Dynamics of Oncological Morbidity in Kryvyi Rih Environment

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ABSTRACT
The article examines environmentally-spatial specifics of morbidity spread in Kryvyi Rih region (Kryvbas). Different approaches to the identification of medical geographic areas are analysed. The paper proposes a typology of diseases, according to which environmental and geopathogenic areas are defined. There were researched spacial specifics of cancer morbidity spread on the territories of Kryvyi Rih over a ten-year period (2007-2017), namely in Southern environmentally-geopathogenic area, whose territory accommodates the majority of enterprises of metallurgical complex. There was established a dependence of oncopathologies spread on the distance to stationary pollution sources. Such a dependence confirms the universal spatial regularity of disease spread pursuant to a "semi-periphery" model.
Keywords: *morbidity, environmentally dependent diseases, oncological diseases, cancer-causing chemicals, manufacturing enterprises, environmentally-geopathogenic area*

1. INTRODUCTION

Old industrial regions of Ukraine, to which Kryvbas belongs, were formed while undergoing several subsequent phases – from mining centre of physically-muscular industry in the 18th-19th centuries, through the increase of concentration of production during industrial development to modern powerful metallurgical complexes, which cover the area, currently known as "Grand Kryvbas" [1].
On the sidelines of industrial growth the intensity of urbanization processes increased, there occurred the aggravation of the problems inherent with cities, among which ecological was the most pressing one [2], [3]. The direct consequence of its aggravation became so-called "environmental diseases" [4], [5]. Significant city areas preconditioned "synergism" phenomenon in the development of various diseases. "Overlapping" traditional diseases, environmental ones cause collateral complex effect: in environmentally problematic zones there is the overfrequency of pathology of chronic digestive apparatus and kidneys, neoplasms, endocrine diseases, abnormal neuropsychic and physical development; allergic disorders, recurrent outbreaks of respiratory diseases, noticeable secondary immunodeficiency [6] - [8].
Previously it was proved, that the spread of epidemic diseases enables the implementation of the model of centre-periphery disease spread (by T. Hägerstrand's Innovation Diffusion Theory) [9]. In the case in point, the centre(s) can be manufacturing enterprises with stationary pollution sources, and the periphery – residential areas, where population lives.
The problem of environmentally-dependant morbidity sparks interest not least because of its ten-year-old research period [10]. Herewith we consider the problem of progression of neoplastic diseases the most interesting, which, according to medical statistics, rank second after cardiovascular diseases [11] and are related to urban environment.
The thematic justification is determined by negative dynamics of morbidity of Kryvbas population in environmental diseases [12], [13] and necessity for the research of geospatial specifics of their spread. How has the situation changed within 10 years? Have the regularities of disease spread maintained over the years? These are the questions, which the authors expect to get answered.

1.1. Related Work

Traditionally in the areas of large cities the morbidity research is conducted by specialists in occupational and parasitic diseases, epidemiologists, family physicians et. al. [14] - [16].
More recently, this problem has sparked the interest of specialists in medical ecology and human ecology [17] - [21]. Striving to examine spatial patterns in disease spread is primarily related to medical geography and has traditions of its own [22] - [25].
Ecological state of the environment and the resulting morbidity in urban environment of large cities is rather a new problem, which has recently been widely reported in scientific literature [26] - [29]. *The novelty of the research proposed* is driven by the insufficient information on the morbidity of population of old industrial regions and

powerful metallurgical complexes, as exemplified by Kryvyi Rih city, subject to the ecological situation within the city.
The *research methodology and technique* are based on both classical and modern works of medical geographers, cartographers, geochemists, medical workers. Generally speaking, the research of the problem mentioned (taking into account its complex character) demands the implementation of the complex of methods and methodological approaches, inherent with various sciences. In point of fact, with the aim of more distinct spatial differentiation of morbidity, there was used a typology of diseases depending on the influence of separate factors (ecological, social, biology-genetic, production) [30].

1.1.1. Manual interactive assumption generation

The research hypothesis is the assumption that for the period from 2007 to 2017 there has been observed deterioration of municipal dynamics of morbidity in the diseases, related to degradation of atmospheric air quality. In a point of fact, these are: neoplasms, various allergic diseases, vegetative-vascular dystonia, bronchial asthma, bronchitis, various diseases of upper respiratory tract.

1.1.2. Automated assumption generation

The technique presented in the paper is based on the capabilities of a spatial analysis of MapInfo GIS Suite [10], [25], [31] - [33]. A hospital site was chosen (in accordance with city districts) as a primary spatial unit of the research. The cartographic expediency of such choice is founded on appropriate Executive Board documents [34].
In 7 innercity districts of Kryvyi Rih there were processed 18 hospitals, to which 254 hospitals sights were attached: in Central-City district – 2 polyclinics, 1 hospital and 33 hospital sites; in Metallurgical District – 2 polyclinics, 1 hospital and 40 hospital sites; in Saksahanskyi district – 3 hospitals and 49 hospital sites; in Pokrovskyi district – 3 hospitals and 44 hospital sites; in Ternivskyi district – 3 hospitals and 53 hospital sites; in Inhuletskyi district – 2 hospitals and 24 hospital sites; in Dovhintsivskyi district – 1 polyclinic and 11 hospital sites. These particular hospital sites served as a primary spatial unit of chart-making and further spatial analysis.
The initial material for establishment of geographic database of a future GIS was as follows: a paper map of Kryvyi Rih on scale of 1:40 000 (vectorized in MapInfo environment), the data of City Health Department on the address attachment of separate residential units to appropriate hospital sites, also the addresses of health care institutions, registration office data on the morbidity of Kryvyi Rih population in terms of polyclinics and hospital sites during 2007 and 2017; literature data [31].
Thematic maps were created in automatic mode in a software shell of GIS MapInfo Professional. In the course of the research there were created over 20 GIS subject layers, issued in shape of electronic maps, specifically, neoplastic disease distribution maps, 3-D models.
In terms of methodology we followed a concept of ecological-geopathogenic area, developed in our previous works [30].
Modern human ecology and medical geography while studying morbidity uses to a greater extent traditional methods of allocating medical-geographic regions – entitative territorial dynamic systems, rather homogeneous under the terms of public health formation. Starting with the works of the biochemical laboratory (BIOGEL), founded by V. I. Vernadskyi, the key ideas in the theory of medical geography became those ones about biochemical provinces and biochemical zoning. Except for natural biogeochemical provinces, which boundaries often align with the propagation of those that subsurface rocks or soil types, one determines anthropogenic (technogenic) ones, which appearance is related to human technogenic activity – environment pollution, caused by industry growth. The boundaries of technogenic biogeochemical provinces align with the area of chemicals dispersion around enterprises or their groups [35].
Weak spatial determination of modern urban disease environment (stress inducing factors, tension and fast pace of life), substantial "blurring" of causation of diseases incline towards the development of complete new scientific approaches to conducting population morbidity zoning. The dissimilarity of the author's approaches to zoning of population morbidity from traditional medical geographical ones is determined by:
– coverage of the area, where zoning is in process, consequently by the size of primary spatial units, used for such zoning (in the present case it is a hospital site);
– specifics of urban environment in regions of old commercial exploitation, where natural factors of flashpoints of disease outbreaks give way to technogenic and social-infrastructural flashpoints;
– special place of environmentally-dependant diseases or those, which resulted from harmful anthropogenic effect on environment and which flashpoints (oncoanomalies) portray themselves in geographical space pursuant to well-known regularities of space-filling from centre to periphery.
– special methods of "supplying" the continuity in case of influence of environmental-pathogenic factors, especially, in the presence of stationary pollution sources, large industrial and residential areas. The methods indicated are common for urban regions of old commercial exploitation;
– almost entire absence of discreteness in spatial manifestations of environmentally dependent diseases, especially by means of gradual wavelike disease "decay" from stationary sources to periphery [9].

1.2. Our Contribution

Taking into account these new approaches, in the course of the research there were formed new visions of environmentally dependent diseases and synergism phenomenon accompanying them [30]. A vivid display of this phenomenon in urban areas of old commercial exploitation enables to speak of *synergistic diseases*, to which belong those, that are becoming acute amid environmentally dependent diseases [8].
Having become familiar with relevant literary sources [7], [8], we determined and made allowance for three types of diseases:
– environmentally dependent diseases – occupational diseases, oncology diseases, congenital defect, genetic defects, allergies, toxicoses, endemic diseases;
– socially dependant diseases – contagious and parasitic diseases, diseases of the digestive system, chronic obstructive diseases, tuberculosis, hepatic cirrhosis, alcoholism, blood diseases;
– synergistic diseases – overfrequency of allergic diseases, abnormal neuropsychic and physical development, outbreaks of respiratory diseases, high frequency of endocrine diseases,

noticeable secondary immunodeficiency, frequency of chronic pathologies of digestive apparatus and kidneys.

Within the limits of the city there were defined 4 environmental and geopathogenic areas:

1. Southern mining-industrial zone in the composition of Inhuletskyi and a apart of Central-City administrative districts with prevalence of morbidity among allergic diseases and diseases of respiratory apparatus;
2. Southern metallurgical zone in the composition of Dovhintsivskyi, Metallurgical and a part of Central-City districts with prevalence of morbidity among neoplastic diseases;
3. Central residential zone – in the composition of Saksahanskyi and a part of Pokrovskyi districts with prevalence of morbidity among social diseases (some contagious and parasitic diseases, diseases of the digestive system);
4. Northern mining-industrial zone in the composition of Ternivskyi and a part of Pokrovskyi administrative districts with prevalence of morbidity among allergic diseases and diseases of respiratory apparatus, also some social diseases.

The authors' interest in neoplastic diseases is generated primarily by a complex identification of their etiology, and hence, low treatment effectiveness. It, probably, depends to a large extent on the evolution of development of beliefs about such diseases.

Cancer-causing chemicals of anthropogenic origin appeared when humans learnt to use fire (about 500 thous. years ago) [36]. Due to a contemporary view, accepted in medical science, cancerogenese is caused by:

– long-term contact with soot, coal tar oil, solvents, colorants, tobacco smoke;
– intrusion of such cancer-causing chemicals into human organism as: polycyclic aromatic hydrocarbons, benzol, benzoperene, naphthylamine, ester, vinylchlorides, beryl and its compounds, cadmium and its compounds, arcenic and its compounds, nickel and its compounds, radon and its decay products, asbestos, talc.
– cancer-causing manufacturing processes, like coke industry, coal gasification, cast-iron and steel production (agglomeration factories, blast-furnace ironmaking and steel founding, hot-rolled mill products) and casting, deep mining of hematite ore, aluminium smelting, industrial impact of aerosols, which contain sulphuric acid, rubber industry.

Intrusion of such cancer-causing chemicals into human body results in:

– deep mining of hematite ores – lung cancer;
– long-term contact with asbestos – lung cancer, pleura cancer, cancer of abdominal cavity, digestive tract, larynx;
– long-term contact with benzol – oncological diseases of blood-vascular system;
– iron and steel melting – oncological diseases of lungs, digestive tract, blood-vascular system, urinal tract;
– coke industry and coal gasification – oncological diseases of skin, lungs, urinal tract;
– long-term contact with vinylchloride – oncological diseases of liver, blood vessels, brain, lungs, lymphatic apparatus [36].

Our *key research results* are associated with joint GIS instrumental and analytical capabilities, also implementation of cartographic method while researching dynamics of propagation of neoplastic diseases over a 10-year period (2007-2017).

In a point of fact, grounded in the database created in automatic mode, with the use of "ranges" and "diagrams" tools, there was investigated the dynamics of expansion of oncological diseases in Kryvyi Rih city in 2007 (figure 1,2).

2. BACKGROUND

Kryvyi Rih is one of the cities with high risk of oncological diseases and which count is constantly growing. According to the results of previous author's research [10], the highest intensity of oncological diseases in Kryvyi Rih was observed in the Southern and Central parts of the city, where, there are the most powerful emission sources – metal manufacturers, by-product coke plants, mining enterprises, cement plants.

In view of this, we concentrated considerable attention on the Southern (metallurgical) environmentally-geopathogenic zone of Kryvyi Rih, which is comprised of 76 hospital sites of Dovhyntsivskyi, Metallurgical and a part of Central-City districts with prevalence of neoplastic diseases, related to metallurgy, coke chemistry cement industry, and benign neoplasms of skin and mammary glands.

As is seen from the cartogram (figure 1) the highest values of oncological morbidity (45-97 cases per 2000 inhabitants in 2007 are observed on the territory of the following hospital sites: 1–11 of Dovhintsivska city hospital; sites 1–16 of city hospital № 2; sites 1–16 of city hospital № 4; sites 1–16 of city hospital № 9.

The diagram (figure 2) demonstrates that in the structure of neoplastic diseases skin cancer commands the largest part in the hospital sites mentioned above (up to 80% of all cases). Remaining – 25% are almost equally distributed between neoplasms of mammary glands and female genital organs. At the same time, almost at all sites of Dovhintsivskyi city hospital, one can observe oncoanomaly of female genital organs. It is of importance to note that both at most hospital sites of this hospital and city hospital № 4 a number of cases of neoplasm registration is record-breaking all over the city and reaches a value of 35 in cases of these three diseases.

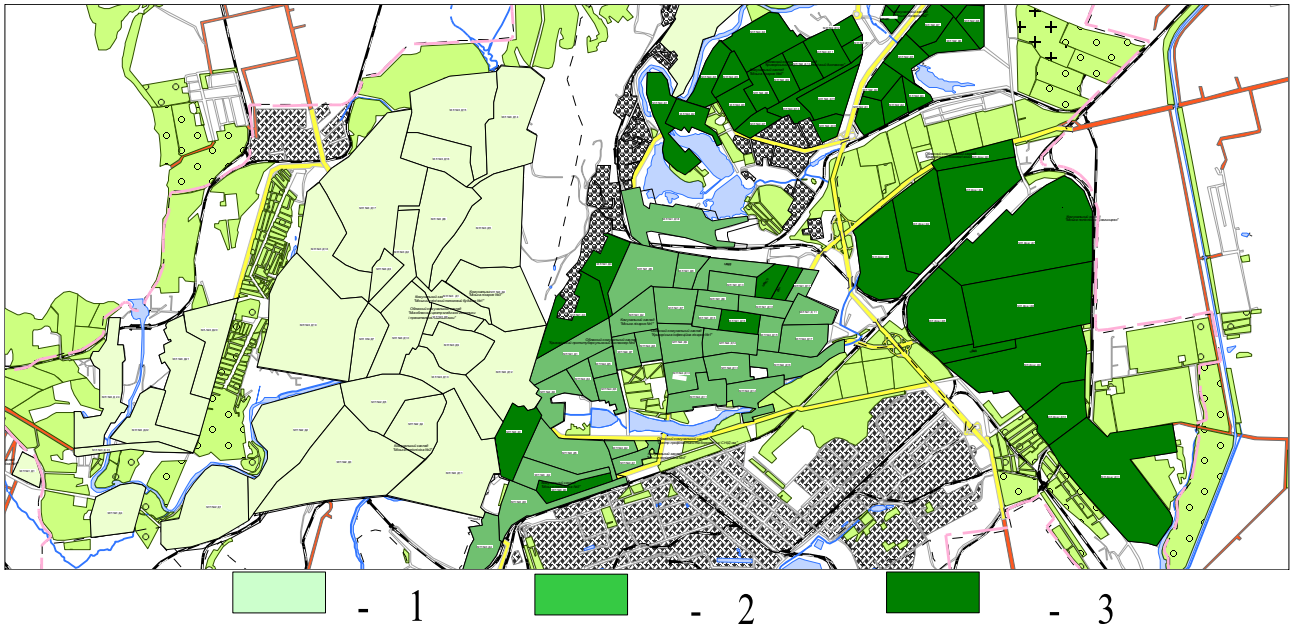

Figure 1 Cartogram of oncological morbidity through Kryvyi Rih in 2007 (fragment of the largest oncological anomalies). Map symbols: number of disease cases per 2000 inhabitants: 1–18-35; 2–36-44; 3–45-97.

Figure 2 Diagram of oncological morbidity through Kryvyi Rih in 2007 (fragment of the largest oncological anomalies). Map symbols: number of disease cases per 2000 inhabitants; Smaller circle – 3 cases, medium circle – 17 cases; larger circle – 35 cases. Red – skin neoplasms; green – neoplasms of female genital organs; blue – neoplasms of mammary glands.

The interpretation of morbidity dynamics in 2007, depicted in figure 1, 2, includes the following:

– the oncoanomalies, depicted in the cartographic models are in direct relationship to the distance to the largest metallurgical centre – "ArcelorMittal" enterprise with its closest industrial surroundings (coking plant, cement plant, red lead manufacturing plant);

– dynamics of progression of oncological morbidity in the region of interest may be in direct relationship to the prevailing airstream direction (southeast), as evidenced by morbidity structure, where skin cancer dominates;

– the majority of the inhabitants of related hospital sites work at the enterprises of the largest metallurgical centre – "ArcelorMittal" enterprise with its closest industrial surroundings (coking plant, cement plant, red lead manufacturing plant).

To establish spatiotemporal tendencies of oncological morbidity development, comparative data using, the authors investigated dynamics of these diseases in 2017 (figure 3).

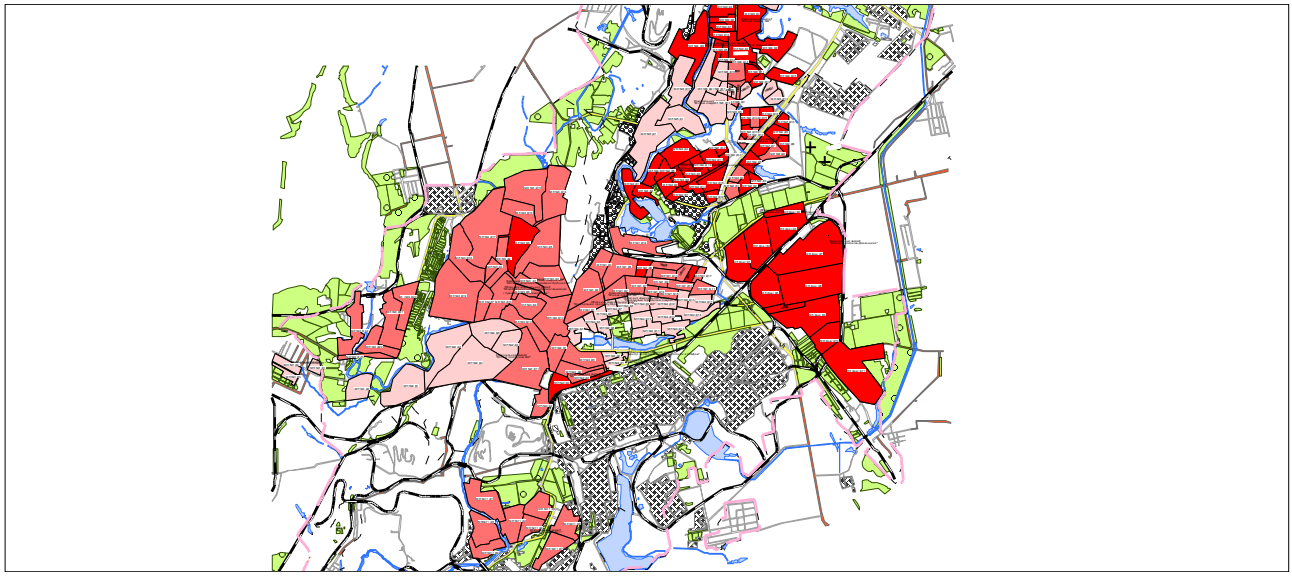

Figure 3 Diagrammatic chart of oncological morbidity spread through Kryvyi Rih in 2017 (fragment of the largest oncological anomalies). Map symbols: number of disease cases per 2000 inhabitants: number of disease cases per 2000 inhabitants; Smaller circle – 5 cases, medium circle – 25 cases; larger circle – 50 cases. Yellow – skin neoplasms; blue – neoplasms of female genital organs; green – neoplasms of mammary glands.

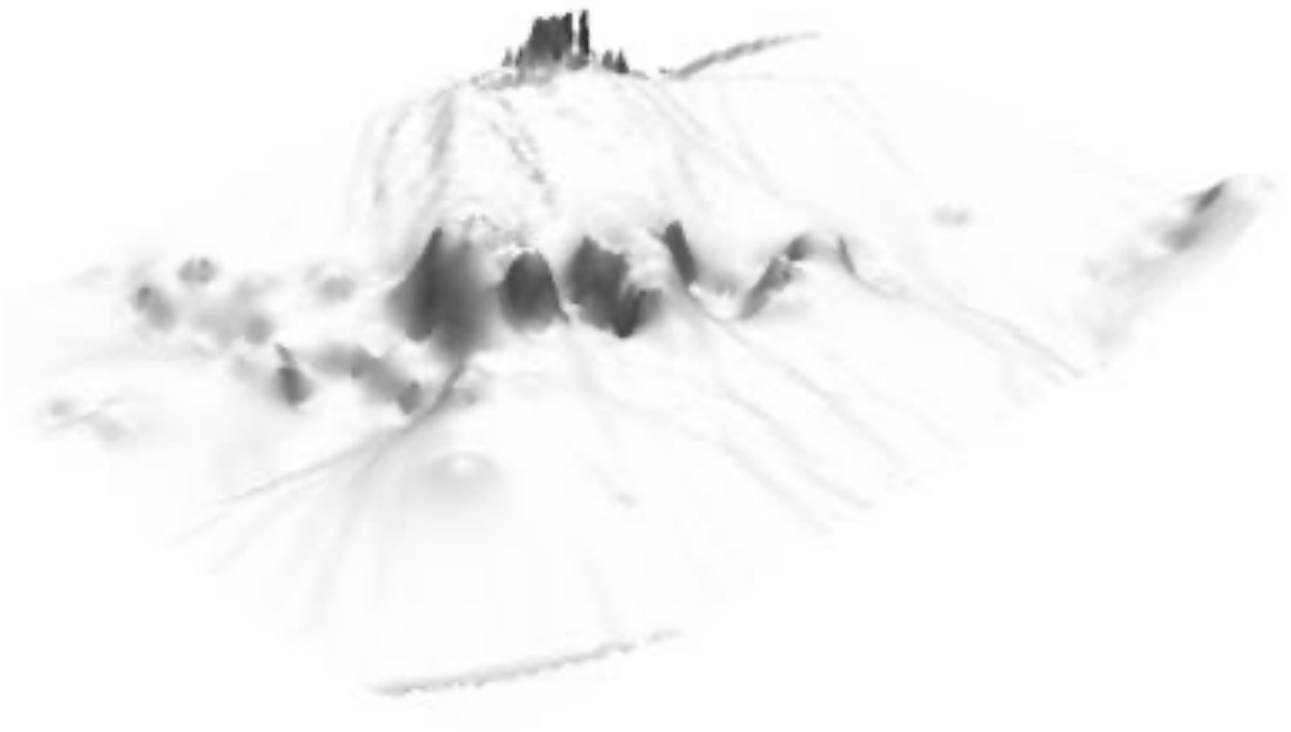

Figure 4 3-D model of oncological morbidity spread in Kryvyi Rih in 2017 (peaks of conditional relief are aligned with the largest oncoanomalies).

Joint data analysis, shown in figures 1, 2 and 3, 4 allows for the following conclusions:

– over a 10-year period (from 2007 to 2017 yrs.) spatial localization of oncoanomalies in Kryvyi Rih sustains the trends, primarily, concentration of its chief peaks in Southern metallurgical and Northern mining-industrial environmentally-geopathogenic zones (figures 1,2,3,4). It is of importance to note that this tendency appeared in 2007 (figures 1,2), was confirmed in 2009 [10], and "consolidated" in 2017.

– comparing the diagrams in figure 2 and figure 3 it can be affirmed that in the past 10 years dynamics of oncological morbidity progression has worsened. Thus, in 2007 among the sick with only three types of diseases (skin cancer, cancer of female genital organs and breast cancer) the

highest value was recorded in 35 cases per 2000 inhabitants, and in 2017 their number reached 50.

– even the most conservative prognosis of dynamics of oncological morbidity among other oncological diseases, which data were not captured by the authors (lung cancer, liver cancer, pancreatic cancer, benign prostatic hyperplasia and others) allow to assume a dangerous situation, especially in Southern metallurgical environmentally-geopathogenic zone.

2. CONCLUSION

The research of dynamics of morbidity in neoplastic diseases in Kryvbas over the last 10 years (2007-2017) allows to entice into prognosis of epidemiological situation except for medical data and approaches, concepts and approaches in medical geography and human ecology. In a point of fact, specifics of urban environment of big cities can have an impact on the run of not only environmentally-dependant but socially-dependant population morbidity. Most notably:

1. There is a broad tendency for morbidity dependence on a peculiar configuration of Kryvyi Rih city, where, due to its stretched linear pattern, two almost autonomous centres are noticeable: Northern (with prevailing mining-ore and mining and concentrating industry) and Southern (except for the mentioned above, with metallurgy, coke chemistry, cement and pigment industry). Such household and socio-economic autonomisation to a large extent preconditions spatial tendencies of disease communication (figure 4). Such spatial "autonomisation" is evidenced by two sites of disese – Southern (with prevalence of "environmental" and "social" diseases) and Northern (with prevalence of respiratory diseases and allergic diseases, caused by high air dustiness as a result of blast-stripping operations in the open pits of Northern and Central MPP).
2. Taking into account a stretched linear pattern of the residential area in Saksahanskyi and Pokrovskyi districts (considering specific configuration of Kryvbas), spread of these diseases sustains the same linear spatial trend, which when using "buffer zone" GIS tool helps in disease localization while taking preventive and antiepidemic measures.
3. Close relationship of morbidity dynamics (both in space and time) with such strictly geographical categories as "space", "distance", "area" result in the fact that environmental factors can spatially "interfere" with social ones. In this case, together they induce appropriate synergy, acting multiplicatively and causing completely different negative effect. This preconditions high morbidity density in city districts, adjacent to Southern industrial hub with developed metallurgy, coke-chemical and cement production.
4. It is certain that spatial differentiation of separate diseases depends on demographic and naturally-geographical aspects of intrinsically-city districts. There was revealed a clear longstanding trend toward increase of skin neoplastic diseases among the inhabitants of Central-City district (adjacent to recreational zone of Karachunovske water reservoir) and growth of neoplasms of mammary glands among the inhabitants of Metallurgical and Dovhintsivskyi districts (in which fertility dynamics is higher compared to other districts). Notably, high confluence of morbidity in neoplasms and dissemination of lead in the soils of central part of Southern industrial hub are observed. Except for neoplasms in this district such "indicative" for lead disease as hepatitis is widespread [31], [37]. The highest morbidity in hepatitis (12 sick per 1000 inhabitants) is observed at more than a half of hospital sites in Metallurgical, Dovhintsivskyi and Saksahanskyi districts. Concerning neoplasms (25 sick per 1000 inhabitants) this tendency is brighter.
5. Among environmentally-caused diseases, neoplastic ones, in particular, stable tendency for growth over the period studied was revealed in the areas of Central-City, Metallurgical, Dovhintsivskyi and Saksahanskyi districts. Concurrently, a certain stability of neoplastic morbidity is typical for the area of Dovhintsivskyi district (23 individuals/1000 inhabitants in 2007 and 26 individuals/1000 inhabitants in 2017), which is directly adjacent to Southern industrial hub and, as a result of geographical specificity (windrose), contacts with emissions of metallurgical, coke-chemical, cement, chemical enterprises.
6. For the period from 2007 to 2017 there has been observed deterioration of municipal dynamics of morbidity in the diseases, related to degradation of atmospheric air quality. In a point of fact, these are: neoplasms, various allergic diseases, vegetative-vascular dystonia, bronchial asthma, bronchitis, various diseases of upper respiratory tract. Consequently, disease density (per 1000 inhabitants) has a tendency to decreasing in South-North direction (while distancing from Southern industrial hub) according to a known "centre-periphery". The negative trend indicated is preconditioned by restoration of ultimate capacity of the largest iron and steel enterprise in Europe "Arcelor-Mittal".

Future prospects of the research of the problem specified are in the development of appropriate practical guidelines. In a point of view, the data of the 3-D modeling performed can be used while planning top-priority preventive and medical measures, notably, conducting current and special medical examination, a system of special preventive actions, undertaken by district doctors, running purposeful campaigns promoting healthy lifestyle, informing population about a threat of environmentally-dependant diseases, et. al.

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