – 0.04,

0.07, 0.03; for G. Tukaya Embankment – 0.04, 0.06, 0.02.

Also within this work there was made a comparison of the maximum settlement and measured concentration. On carbon oxide, nitrogen oxides and sulfur dioxide, the calculated levels of concentration are slightly higher measured by tool methods. This results from the fact that in calculations are taken characteristics that are the most adverse for dispersion of the polluting substances.

4. Discussion

Proceeding from the analysis of the results of inspection of highways of Naberezhnye Chelny, and also according to the results of calculation and tool measurements of air pollution it is possible to offer the following actions connected with the choice of the optimum town-planning decisions:

- Building of underground (elevated) subway to Musa Dzhalil Ave. in the area of bus stop "Avtostantion", on Naberezhnochelninsky Avenue in the area of bus stop "Chelnygorstroy" and of bus stop "Orlovka", on Chulman Ave. in the area of bus stop "Forest" and of bus stop "Park";

- Installation of traffic light regulation on crossings of Chulman Ave. and Hassan Tufan Ave., Chulman Ave. and Druzhby Narodov Ave.;

- Expansion and carrying out capital repairs of Chulman Ave., Syuyumbike Ave.;

- Carrying out of the highway of federal value abroad the settlement, bypassing Naberezhnye Chelny and construction of the roundabout highway of federal value;

- Construction of a piece of the municipal main street of the adjustable movement throughout Moskovsky Ave. and H. Taktash St. before crossing from Kazansky Ave. which will provide additional communication between residential areas of the city and will unload the movement of the main transport streams between "New" and "Old" parts of the city, on the only highway – to Naberezhno-Chelninsky Avenue;

- For the purpose of the cargo movement from external highways of Nizhnekamsk and Yelabuga towards an industrial area of JSC KAMAZ construction of the cargo highway going in parallel to a branch line, leading to the industrial area of JSC KAMAZ which units industrial regions of BSI and KAMAZ, and also has communications with the city main streets and roads.

5. Conclusion

Within this research data on the operating stationary sources of pollution of the atmosphere, their qualitative and quantitative characteristics, the actual emissions were collected and analyzed, and also natural investigations of structure and intensity of transport stream on the main highways of Naberezhnye Chelny were conducted.

On the basis of the obtained data for the first time for the city Naberezhnye Chelny were constructed and analyzed the summary calculation of dispersion of 143 polluting substances including entering into 28 groups of a summation, for each substance were made cards of distribution of level of air pollution all over the territory of the city.

According to the calculation results of dispersion of the polluting substances, there was made the forecast of concentration of PS in a residential zone of the city and were revealed the groups of summation for which the excess of maximum concentration limit is probable: oxide carbon, dioxide nitrogen and the summation formed by these substances of groups. For a zone of carbon oxide with the expected levels of the maximum ground concentration more than 1 maximum concentration limit are observed along large automobile highways and outcomes.

Following the results of the calculation analysis of dispersion of the polluting substances, 5 priority pollutants were defined and was calculated the complex index of atmosphere pollution. The levels of a calculated complex index of atmosphere pollution for 80% of the territory of a residential zone of the city are predicted within 4 (low level of pollution), for 20% – within 6 (high level of pollution). High level of atmosphere pollution is predicted in the inhabited residential districts located in close proximity to an industrial zone and also in areas with high traffic intensity.

According to a street road network scheme of Naberezhnye Chelny, and also according to the information on transport loading of highways, and the analysis of purpose of roads were chosen 5 areas for carrying out tool measurements of air pollution within a sanitary rupture of highways. Tests of atmospheric air were selected in close proximity to highways mainly in a lee-side in the morning and evening rush hours.

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