EFFECT OF ATMOSPHERIC TECHNOGENIC EMISSIONS ON HEALTH INDICATORS OF CHILD POPULATION

WPŁYW ATMOSFERYCZNYCH EMISJI TECHNOGENICZNYCH NA WSKAŹNIKI ZDROWIA WŚRÓD POPULACJI DZIECIĘCEJ

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ABSTRACT

Introduction: The identification of scientifically grounded dependency of the atmospheric pollution effect on the health level of the child population within particular area makes it possible to assess the degree of district environmental safety and provides the possibility for implementation of targeted programs and risk preventing strategies associated with atmospheric emissions.

The aim of the study is to assess the dependence of child morbidity rate development caused by atmospheric chemical pollution, which resulted from the stationary and mobile sources activity in terms of the Poltava region (Ukraine) as a model.

Materials and methods: Analysis of the general morbidity rate, respiratory diseases and congenital malformations rate was based on statistical data of the Poltava Regional Health Department, the assessment of air pollutant emissions level in cities and districts of the region over 2011-2015 years was performed using data provided by the Main Statistics Department of the Poltava region and the Department of Ecology and Natural Resources of the Poltava Region State Administration; the Microsoft Excel package with Pearson correlation coefficient and two-choice Student's t-test was used for the data analysis.

Results: According to the research data it was determined that each district had its own specific features in environmental hazards formation and common correlation pattern for all 25 administrative districts of the Poltava region was not specified. Ranking of regions by the level of pollutant emission effect on the child morbidity rate makes it possible to distinguish more dangerous ecological regions. Eight areas with significant and moderate relations between the child morbidity rate and air pollution caused by mobile sources and seven areas where air pollution was caused by stationary ones have been revealed. The main sources of air pollution are industrial emissions of the fuel and energy enterprises, manufacturing and extractive industries, vehicle and agriculture emissions. Kremenchuk and Horishni Plavhi cities include more significant factors in formation of child morbidity rate.

Conclusions: Considering identified factors and dependencies, the targeted regional program aimed at specification, elimination and prevention of the harmful environmental factor affecting children's health can be projected.

KEY WORDS: technogenic emissions, child morbidity, respiratory diseases in children, correlation dependence, ecological safety

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INTRODUCTION

The anthropogenic and technogenic load on the environment in Ukraine is several times higher than in the developed countries of the world. According to the strategy of the state environmental policy of Ukraine for the period until 2020, achieving a safe environment for the human health is an important task of the state. The assessment of the environmental factor effect on the population health, analysis and prediction for environmental risks are necessary components for the implementation of the Law of Ukraine «On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period until 2020» [1]. The World Health Organization (WHO) indicates the importance of air quality monitoring in terms of its effect on the population health, which provides reliable information, the basis for managerial decisions [2]. The air pollution indicator as a marker of progress for achieving the sustainable development goals in cities and energy sectors was proposed by the World Health Organization, while working on the document «Measuring the benefits for sustainable development and health» [3].

The identification of scientifically grounded relations and the effect intensity of the atmospheric pollution factor within the particular area on the health level of the child population enables to assess the degree of environmental safety of the region and provides the opportunity for implementation of the properly targeted programs and activity algorithms for the risk prevention associated with air emissions.

The data regarding the negative environmental pollution impact on the health indicators of child population are widely presented in world and domestic scientific literature. The various studies have determined that chemical pollution of the air causes the delayed effect onthe level of primary andgeneral child population morbidity as a whole. The development of bronchial asthma as well as acute respiratory pathology in children in relation to atmospheric air pollution has been proved [3-9].

According to the World Health Organization, the air pollution is one of the main environmental risk factors for pop-

ulation health. Dicrease in the air pollution level can provide the reduction of diseases development such as stroke, cardiac pathology, lung cancer, chronic and acute respiratory disorders, including asthma [3]. The correlation analysis of air pollution and medical data of the Rivne region used by the authors [6], have determined that the respiratory morbidity rate and mortality from these diseases can be considered as the indicative nosological units of the atmospheric quality. Some scientists [7] have stated that air pollution causes the delayed effect on the health condition of rural children in the Chernihiv region. The comprehensive assessment of the medico-ecological situation intensity for the Chernivtsi region was developed, including determined correlation dependencies of air pollution and health indicators [8]. The analysis of foreign scientific studies makes it possible to distinguish the presence of common problems. Thus, the effect of air pollution on respiratory diseases and bronchial asthma development in children has been proven [9, 10]. The positive correlation between the daily levels of air pollution markers and hospitalization of children with pneumonia has been determined on the basis of the meta-analysis [11]. However, it should be considered, that the lack of research studies in low and middle-income countries restricts the quantitative generalization, since the air pollution susceptibility may differ in these population groups. Previously, we have presented research studies on the role of air pollution in the respiratory pathology development in children [12-14]. The World Health Organization report [15] summarized the risk assessments and recommended the well-argued air quality standards for particulate matter, ozone, nitrogen dioxide, sulfur dioxide. However, it was noted that negative effects on the population health can occur at medium and even low concentrations of pollutants.

Considering the methodology for evaluation of the environmental effect on the population health, the indicative values (ecologically dependent) of high-grade pathologies are the most evident, which, primarily, include respiratory diseases in children [12]. The primary incidence rate – the level of newly registered diseases during the calendar year on the given territory was used for evaluation of the health level of the Poltava region population; all acute and first-diagnosed chronic diseases during the year were also included into the research. Knowledge on morbidity and its structure provides a powerful tool for protecting society and every individual from the unfavorable environmental factors effect. The highest incidence rates are registered among the child population, because the level of seeking for medical care decreases for various reasons with the age increase (lack of necessity for a sick leave, queues, consultations in private clinics), and consequently, the information value of such indicators decreases.

Therefore, the issue regarding the environmental factors effect on the general health condition of the children and identification of dependencies and interrelations between these factors at the regional level, including Ukraine in general and its individual regions, is urgent nowadays.

THE AIM

The aim of the study is the evaluation of the children morbidity rate development related to the air chemical pollution caused by the stationary and mobile sources in terms of the Poltava region of Ukraine as a model region.

The following main tasks for the goal achievement have been solved:

- analysis of the air emission dynamics caused by the stationary and mobile sources in cities and administrative districts of the Poltava region during 2011-2015 years;
- evaluation of the dynamics for the indicators of general child morbidity, respiratory diseases in children, the incidence of congenital malformations in the cities and regions of the Poltava region during 2011-2015 years as the indicative pathology in the assessment of the environmental condition;
- determining of the interrelations between emission values and child morbidity rate by Pearson correlation analysis method and Student's t-test;
- ranking of the administrative districts of the Poltava region based on the relation of the general morbidity and respiratory morbidity to the air emissions cased by the stationary and mobile sources according to the correlation nature;
- identification of the basic principles for development of the targeted regional program aimed at providing the ecological safety for the child population.

MATERIALS AND METHODS

The analysis of the general morbidity level, respiratory diseases and congenital malformations levels has been carried out according to the statistical data of the Poltava Regional Health Department; the level of air emissions in cities and districts of the region according to the data of the Main Statistics Department in the Poltava region and the Department of Ecology and Natural Resources of the Poltava Regional State Administration over the period 2011-2015 years has been assessed. The relation between the studied indicators has been analyzed by Microsoft Excel package and the correlation analysis has been performed using Pearson coefficient and Student's t-test [16, 17] to determine the development of primary child morbidity related to the level of air pollution in the Poltava region.

RESULTS AND DISCUSSION

The level of air pollution in the Poltava region is caused by the amount of pollutant emissions from the stationary and mobile sources. In 2015, the stationary sources produced 55.607 thousand tons of pollutants (without carbon dioxide emissions), which was 7.308 thousand tons or 11,6% less than in 2014. Among the stationary sources, the enterprises of Kremenchuk and Horishni Plavni are the main producers. Also, the regions with gas transmission enterprises localization are annually included into the list of the major producers of the air pollutants, namely, Lokhvytsia region (9,14% of the regional emissions), Hadiach region (5,9%), Zinkiv region (3,23%), Shyshaky region (3,21%) and Dykanka region

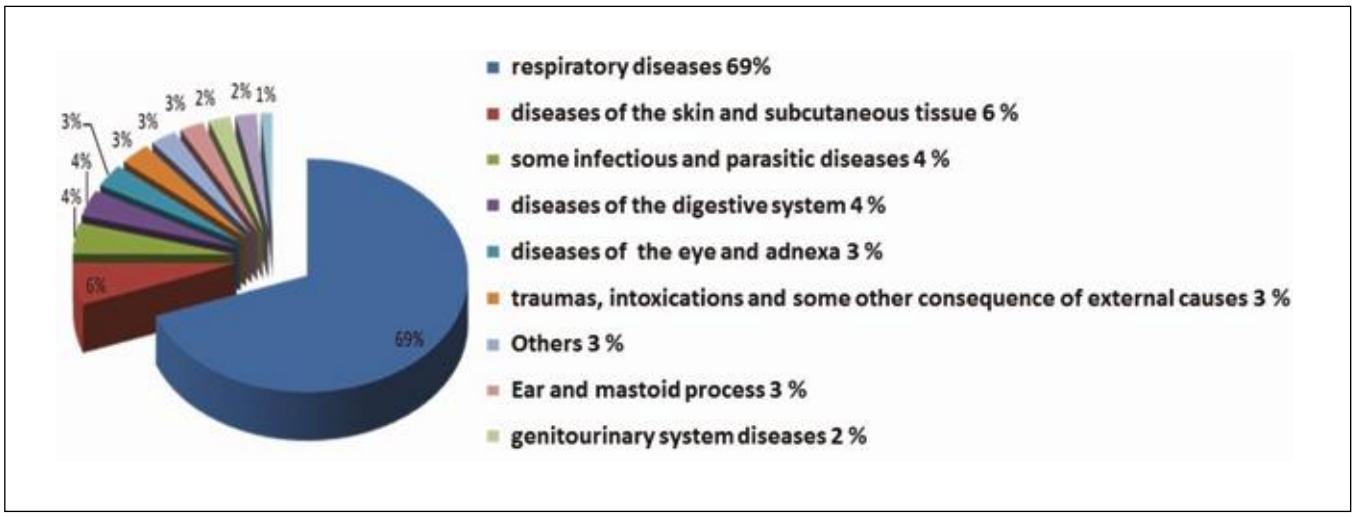

Fig. 1. Morbidity according to selected classes of the registered diseases in children aged 0-17 years in the Poltava region over 2011-2015 years

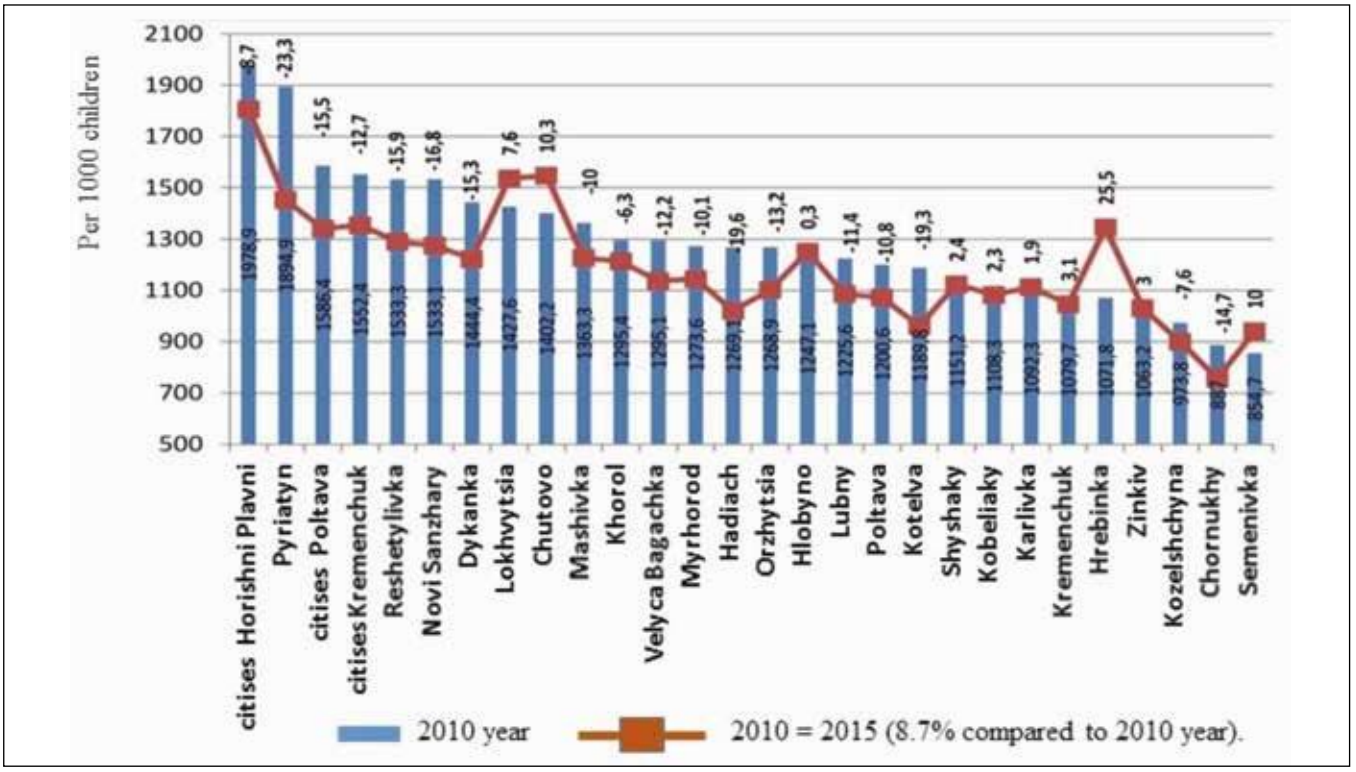

Fig. 2. Morbidity dynamics of children aged 0-17 years in the Poltava region over 2011-2015 years

(3,11%) [17]. The toxic effects of air pollutants due to combustion of fossil fuels caused by the mobile and stationary pollution sources are widely represented in the present day literature. The data regarding emissions resulted from the mobile and stationary pollution sources in the Poltava region have been analyzed in the research. Such pollutants included a number of heavy metals and their compounds (vanadium, iron, aluminum manganese), compounds of chlorine and fluorine.

The structure of morbidity in children aged 0-17 years in the Poltava region presented the significant prevalence of the respiratory diseases, which were ecologically dependent pathologies of the high degree (Fig. 1). More often, the primary incidence was registered in Horishni Plavni (Komsomolsk); the morbidity rate has increased in Lokhvytsia, Chutovo and Hrebinka districts (Fig. 2) for the last five years. Horishni Plavni, Lokhvytsia and Pyriatyn districts were registered as the regions with the high incidence of respiratory diseases for the last five years (1192,1, 1147,7, 1107,9 per 1000 corresponding population). Significantly increased (more than 25%) incidence of respiratory diseases was registered in children of Hrebinka and Semenivka districts (up to 858,0, 708,5 per 1000 population, correspondingly) [19].

Table I. Dynamics of the number of emissions and child morbidity in the administrative districts of the Poltava region

Administrative districts of the region	Δincr stat, t	Δincr mob, t	Δcon malf (per1000 individuals)	Δmob children (per 1000 individuals)	Δresp dis (per 1000 individuals)
Velyka Bahachka	-75,5	37,7	-0,6	-310,7	-191,8
Hadiach	-1153,4	-2191,8	1,3	-440,3	-313,8
Hlobyno	284,3	4,8	-0,6	-21,8	28,1
Hrebinka	123,2	-454,6	2,8	476,5	373,7
Dykanka	-2270,8	-249,6	-1	-506	-409,9
Zinkiv	-686,5	-318	-1,6	-102,5	-59
Karlivka	-228,7	-566,6	3	111,3	146,6
Kobeliaky	-17,5	-431	2,3	-35,2	13,7
Kozelshchyna	-17,8	-94,4	2,5	-173,5	-177,5
Kotelva	-113,6	-179,6	-1,3	-396,5	-297,3
Kremenchuk	-35,3	-61,1	1,1	-190,4	-198
Lokhvytsia	-2045,9	-688,8	-1,6	206,3	177,7
Lubny	2396,2	-469,7	-3,5	-179	-128,5
Mashivka	-702,6	-423,4	0,6	-139,2	-36,5
Myrhorod	-39	-285,5	3,5	-213,3	-201,4
Novi Sanzhary	-261,6	-126	-0,2	-214,3	-264,3
Orzhytsia	-18,3	-285,9	2,5	-145,5	-81,1
Pyriatyn	-32,3	-396,5	-1,3	-660,7	-547,9
Poltava	-294,9	-691,1	0,7	-163,6	-101,8
Reshetylivka	-1785,1	-225,5	3,1	-341,8	-389,1
Semenivka	108,2	-23,9	0,5	261,4	302,7
Khorol	-97,6	-485,3	0,6	-40	-63,9
Chornukhy	-166,5	-146,5	3,3	6,2	46,9
Chutovo	-66,5	-133,8	8,6	440,5	322,2
Shyshaky	-128	-346,7	-0,7	-273,6	-205,1

Table II. Correlation coefficients of the emission dynamics with indicators of child morbidity in the Poltava region

Sources of emission	Δcon malf (per1000 individuals)	Δmob children (per1000 individuals)	Δresp dis (per1000 individuals)
Δincr stat, t	-0,07	0,17	0,19
Δincr mob, t	0,05	0,16	0,11

The table I presents the emission dynamics (in tons) caused by stationary (Δincr stat) and mobile (Δincr mob) sources during 2015 compared to 2010 and the dynamics of the number (per 1000 individuals of the corresponding category) of congenital malformations (Δcon malf), general child morbidity (Δmorb children) and the respiratory diseases (Δresp dis). The data represented in the tables I and II have determined that no single correlation pattern for all areas of the region existed. Each region had its own specific mechanisms of the environmental hazards formation caused by the mobile and stationary sources of emissions. Weak correlations between the stationary and mobile sources of emissions and the general child morbidity as well as respiratory diseases have been revealed. Consequently, the study of child morbidity rate as an indicator of the environmental risk condition caused by air pollution requires the more detailed analysis of the multi-year dynamics rate for each district of the Poltava region separately. The results of such analysis are presented in the table III.

The intersystem relations «person – environment» are weakly correlated, then the significant and moderate correlations will be considered as relevant [17]. The obtained results have determined that the level of general child morbidity as well as respiratory morbidity was directly associated with the air pollution from the mobile sources in Zinkiv, Hadiach, Dykanka, Myrhorod, Kremenchuk, Kotelva, Poltava and Pyriatyn districts (Tables III, IV). These areas are charac-

Table III. Ranking of the correlation coefficient for general child morbidity and the amount of stationary and mobile sources emissions in districts of the Poltava region

Value and nature of correlation	Administrative districts of the region	
	Caused by the mobile sources	Caused by the stationary sources
Significant dirrect 1,0 ≥ r ≥ 0,7	Zinkiv Hadiach Dykanka	Poltava district Reshetylivka
Moderate dirrect 0,69 ≥ r ≥ 0,30	Kremenchuk Kotelva Myrhorod Poltava Pyriatyn Shyshaky	Hadiach Dykanka Mashivka Velyka Bahachka Novi Sanzhary Chornukhy Zinkiv
Weak dirrect 0,29 ≥ r > 0	Kozelshchyna Lubny Reshetylivka Velyka Bahachka	Semenivka Kotelva Kremenchuk Kozelshchyna Karlivka
Weak inverse 0 > r ≥ - 0,29	Hlobyno Mashivka Kobeliaky Semenivka Hrebinka Chutovo Orzhytsia	Myrhorod Khorol Orzhytsia Hlobyno Shyshaky
Moderate inverse -0,3 ≥ r ≥ -0,69	Khorol Novi Sanzhary Karlivka	Hrebinka Lubny Kobeliaky Chutovo Pyriatyn
Significant inverse -0,7 ≥ r ≥ - 0,99	Chornukhy Lokhvytsia	Lokhvytsia

terized by the relatively high degree of pollution caused by the mobile sources. Poltava, Reshetylivka, Novi Sanzhary, Hadiach, Mashivka, Dykanka, Velyka Bahachka districts are characterized by the relatively high pollution level from the stationary sources (Tables III, IV). The main sources of emissions are the fuel and energy enterprises, manufacturing and extractive industries, vehicles and agriculture.

Considering the fact that the level of anthropogenic load on the air basin is the most significant in the regional cities, namely, in Horishni Plavni and Kremenchuk, the further investigations of the child morbidity structure and its relation to the environment are required.

The correlation analysis of statistical data regarding the child morbidity and air emissions from the mobile and stationary sources in the main industrial cities of the Poltava region during 2010-2015 years are presented in the tables V, VI.

When calculating the values in the table 6 as a null hypothesis, it was assumed that the difference between the sample correlation coefficient and the correlation coefficient of the general population equaled 0 [16]. The critical limits of Student's coefficients for these samples ranged from 2,26 to 2,57.

Consequently, the data of tables V and VI have determinedthat the emissions from mobile sources significantly effectedthe child morbidity development in Poltava city. Emissionscaused by stationary sources have presented the clear correla-tion with the general morbidity indicators, but the correlationcoefficient was not significant. Thus, the relation was evident, but the main effect on the general morbidity developmentwas caused by the mobile sources. Also, Poltava city was characterized by significant direct relation in the numberof congenital malformations and respiratory diseases to themobile and stationary sources emissions. Horishni Plavni wascharacterized by the moderate direct correlation between theamount of mobile and stationary sources emissions and thedevelopment of congenital malformations; mobile sourcesemissions moderately effected on the development of thegeneral child morbidity. The moderate direct relation of the re-spiratory diseases to the stationary sources emissions and theeffect of the mobile and stationary sources on the congenital malformations development were registered in Kremenchuk.The study has determined that the regions with the higher emission level presented more close correlation with the level

Table IV. Ranking of the correlation coefficient for respiratory morbidity in children and the emission amount from the stationary and mobile sources in districts of the Poltava region

Value and nature of correlation		Administrative districts of the region
Caused by the mobile sources	**Caused by the stationary sources**	
Significant dirrect 1,0 ≥ r ≥ 0,7	Hadiach Kotelva	Novi Sanzhary Poltava district Reshetylivka
Moderate dirrect 0,69 ≥ r ≥ 0,30	Zinkiv Kremenchuk district Dykanka Myrhorod Lubny Pyriatyn Shyshaky Poltava district	Hadyach Mashivka Dykanka Semenivka Hlobyno
Weak dirrect 0,29 ≥ r > 0	Reshetylivka	Velyka Bahachka Kotelva Kremenchuk district Kozelshchyna Zinkiv Chornukhy
Weak inverse 0 > r ≥ - 0,29	Kozelshchyna Semenivka Novi Sanzhary Chutovo Velyka Bahachka Mashivka	Karlivka Hrebinka Lubny Chutovo Pyriatyn Kobeliaky Lokhvytsia
Moderate inverse -0,3 ≥ r ≥ -0,69	Khorol Hrebinka Kobeliaky Hlobyno Orzhytsia Karlivka	Shyshaky Hrebinka Lubny Chutovo Pyriatyn Kobeliaky Lokhvytsia
Significant inverse -0,7 ≥ r ≥ - 0,99	Chornukhy Lokhvytsia	

of general child morbidity. This fact confirmed the dose-dependence of the general morbidity indicators and respiratory morbidity in children andthe importance ofair basin protection in the region considering the ecological safety for the child population. Theoretically, the indicators of respiratory diseases in children should be more sensitive to the air quality, than the general child morbidity. The data of our research work have determined that the respiratory morbidity in children was more sensitive to emissions caused by the stationary sources in Novi Sanzhary, Semenivka, Hlobyno districts. The respiratory diseases resulted from the mobile sources were more sensitive only in Kotelva district. This can be explained by the structure of the child morbidity, because the incidence of respiratory diseases takes the leading place in its formation (Fig. 1).

The correlation dependencies identified in the research work can be confirmed by the other scientific studies. According to the data [20], respiratory diseases in children are caused by the climatic (r = 0.63) and environmental factors synergism (r = 0.36). The level of ecology-dependent morbidity in children and adolescents depends on the complex of ecological and hygienic factors, where the part of atmospheric chemical pollution is significant (according to regression analysis) [21].

The districts with the significant inverse correlation dependence are of particular attention. So, the decrease in air pollution caused by the mobile and stationary sources has been registered in Chornukhy district in recent years, but the child morbidity is increased, including respiratory diseases. Chornukhy district is one of the most depressed areas of the region and is characterized by the highest overall mortality rate (23,4 per 1000 population for the period 2011-2015 years), the high average age (43,8 years), the lowest number of children aged 0-17 years – 1657 children as of 01.01.2015, the lowest population density. During that period, the district was characterized by the least anthropogenic load on the air environment. Considering such conditions, the formation of

Table V. Air emission effect on the level of child morbidity in the main industrial cities of the Poltava region

Emissions \ Diseases		Respiratory diseases	Congenital malformations	General morbidity
Caused by the mobile sources	Poltava	0,864	0,697	0,807
	Horishni Plavni	-0,468	0,634	0,333
	Kremenchuk	0,236	0,403	0,201
Caused by the stationary sources	Poltava	0,806	0,924	0,868
	Horishni Plavni	0,138	0,372	0,072
	Kremenchuk	0,300	0,356	0,284

Table VI. The significance of correlation coefficients according to Student's t-test

Emissions \ Diseases		Respiratory diseases	Congenital malformations	General morbidity
Caused by the mobile sources	Poltava	21,576	22,677	20,919
	Horishni Plavni	10,405	-2,1411	9,9312
	Kremenchuk	25,429	27,609	24,772
Caused by the stationary sources	Poltava	3,7341	12,125	-0,0681
	Horishni Plavni	43,969	-2,2108	40,758
	Kremenchuk	26,888	28,527	26,387

the child morbidity indicators includes the level of the social and economic sphere development in the region. Lokhvytsia district refers to the most polluted areas caused by the stationary sources of the oil and gas enterprises. It is characterized by the highest density of emissions per square meter and the amount of emissions per capita [19]. The causes of the inverse correlation can be identified after analyzing the structure, the toxicity of emissions as well as the presence of other evident causes for the child morbidity formation.

The obtained results (Tables 5, 6) make it possible to determine that the amount of mobile sources emissions is one of the most significant factors affecting such indicators of the ecological safety condition as child morbidity on the territory of Poltava city. Considering the multifactor effect on the level of child morbidity indicators, the moderate direct correlations confirm the dependence of respiratory diseases and general child morbidity on air pollution. Weak and inverse relations, most likely, demonstrate the presence of other important factors in the child morbidity formation, which requires the further investigation of its structure.

The study also statistically determined the relation of the congenital malformations development to the general air pollution in Poltava and Kremenchuk cities. Mutagenic effect is characteristic of the pollutants, which can change the genome structure. Heavy metals, aromatic polycyclic hydrocarbons, benzene are included to this list. According to the data of Ukrainian scientists [22], significant positive correlations with the total number of congenital heart defects were obtained considering emissions of metals and their compounds ($r = 0.60$), nitrogen and its compounds ($r = 0.64$), nitrogen dioxide ($r = 0.46$), carbon monoxide ($r = 0.60$), carbon dioxide ($r = 0.72$) and non-methane easily-oxidizable compounds ($r = 0.69$) in Zaporizhzhia region. The relationship between the congenital malformations development and air pollution is also proved by the foreign scientists [23-25].

CONCLUSIONS

Analysis of the statistical data over 2010-2015 years regarding the amount of emissions into the atmosphere by the mobile and stationary sources and indicators of child morbidity enables to determine, that no single correlation pattern for all districts of the Poltava region exists. Each district has its own specific features in the environmental hazards formation. Emissions to the atmosphere significantly effect on the development of child morbidity in Poltava city, while in Kremenchuk and Horishni Plavni, probably, the more significant factors for the morbidity rate formation in children under the age of 17 years can be observed. Ranking of the administrative districts according to the level of emission effect on the child morbidity makes it possible to determine the most dangerous ecological areas. Emissions from the mobile sources directly affect the level of general child morbidity and respiratory diseases development in Zinkiv, Hadiach, Dykanka, Myrhorod, Kremenchuk, Kotelva, Poltava, Pyriatyn districts, from the stationary ones – in Poltava, Reshetylivka, Novi Sanzhary, Hadiach, Mashivka, Dykanka, Velyka Bahachka districts. The program addressed for the above-mentioned districts can be developed considering the identified dependencies; it should be aimed at determining, eliminating and preventing the impact of harmful environmental factors on the health of child population.

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