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ANALYSIS OF AIRBORNE FACTORS OF IVANO-FRANKIVSK POPULATION MORBIDITY

Introduction

Air pollution is made of pollutants of natural or anthropogenic (human-induced) origin. Air pollution is a mixture of solid particles and gases in the air including caremissions, industrial emissions components, dust, pollen and mold spores as they maybe suspended as particles.

The Environmental Protection Agency (US EPA) has identified six pollutants as “criteria” air pollutants having the clearest relation to the environment quality degradation and human health threats. These six pollutants are carbon monoxide, lead, nitrogen oxides, ground-level ozone, particle pollution (often referred to as particulate matter), and sulfur oxides.

They are also the most typical pollutants of urban areas, responsible for the increased disease burden of industrial cities around the world. Most of the countries of the world have developed and implemented human health-based and/or environmentally based criteria (science-based guidelines) for setting permissible levels for these substances.

At the same time traffic and related sources of pollution are among the top polluters, responsible for growing morbidity among residents of cities without heavy industrial pressure, even those located in recreational areas.

Moreover, many urban territories have no dominant source of air pollution and it is rather a complex of factors, which has shaped the final air quality status. For such cases there is a need to conduct analysis of the interactions between the population health and specific air pollutants via math methods. Having established the most probable interactions it is possible to develop and implement the actions for the efficient reduction of morbidity by control and reduction of air pollution levels with specific pollutants.

Analysis of previous research

There are two main types of air pollution: ambient air pollution (outdoor pollution) and household (or indoor) air pollution. Indoor pollution refers to pollution generated by burning gas, evaporation from construction and decorative materials, cleaning agent in poorly ventilated spaces. Both indoor and outdoor air pollution can contribute to each other, as air moves from inside buildings to the outside, and vice versa [1]. They can both contribute the same pollutants, thus, the common sources of CO in urban areas are cigarette smoke and vehicle exhaust [2]. Several factors can affect outdoor air quality including climate change, topography, weather conditions, exposure to pollution etc. It has been established that climate change influences outdoor air pollutant concentrations in many ways like temperatures, cloudiness, humidity, frequency and intensity of precipitation, and wind patterns [3]. Some air pollutants such as ozone, sulfates, and black carbon in turn contribute to changes in the global and local climate [4].

The sources and pathways of criteria pollutants in urban environments are currently well studied, in particular, by D. Satterthwaite, L. Schell and M. Denham, F. Hülsmann et al., E. Van Bueren, F. Atash, A. Cattaneo et al., M. Loh et al., S. Sonwani and P. Saxena.

However, the research works aimed at the determination of their human health impacts need more sophisticated work with high level of results reliability.

Nevertheless, it has been demonstrated, that both non-specific and specific health effects are conditioned by air pollution of urban air.

Nonspecific effects of pollutants on human health include respiratory diseases, asthma, chronic obstructive pulmonary disease, pneumonia, etc.

Specific effects of air pollution can be carcinogenic, mutagenic and teratogenic.

Although carbon monoxide levels are relatively low in urban environment, data from the APHEA-2 project (Air Pollution and Health: A European Approach) studying the relation between air pollution and total cardiovascular mortality in 19 European cities, reported a significant association of carbon monoxide with cardiovascular mortality [5]. Carbon monoxide at low concentration, as found in urban environment, has also been correlated with hospital admissions, mortality and morbidity related to cardiovascular dysfunctions [6].

Air pollution is also mentioned among the common environmental factors that contribute to cancer in line with tobacco, diet and obesity, infections, radiation, and sedentary lifestyle [7]. About 10–15 % cases of lung cancers are often caused by a combination of genetic factors and exposure to radon gas, asbestos, second-hand smoke, or other forms of air pollution [8]. There is growing epidemiologic evidence for adverse effects on the fetus and newborn from maternal prenatal exposure to ambient air pollution [9]. Air pollutants such as carbon monoxide, sulfur dioxide, and particulate matter have been associated with increased infant mortality, particularly post neonatal respiratory mortality, low birth weight, and preterm birth [10].

Air pollution also has adverse effect on the economy of the world. According to a joint study by the World Bank and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington, Air pollution costs the world economy \$5 trillion per year as a result of productivity losses and degraded quality of life [11]. In China, Xiaoping et.al., discovered that the total health damages due to year 2000 anthropogenic emissions from Zaozhuang, using the “willingness-to-pay” metric, was equivalent to 10% of Zaozhuang's GDP [12]. The impact of the traffic related air pollution is known to be responsible for considerable additional morbidity, as it is shown by Künzli et.al., that air pollution caused 6 % of total mortality in some European countries and about half of that was attributed to motorized traffic [13]. Similarly, in 2014, Jakubiak-Lasocka et.al., studied the impact of traffic related air pollution on health in Poland and indicated that about 827 Warsaw citizens die a year as a result of traffic-related air pollution, about 566 and 250 hospital admissions due to cardiovascular and respiratory diseases, more than 128,453 restricted activity days are attributed to the traffic emissions and from the social perspective, these losses generate the cost of 1,604 million PLN (1 EUR-approx. 4.2 PLN) [1].

Air pollution can also have distant long term effects, taking several years before manifesting health challenges, for example, children exposed to air pollution may not develop ailments related to air pollution until they're older. A study examining predictors of respiratory health in adulthood by Barakat-Haddad et.al., confirmed that 29 % of adults exposed to air pollution in yearly agehad at least one respiratory condition and 24% demonstrated persistent respiratory symptoms [14].

For Ukraine the studies of air pollution related health disorders are not very common, and are mostly limited to the analysis of general levels of morbidity and possible environmental reasons, like those done by Tarasova et al. Shushpanov D., Buchavyi Yu., and consideration of emissions sources to the potential health risks in cities (Batluck V. and Azarsky K., Malysheva V., Gutarevych Yu.). More detailed study by Popov et.al. demonstrated, that air pollution exceeding the maximum permissible concentration in the summer months of 2017 in Kyiv contributed to the increasing morbidity rate in Kiev by 20–30 % with the worst situation observed in the northwestern part of the city [15]. However, regional based research works are mostly attributed to major cities, like Kyiv and Kharkiv, but lacks attention to smaller urban settlements still having considerable levels of air pollution.

Problem statement

Ivano-Frankivsk is a city with significant industrial and economic potential. The great prospects of the city are connected with the proximity of the Carpathians as a unique region of tourism and recreation. The Ivano-Frankivsk region is generally considered relatively unpolluted due to its close proximity to recreational and natural protected area of the Carpathians. The most serious environmental concerns and health threats are mostly attributed to the Kalush industrial area [16]. At the same time, the city is characterized by increased integrated indicator of anthropogenic pressure on the environment.

The air pollution at the territory of Ivano-Frankivsk is conditioned by the intensive traffic, both roadway and railway, especially in the center and heavy industrial enterprises, in particular, cement plant, machine building and electronic equipment. Additionally, the territory of the city is exposed to pollution transported from the refining and mining industries located at the adjoined areas. The historical part of the city, as well as densely built residential districts are poorly aerated and that contributes to pollution accumulation and retention. However, there has been no research to measure the impact of this pollution on human health.

The **aim** of the given research is to perform the analysis of correlation/dependence between the air pollution composition and morbidity in the city with mixed air pollution, coming from heterogeneous sources on the example of Ivano-Frankivsk.

Tasks are:

- to study the evidence-based data on the relationships between air pollution and health disorders among population of cities;
- to characterize the possible sources of anthropogenic pressure on the environment of Ivano-Frankivsk;
- to define the degree of relationship (if it exists) between the pollutants and the residents' health;
- to make recommendations for policy makers based on findings of this research.

Methods and materials

Linear Regression is a statistical method for expressing the relationship between variables. The dependent variable is a function of the slope and intercept between it (dependent) and independent variables. This study seeks to establish the extent of relationship between the dependent and independent variables. The relationship is thus expressed in terms of the value of the intercept, slope (m), and the value of the Spearman Coefficient. R studio software was used to code and design the graphs and generate statistical results.

Correlation Coefficients were computed to examine the relationship amongst pollutants and between pollutants and diseases. To investigate relationships between pollutants and diseases, the

Pearson's coefficient was used as a tool for regression analysis.

Multi-Linear Regression Analysis is important to know the relationship between the dependent variables like Morbidity and the other independent variables (Population, Industrial pressure, etc.).

A multi-linear regression model is generated only when all or some of the independent variables show significant relationship with the dependent variables (morbidity and cancer cases). This relationship is then rated by the p-values, R and multiple R-squared values of each independent variable as it relates to the dependent variables.

The dependent variables used in the analysis were the incidence of cancer and children morbidity, mainly because children have their immune system still developing and therefore making them vulnerable and sensitive to environmental changes and pollution. According to the World Health Organization, worldwide, up to 14 % of children aged 5–18 years have asthma relating to factors including air pollution. Every year 543,000 children younger than 5 years die of respiratory disease linked to air pollution [14].

The data on morbidity were obtained from the department of medical statistics of the Municipal Non-Profit Medical Enterprise and attributed to the demographic characteristics of urban districts. For the purpose of the analysis the territory of the city was divided into 6 districts, based on the city layout and medical attribution of the areas to certain medical establishments. Additionally the data on the level of industrial pressure by districts were collected and averaged for urban districts (Table 1).

Table 1

Initial data for the analysis

Urban district	Children morbidity (incidence per 1000 children)	Cancer cases (incidence per 1000 children)	Industrial pressure	Number of population*
Railway	1234	5.8	3	30733
Cascade	1167	4.5	2	51417
South	1389	6.5	3	68633
Old city	984	3.8	1	31583
Apiary	1121	4.8	2	53200
Central	1013	4.3	1	19317

***Note:** the number of population by districts also accounts the residents of adjoining villages with only administrative separation from the urban area.

The level of industrial pressure was determined based on the number of functioning industrial facilities within the territory of each district and intensity of traffic. The circulation of air under the influence of hydrological network and relief of the

city, as well as the distribution of green plantations were also accounted in the evaluation of industrial pressure.

Thus, it was ranked 1 to 3, where 1 is the lowest and 3 is the highest level.

The independent variables of the study are the level of industrial pressure and level of air pollution with a range of common pollutants: CO, PM10, Pb and Phenol (Table 2).

The concentration of pollutants was defined using the data of the State Environment Monitoring system at the territory of the city at 29 points. The obtained data were average values of the concentration during 2018-early 2020 and they were recalculated into mean values for each urban district. Further analysis was performed with the integral air quality characteristics — the complex index of atmosphere pollution (IAP).

It is presently the most widespread and recommended methodical approach to the assessment of air condition in Ukraine. IAP is defined as the sum of ratio of the air concentration to MPC, accounting the toxicity of substance as compared to SO₂.

Results and discussions

Using the data about the pollution of air within the city of Ivano-Frankivsk, the averaged values of IAP were calculated (Table 3) and the map of air pollution intensity was built to demonstrate the spatial distribution of pollution (see figure).

Table 2

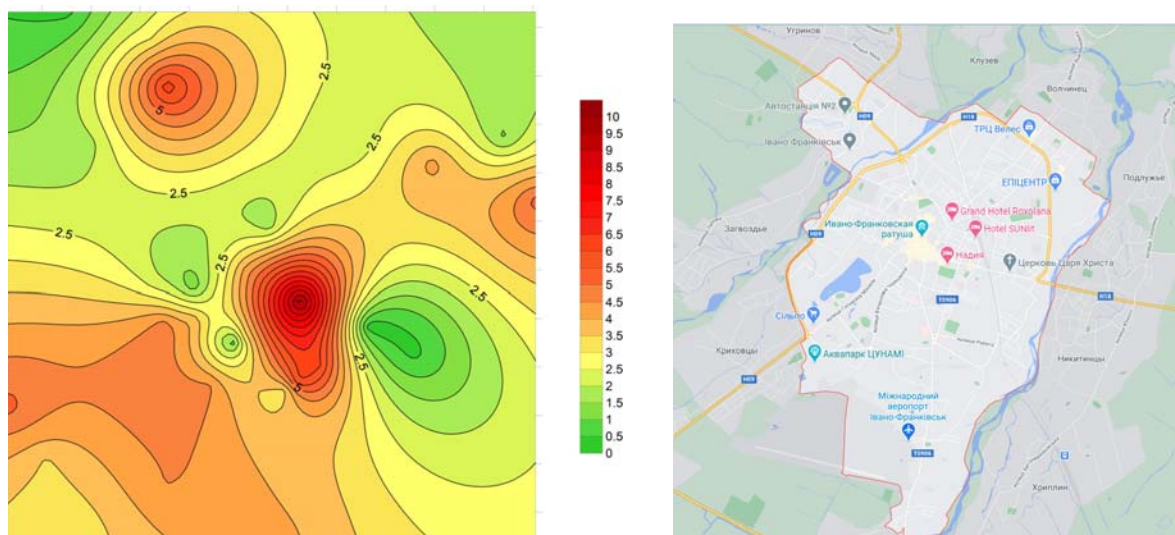
Hygienic parameter of pollutants

Parameters	CO, mg/m ³	PM10, mg/m ³	Pb, mg/m ³	Phenol, mg/m ³
MPC	5	0.5	0.001	0.01
Hazard class	4	3	1	2
Effect index	0.86	1	2.4	1.3

Table 3

Air pollution by districts

District	Mean IAP	Level of pollution
Railway	4.82	slightly polluted
Central	3.9	slightly polluted
Cascade	3.19	slightly polluted
Old city	2.9	slightly polluted
Apiary	3.72	slightly polluted
South	3.12	slightly polluted



Distribution of air pollution levels (IAP) at the territory of the city

The analysis of spatial distribution of air pollution shows that the urban district with the highest level of pollution is the Railway district, and the highest contribution to pollution is made by lead and PM10, the Apiary district follows the Railway district with PM10 also as the most important

pollutant. The Old city district has the lowest level of pollution; however, the air quality in all the districts is ranked as slightly polluted.

In terms of individual pollutants, it can be concluded that carbon monoxide’s concentration was steadily lower compared to other pollutants.

PM10 and lead had consistently high concentration among the pollutants while phenol's concentration alternated between high and low.

The results of data processing showed positive correlation for carbon monoxide when it was plotted against health data (morbidity ($R = 0.8$) and cancer cases ($R = 0.85$)). Another pollutant that showed a positive correlation with health data is PM10 ($R = 0.68$ for cancer cases and $R = 0.77$ for morbidity).

Pb showed no dependence on the health data ($R = -0.56$) when plotted against children morbidity and ($R = -0.42$) when plotted against cancer cases. Phenol also showed no dependence on the health data ($R = -0.42$) when plotted against children morbidity and ($R = -0.39$) when plotted against data cancer cases.

Additionally, correlation analysis was carried out between IAP average by district with cancer cases and morbidity and the results showed no dependence ($R = 0.16$ for morbidity) and ($R = 0.10$ for cancer cases).

Also, correlation analysis was carried out between industrial pressure average with cancer cases and morbidity and the result showed a positive correlation with both cancer cases and morbidity ($R = 0.67$ for morbidity) and ($R = 0.64$ for cancer cases) (Table 4).

Industrial pressure, PM10 and Carbon monoxide showed a positive correlation with cancer cases and morbidity which can mean that they influence the health of the population, while they may not be the primary cause of morbidity in Ivano-Frankivsk, they can be part of the contributing factors.

Table 4

The statistical relationship between pollutants and health indicators

	Morbidity				Cancer Cases			
	Slope	Intercept	R	R Squared	Slope	Intercept	R	R Squared
CO	0.0003	0.066	0.800	0.55	0.05	0.198	0.847	0.64
PM10	0.000351	0.47	0.77	0.50	0.045	0.65	0.68	0.32
Pb	-0.00034	1.53	-0.56	-0.31	-0.038	1.33	-0.422	-0.178
Phenol	-0.00060	1.54	-0.42	-0.177	-0.084	1.26	-0.39	-0.15
IAP	-0.02	4.605	0.16	0.02	-3.87	4.14	0.10	0.01
Industrial Pressure	-0.02	4.6	0.67	0.445	-3.88	4.15	0.64	0.43

Recommendations

- The air quality monitoring should be strengthened and expanded both in terms of pollutants and number of posts.

- Relevant air quality and health data should be made available for analysis purposes and public awareness.

- The population should be aware about air pollution, the risks and health impacts and emphasis must be made on indoor air quality regulation in homes and offices to minimize the level of pollutants they are exposed to daily.

- The results of analysis show that the most probable source of air pollution in the city of Ivano-Frankivsk is transport and its infrastructure, thus there is an urgent need to optimize the road infrastructure and strengthen the control over the technical condition of vehicles to reduce their health footprint.

- Pollutants that showed no dependence should be analyzed against different diseases to discover possible relationships.

CONCLUSIONS

Air pollution is able to cause human health effects of various severity. This study analyzed the

relationship between air pollutants and ailments. The results are formulated as follows:

- 1) The impacts of air pollution on human health are proved and studied in a variety of research works. The intensity of air pollution seems to be one of the major factors reducing quality of life at urban areas around the world independent from the level of economic development. The exact interaction between specific air pollution at any given city and population's morbidity is of high importance for the reduction of human health risks and prevention of disease burden growth.

- 2) Ivano-Frankivsk is a city with well developed infrastructure; it is densely populated and faces a range of environmental problems due to excessive traffic and industrial pressure. The major issues are air pollution and poor waste management.

- 3) The level of pollution in Ivano-Frankivsk was evaluated in integrated form by the air quality index. It has showed that most of the territory is slightly polluted, while the central part of the city affected by the most intensive traffic and railway station has rather elevated pollution levels. The data about the concentration of pollutants showed the most contribution is done by PM10 and lead. It also showed the Old city district is the least polluted.

Carbon monoxide concentration was relatively low in all districts

4) To determine the relationship between air pollutants and ailments, regression analysis was carried out. The results showed a positive correlation between industrial pressure, PM10 and carbon monoxide with morbidity and cancer cases, thus, it can be concluded that even the lowest concentration of pollutants in air are still harmful to humans. Thus, there is a need for substance specific analysis to improve the efficiency of air quality control and diseases prevention.

5) The need for dust and CO pollution monitoring and reduction were given. Additionally, the interaction between phenol and lead and other diseases should be studied, as it showed no dependence on morbidity in the given research. The reduction of carbon footprint in the city of Ivano-Frankivsk, availability of air quality and health data for more analysis and rising general awareness of the public about the impacts of air pollution are the necessary conditions for the improvement of the situation.

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Радомська М. М., Оелоле Г. Т.

АНАЛІЗ ПОВІТРЯНИХ ФАКТОРІВ ЗАХВОРЮВАННЯ НАСЕЛЕННЯ М. ІВАНО-ФРАНКІВСЬКА

Якість повітря в містах продовжує погіршуватися через збільшення кількості забруднюючих речовин, що викликають ряд загроз для здоров'я людини. Аналіз результатів досліджень доводить, що існує тісний зв'язок між забрудненням повітря і зростанням числа неспецифічних респіраторних захворювань, алергії, захворювань легенів і канцерогенних процесів серед міського населення. Відповідні дослідження проводилися для міст по всьому світу, але в Україні відсутні аналітичні дані про захворювання, обумовлених забрудненням повітря. З цієї причини метою дослідження був аналіз статистичних даних про дитячої захворюваності та захворюваності на рак для встановлення їх залежності від рівня концентрації забруднюючих речовин в атмосферному повітрі на прикладі м. Івано-Франківська. Місто розташоване в безпосередній близькості від Карпатського регіону, для якого характерний низький рівень антропогенного перетворення, але має ряд джерел забруднення промислового і транспортного типу. Крім того, територія зазнає трансграничного впливу потужних промислових комплексів з прилеглих внутрішніх і зарубіжних територій. Аналіз був зосереджений на впливі на здоров'я чотирьох забруднюючих речовин: оксиду вуглецю, свинцю, фенолу і РМ10. Концентрації забруднюючих речовин, а також дані про стан здоров'я в місті були взяті з офіційної статистики медичного та екологічного моніторингу. Загальна якість повітря оцінювалася шляхом розрахунку інтегрального показника якості повітря за державними стандартами. Потім індекс забруднення атмосферного повітря і медичні дані були згруповані відповідно до меж медичних округів. Крім того, рівень промислового навантаження в кожному районі було визначено кількісно з використанням рейтингової системи. Регресійний аналіз використовувався для визначення взаємозв'язку між забруднювачами та хворобами. Просторовий розподіл забруднення свідчить про те, що повітря у місті в основному забруднене РМ10, але характеризується незначним забрудненням іншими компонентами; найбільш забруднені райони — Залізничний і Пасічна. Результати регресійного аналізу показують взаємозв'язок концентрацій СО і РМ10 з даними про стан здоров'я в Івано-Франківську. Для поліпшення стану здоров'я населення необхідно докладати зусилля до зниження викидів забруднюючих речовин, що мають найбільшу кореляцію з рівнем захворюваності. Рекомендації щодо подальших організаційних та інформаційних заходів дано спеціально для досліджуваного міста.

Ключові слова: вплив на здоров'я; якість повітря; регресійний аналіз; забруднювачі.

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ANALYSIS OF AIRBORNE FACTORS OF IVANO-FRANKIVSK POPULATION MORBIDITY

Air quality in urban areas continues to deteriorate due to increasing number of pollutants, causing a range of threats for human health. The analysis of research results prove that there is a strong connection between the air pollution and growing incidence of non-specific respiratory disorders, allergies, lung diseases and carcinogenic process among urban population. The corresponding studies have been performed for cities around the world, but in Ukraine there is a lack of analytical data about the diseases conditioned by air pollution. For this reason the research was aimed at analysis of statistical data about children morbidity and cancer incidence to establish their dependence on the level of air pollutants concentration on the example of the city of Ivano-Frankivsk, which is located in close proximity to the Carpathian protected area, but has a range of pollution sources of industrial and transport type. Additionally the area is exposed to the trans boundary effects of powerful industrial complexes in neighboring domestic and foreign territories. The analysis was focused on the health impacts of four pollutants in the city of Ivano-Frankivsk: Carbon monoxide, Lead, Phenol and PM10. The pollutants concentrations as well as the health data of the city were taken from official medical and environmental monitoring statistics. The general air quality was evaluated by computing the integral index of air quality according to the state standards. Afterwards index of air pollution and medical data were grouped according to the medical districts delineation. Additionally the level of industrial pressure at each district was quantified using rating system. The regression analysis was used to determine the relationship between the pollutants and illnesses. The spatial distribution of pollution suggests that the city is mainly polluted with PM10 while being slightly polluted with the other pollutants; the most polluted areas are Railway and Pasichna. Results of the regression analysis show the relationship between carbon monoxide and PM10 with the health data for Ivano-Frankivsk. For the improvement of the population health status it is necessary to invest efforts in the reduction of emissions of the pollutants having highest correlation with morbidity levels. The recommendations for further organizational and information solutions were given specifically for the city under study.

Keywords: health effects; air quality; regression analysis; pollutants.

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