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CARDIOVASCULAR DISEASES IN UKRAINE UNDER CONDITIONS OF GLOBAL WARMING

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Purpose: to establish the relationship between cardiovascular diseases in Ukraine and an increase in the average annual temperature.

Materials and Methods. The data of the State Statistics Service of Ukraine on the number of cases of cardiovascular diseases from 1990 to 2013, as well as on the share of the urban and rural population in various regions for 1990, 2000 and 2013 were analyzed. Statistical data starting from 2014 were not used due to their absence from the temporarily occupied territories of Ukraine. Average annual temperatures were obtained from the global database – The Global Historical Climatology Network. With the help of the National reports on the state of the natural environment in Ukraine, atmospheric air pollution in the regions of Ukraine was assessed. Statistical processing of the obtained results was carried out using correlation and regression analysis with determination of the reliability of the approximation.

Results. A direct average correlation between average annual temperatures and the number of newly registered cases of cardiovascular diseases in Ukraine between 1990 and 2013 was established (correlation coefficient +0.5). After carrying out an analysis between the regions of Ukraine, it was established that in the regions with direct strong and medium correlations between the number of newly detected diseases of the circulatory system and average annual air temperatures (Dnipropetrovsk, Zaporizhzhya, Luhansk, Kharkiv, Donetsk, Autonomous Republic of Crimea, Kyiv, Sumy, Kherson, Odesa, Mykolaiv, Kirovohrad, Lviv, Zhytomyr regions) the urban population prevails, as well as a higher air pollution index. In other regions of Ukraine, where the rural population predominates, a weak straight line is established, as well as inverse correlation dependences and a lower level of atmospheric air pollution.

Conclusions. In recent decades, the average annual temperature of the environment has been increasing, which has a negative effect on human health, in particular on the cardiovascular system, causing its damage. Therefore, it is important to start acting now to avoid the negative consequences of global warming.

KEY WORDS: average annual temperature; cardiovascular diseases; urban and rural population; pollution index.

Cardiovascular diseases are one of the biggest problems of modern medicine. Their prevalence poses an extreme threat to human life and health, as it determines the main mortality of the population and increasingly affects young people [19]. According to the Global Burden of Disease (GBD) study for 2019, cardiovascular disease is the leading cause of death in Ukraine, according to which our country remains one of the world leaders [13].

The ambient temperature in Ukraine and the world has risen by almost 1.5 °C over the past 30 years [8]. An intergovernmental group of climate change experts has concluded that greenhouse gases such as carbon dioxide, methane and nitrous oxide have caused the average annual temperature of the Earth to rise [12]. The impact of particulate matter (PM) on the acceleration of global warming has also been proven, especially in cities and large cities, where pollution is greatest [10]. And the current military conflict, which has been ongoing in Ukraine since 2014, accelerates global warming and further limits the possibilities of an appropriate response to global climate changes, which contributes to the reduction of adaptation possibilities [9, 11].

Of greatest interest to medicine are the causes and modifiers of cardiovascular disease, a list of which can be found in the available literature [2, 6], but among them there is no data on the role of modern climate change in the spread of these diseases, although we live in global warming.

Global environmental changes caused by human activities and population growth are changing our planet in such a way that they pose a serious threat to human health, and it is projected that these threats will increase in the coming decades if no action is taken [17, 22].

Purpose: to establish the prevalence of cardiovascular diseases in Ukraine and its relationship with the increase in average annual temperature.

Materials and Methods. Data on the prevalence of diseases of the circulatory system are available on the website of the State Statistics Service of Ukraine [1]. The number of registered cases per thousand population from 1990 to 2013 was taken into account. Statistics have not been used since 2014 due to their absence from the temporarily occupied territories of Ukraine.

The data of the State Statistics Service of Ukraine [1] on the share of urban and rural population in different oblasts for 1990, 2000 and 2013 are also analyzed.

To assess the air pollution of the regions of Ukraine, the National Reports on the State of the Environment in Ukraine for 2004 and 2012 were analyzed [3, 4]. The Air Pollution Index was taken into account. This is a complex indicator that combines the levels of 31 pollutants in the atmosphere (suspended particles, sulfur dioxide, carbon monoxide, nitrogen dioxide, formaldehyde, phenol, ammonia, etc).

The average annual temperature is obtained from the global database of daily climate data – The Global Historical Climatology Network [14].

Statistical processing of the obtained information was performed using correlation and regression analysis to determine the reliability of the approximation [5] using Microsoft Exel and Statistica 12.

The research was conducted in accordance with modern requirements of moral and ethical standards in Ukraine and the world (minutes of the meeting of the Commission on Bioethics of I. Horbachevsky Ternopil National Medical University No. 67 from January 4, 2022).

Results. According to the State Statistics Service of Ukraine [1], in the pre-war period from 1990 to 2013 there was an increase in cardiovascular disease. Statistical regression analysis of the prevalence of diseases of the circulatory system clearly shows a progressive increase in the number of reported cases per thousand population from 1149 in 1990 to 2256 in 2013, as shown in Figure 1.

The increase in the number of established diseases of the circulatory system in the study period occurred against the background of negative population dynamics. The number of Ukrainians has decreased by almost 10 million at this time, as shown in Figure 2.

Analyzing the indicators of average annual temperatures obtained in the database of daily climate data – The Global Historical Climatology Network [14], it was found that the ambient temperature increases over the years. Figure 3 shows the increase in average annual temperature by more than 1.5 °C in 2013 compared to 1990.

The statistical analysis established a direct average correlation [5] between average annual temperatures and the number of reported cases of cardiovascular disease in Ukraine in the period from 1990 to 2013 (correlation coefficient +0.5, see Figure 4).

Correlation analysis between the number of registered cases of circulatory system diseases and the data of the average annual ambient temperature during 1990–2013 established direct strong and average correlations in such areas as Dnipropetrovsk (+0.8), Zaporizhia (+0.7), Luhansk (+0.7), Kharkiv (+0.6), Donetsk (+0.6), Autonomous Republic of Crimea (+0.6), Kyiv (+0.5), Sumy (+0.5), Kherson (+0.5), Odesa (+0.4), Mykolaiv (+0.4), Kirovohrad (+0.4), Lviv (+0.4) and Zhytomyr regions (+0.4) (See figure 5: a, b).

Weak direct correlation between the number of registered cases of cardiovascular diseases and data on average annual temperature was found in such regions as Vinnytsia (+0.3), Ternopil (+0.3), Ivano-Frankivsk (+0.2), Rivne (+0.2), Volyn (+0.2), Poltava (+0.2), Khmelnytsky (+0.2), Chernihiv region (+0.18). Weak inverse correlation was found in Zakarpattia (-0.01), Chernivtsi (-0.15) and Cherkasy regions (-0.02) (See Figure 6: a, b).

Thus, we have established a direct correlation between the average annual temperatures and the number of registered cases of cardiovascular disease in the period from 1990 to 2013. The search for these regularities by regions revealed dependencies ranging from direct strong correlations in Dnipropetrovsk, Zaporizhia, and Luhansk regions to their

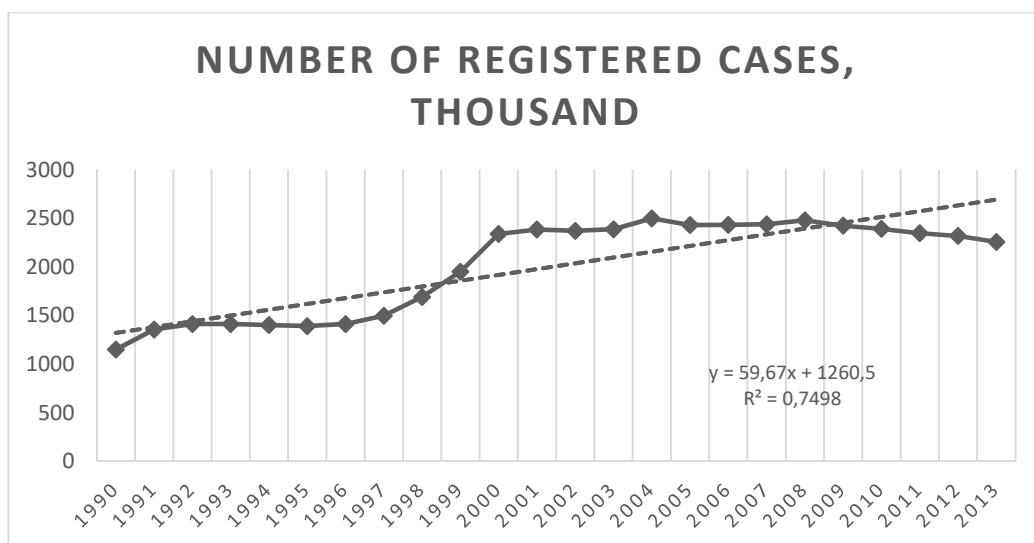


Figure 1. The number of registered cases of cardiovascular diseases in Ukraine for 1990–2013. The reliability of the approximation $R^2 = 0.7$.

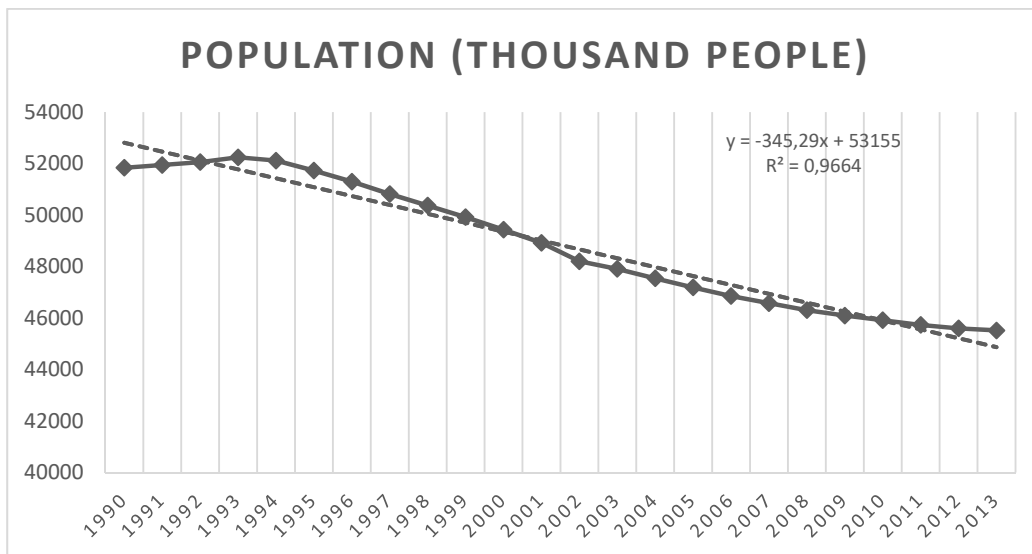


Figure 2. Population of Ukraine (1990–2013). The reliability of the approximation $R^2 = 0.9$.

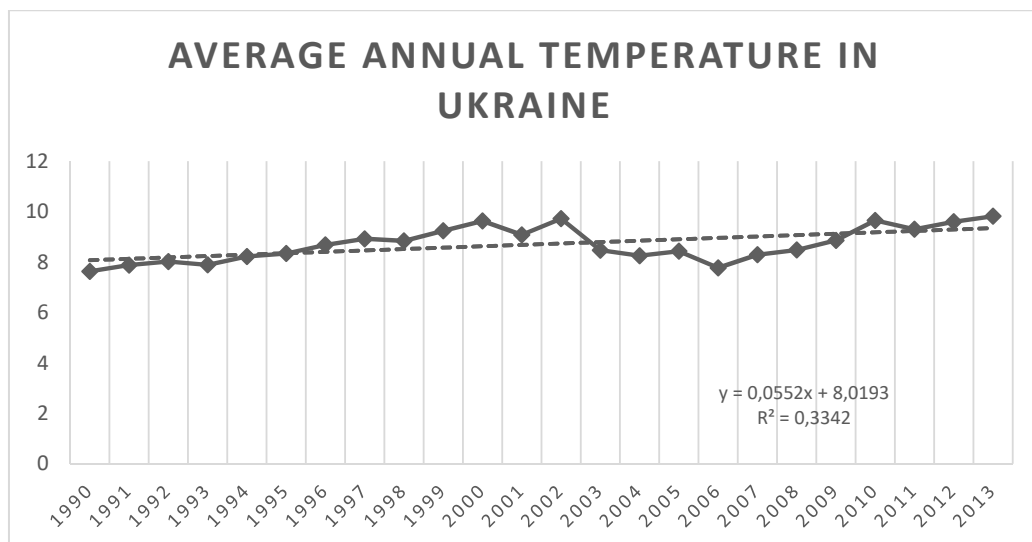


Figure 3. Data on the average annual temperature in Ukraine during 1990–2013.

weak inverse correlations in Zakarpattia, Cherkasy, and Chernivtsi regions.

To identify the impact of possible other factors that have led to such a variety of correlations by region, we conducted a study to examine the quantitative relationship between urban and rural populations and air pollution in them.

As a result of the analysis of the data of the State Statistics Service of Ukraine [1] on the share of urban population in different regions for 1990, 2000 and 2013, it was found that in Donetsk on average it was 90.5 %, in Luhansk – 86.5 %, in Dnipropetrovsk – 83.5 %, in Kharkiv – 79.5 %, in Zaporizhia – 76.5 %, in Mykolaiv – 67 %, in Odesa – 66.5 %, in Sumy – 65 %, in the Autonomous Republic of Crimea – 64 %, in Kirovohrad – 61 %,

Kherson – 60.5 %, Poltava – 60 %, Lviv – 60 %, Chernihiv – 59 %, Kyiv – 58 %, Zhytomyr – 56 %, Cherkasy – 55 % and Khmelnytsky – 53 %. At the same time, there was a tendency to reduce the rural population in them. In such regions of Ukraine as Volyn and Vinnytsia, urban and rural populations are distributed approximately equally. In Zakarpattia, Ivano-Frankivsk, Chernivtsi, Ternopil, Rivne regions there was a predominance of rural residents.

Comparing the above data, it was found that in oblasts with direct strong and medium correlations between the number of registered cases of circulatory system diseases and average annual ambient temperatures, the percentage of urban population ranges from 90 % in Donetsk to 56 % in Zhytomyr region. In

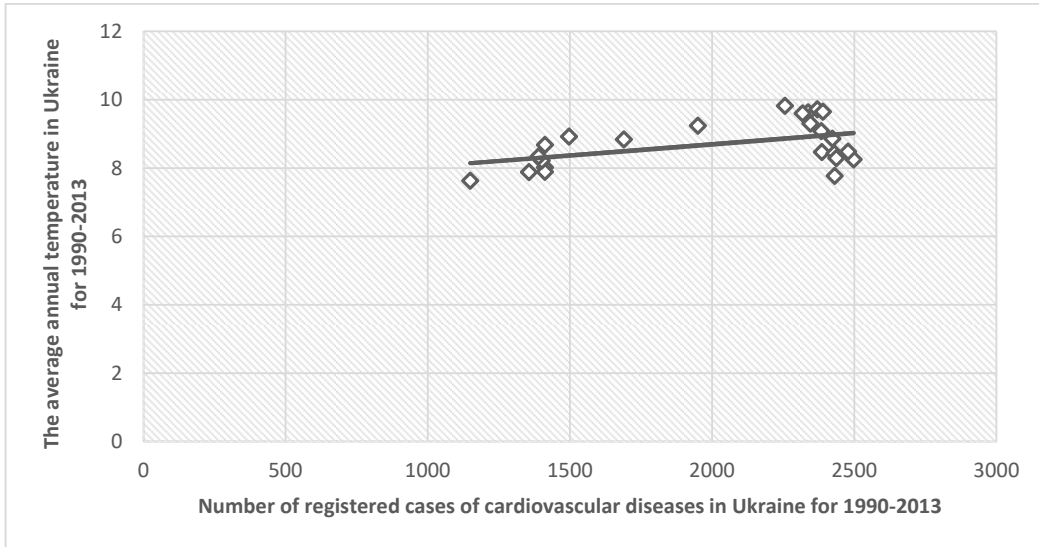
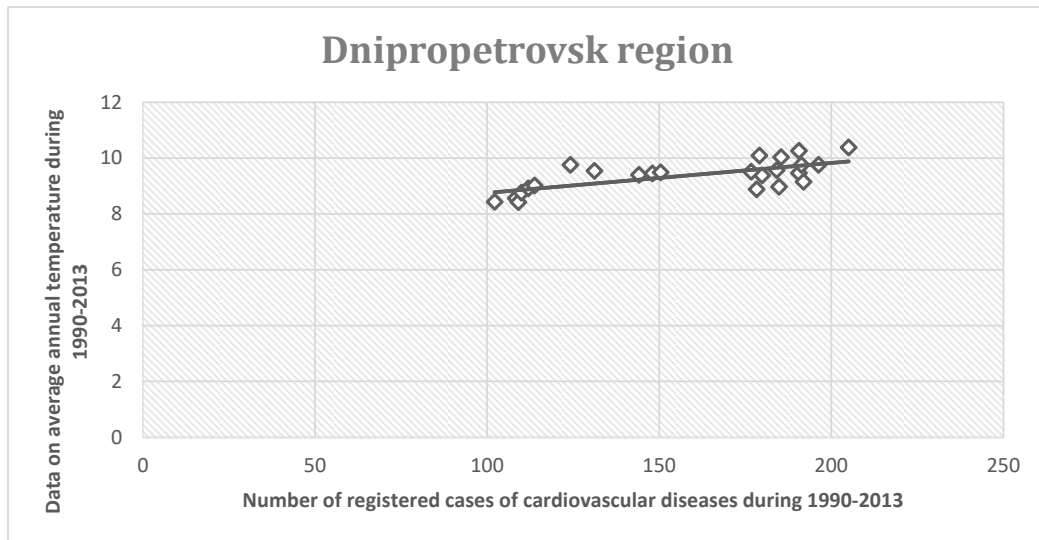
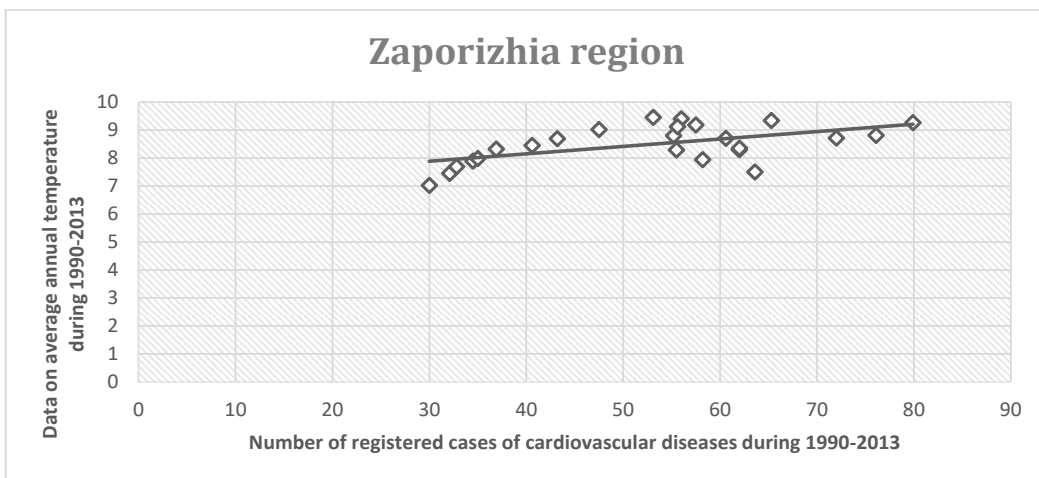


Figure 4. Correlation field of the relationship between the average annual temperature and the number of registered cases of cardiovascular disease in Ukraine (1990–2013). Correlation coefficient +0.5.

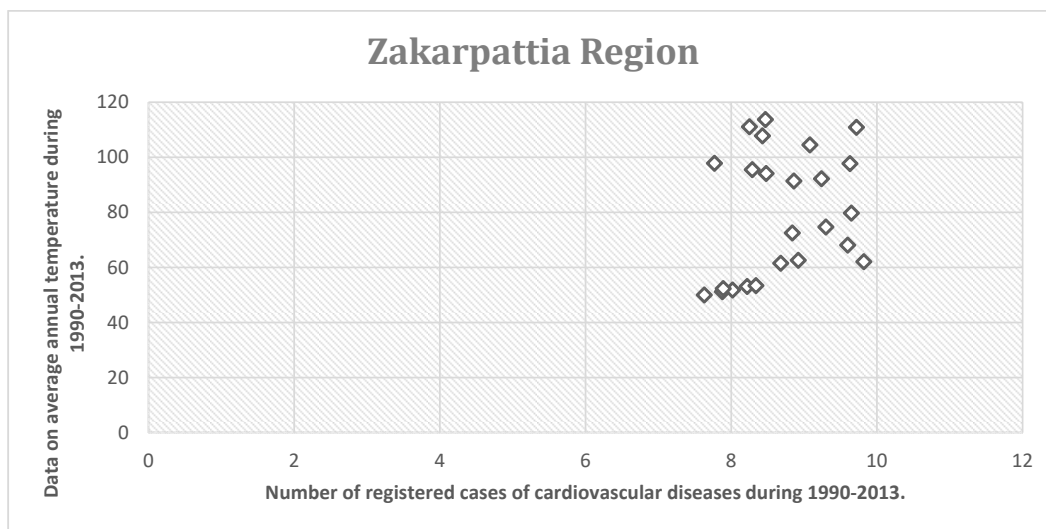


a

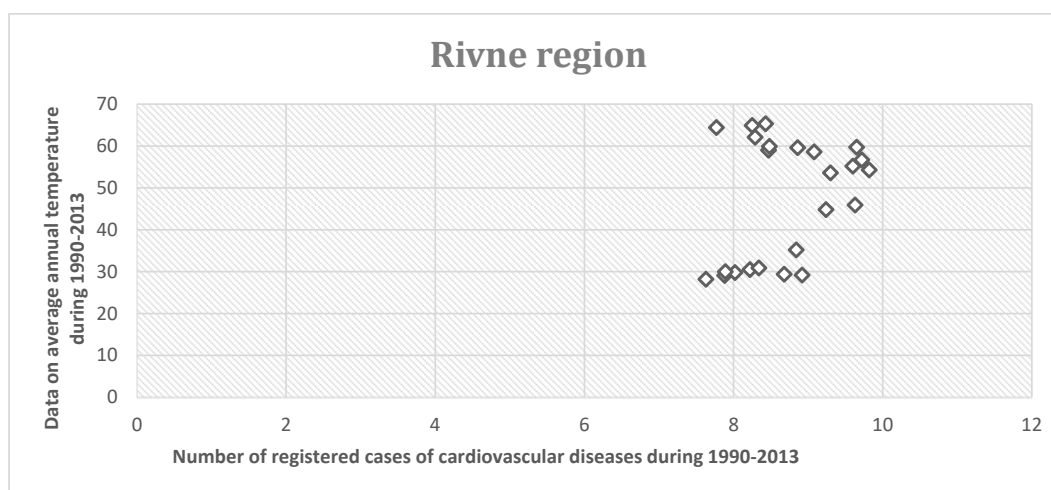


b

Figure 5. Correlation field between average annual temperature data and the number of registered cases of cardiovascular diseases during 1990–2013 in Dnipropetrovsk (a) and Zaporizhzhia (b) regions.



a



b

Figure 6. Correlation field between average annual temperature data and the number of registered cases of cardiovascular diseases during 1990–2013 in Zakarpattia (a) and Rivne (b) regions.

areas with weak, both direct and inverse, correlation, the urban population averaged 43–48 %.

Thus, according to our data, the following pattern is observed: in 13 regions and the Autonomous Republic of Crimea with strong and medium correlations between newly diagnosed circulatory diseases and average annual ambient temperature, the urban population predominates and vice versa, in 11 regions with weak both direct and indirect inverse correlation – rural.

Analyzing the air pollution of the regions of Ukraine according to the available National Reports on the State of the Environment in Ukraine for 2004 and 2012 [3, 4], its growth was established. Thus, if in 2004 the index of air pollution above the average was observed in 17 cities, in 2012 – in 24.

There is a link in areas with direct strong and medium correlations between cardiovascular disease

and average annual temperatures with significant levels of air pollution in their cities.

In accordance with the aim of the work, it was found that there is a direct correlation between the increase in average annual ambient temperature in global warming in the pre-war period and the prevalence of cardiovascular disease (correlation coefficient +0.5). The available literature describes a number of causes and risk factors for cardiovascular disease [2, 6], but among them there is no increase in ambient temperature as one of the risk factors for circulatory diseases. Our research confirms that the increase in the average annual ambient temperature leads to an increase in the number of cases of cardiovascular disease.

Thus, we see that the effects of climate change were felt in the pre-war period, and in the future they will intensify even more. Increasingly frequent and severe periods of heat, so-called “heat waves”, are

one of the main threats to human health today [18]. Mankind is able to adapt to the gradual increase in average annual temperature, and the rapid and prolonged periods of heat waves that occur during global warming, create an increased burden on the cardiovascular system [15].

After analyzing data from scientific sources on the impact of global warming on cardiovascular disease, it was found that endothelial dysfunction plays an important role in thermal damage to the cardiovascular system. Scientists have found that hot weather can impair the tone and structure of blood vessels due to various biological factors such as nitric oxide, cytokines and systemic inflammation [20]. Heat stress also leads to physiological reactions to changes in temperature, which leads to increased sweating, increased heart rate, dilation of superficial vessels and changes in coagulation. This can cause an imbalance in the autonomic regulation of the heart, increase blood pressure and worsen blood clotting reactions [16].

Analyzing the regularity established by us, in regions of Ukraine with strong and medium correlations between the number of registered cases of circulatory system diseases and average annual ambient temperatures, the urban population predominates and, conversely, in regions with weak both direct and inverse correlation, rural population, it can be argued that the inhabitants of megacities are more sensitive to rising temperatures. This pattern can be explained by the emergence of the so-called "heat island" effect, which is described in many literature sources. Experiments to measure air temperature in urban areas have shown that unshaded green spaces and unventilated surfaces of infrastructure, heated by direct sunlight, still radiate heat after sunset, which is not observed in suburban and rural areas. Reflected radiation slows down the night cooling of the air and significantly prolongs the time of overheating of the environment, which leads to the effect of "heat island" in cities and large cities [23]. The results of the study show that these heat islands cause unique problems in urban areas that are not typical of other types of human settlements and can further exacerbate the negative impact of heat waves on human health during periods of heat [18].

We also found higher levels of cardiovascular disease in the areas with strong and medium direct correlations between the number of reported cases of cardiovascular disease and average annual ambient temperatures, with an urban predominance compared to rural areas. This can be explained by the impact of particulate matter (PM) and greenhouse

gases (carbon dioxide, methane, nitrous oxide) on the acceleration of global warming in cities and major cities, where pollution is greatest. The literature also confirms the relationship between particulate matter concentration and cardiovascular mortality [10].

In view of the above, it can be argued that the average annual ambient temperature has been rising in recent decades, adversely affecting human health, in particular the cardiovascular system, causing damage. It is therefore important to act now to avoid the negative effects of global warming. Ukraine, together with other countries, must actively implement policy measures to reach the Paris Agreement within the framework of the UN Framework Convention on Climate Change [7]. It is important to take into account the increase in the spread of cardiovascular diseases in Ukraine under conditions of global warming, as a prerequisite for secondary prevention of diseases of the circulatory system. It should not be forgotten that people differ in their sensitivity to environmental influences, and those with increased sensitivity are at risk.

Conclusions

1. In Ukraine from 1990 to 2013 there was an increase in the incidence of cardiovascular disease against the background of increasing average annual air temperature.

2. There is a direct correlation between the average annual temperatures and the number of newly registered cases of cardiovascular diseases in Ukraine in the period from 1990 to 2013 (correlation coefficient +0.5).

3. In regions of Ukraine with direct strong and medium correlations between the number of newly registered cases of circulatory system diseases and average annual air temperatures, the urban population predominates, and vice versa, in regions with weak both direct and inverse correlation – rural.

4. Atmospheric air in cities with strong and medium direct correlations between the number of newly diagnosed cases of cardiovascular disease and average annual ambient temperatures, with a predominance of urban population, is characterized by significant pollution compared to areas with a predominance of rural population.

Prospects for further research are aimed at monitoring the effects of an increase in the average annual temperature of the environment on the activity of the human cardiovascular system. If we consider climate change as one of the risk factors for the development of diseases of the circulatory system, then these negative consequences can be partially measured and avoided.

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СЕРЦЕВО-СУДИННІ ЗАХВОРЮВАННЯ В УКРАЇНІ В УМОВАХ ГЛОБАЛЬНОГО ПОТЕПЛІННЯ

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Мета: встановити взаємозв'язок серцево-судинних захворювань в Україні із підвищенням середньорічної температури.

Матеріали і методи. Проаналізовано дані Державної служби статистики України щодо кількості випадків серцево-судинних захворювань з 1990 по 2013 рік, а також щодо частки міського і сільського населення у різних областях за 1990, 2000 та 2013 роки. Статистичні дані, починаючи від 2014 року, не використовувалися у зв'язку з їх відсутністю з тимчасово окупованих територій України. У світовій базі даних – The Global Historical Climatology Network – отримано показники середньорічних температур. За допомогою національних доповідей про стан навколишнього природного середовища в Україні оцінювали забрудненість атмосферного повітря регіонів України. Статистичну обробку отриманих результатів проводили за допомогою кореляційного та регресійного аналізу з визначенням достовірності апроксимації.

Результати. Встановлено прямий середній кореляційний зв'язок між середньорічними температурами та кількістю вперше зареєстрованих випадків серцево-судинних захворювань в Україні в період із 1990 по 2013 рік (коефіцієнт кореляції +0,5). Після проведення аналізу між регіонами України встановлено, що в областях із прямими сильними та середніми кореляційними зв'язками між кількістю вперше виявлених хвороб системи кровообігу і середньорічними температурами повітря (Дніпропетровська, Запорізька, Луганська, Харківська, Донецька, Автономна Республіка Крим, Київська, Сумська, Херсонська, Одеська, Миколаївська, Кіровоградська, Львівська, Житомирська області) переважає міське населення, а також більший індекс забруднення атмосферного повітря. В інших областях України, де переважає сільське населення, встановлена слабка пряма, а також обернена кореляційні залежності і нижчий рівень забруднення атмосферного повітря.

Висновки. Протягом останніх десятиліть зростає середньорічна температура навколишнього середовища, що негативно впливає на здоров'я людей, зокрема на серцево-судинну систему, викликаючи її ураження. Тому важливо починати діяти зараз, щоб уникнути негативних наслідків глобального потепління.

КЛЮЧОВІ СЛОВА: середньорічна температура; серцево-судинні захворювання; міське та сільське населення; індекс забруднення.

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