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CAUSES, CONSEQUENCES AND PERSPECTIVES OF INCREASING AVERAGE AIR TEMPERATURE IN THE WORLD, UKRAINE, AND KIEV

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The causes, consequences and perspectives of increasing average air temperature in the world, Ukraine, and Kiev are discussed. It is shown that the increase of the global temperature leads to the polar ice melting and thermal expansion of the ocean water, which provokes the floods, changes in the duration of seasonal processes and natural disasters.

Global climate change, which is characterized by the changes of temperature regime and warming, occurs also in Ukraine. This phenomenon is especially acute due to urbanization.

The serious obligations under the Framework Convention, the Kyoto Protocol and the Copenhagen resolution are required to prevent the impact of climate change.

Keywords: climate change, air temperature, consequences

Climate change is a variation of climatic parameters of the Earth's atmosphere as a whole or its separate regions over time. This process is accompanied by changes of global temperature due to natural variability or human activity.

The **Objective of this Article** is the study of the causes, consequences and perspectives of increasing average air temperature in the world, Ukraine, and Kiev.

The **Materials and Methods**. The analysis of long-term meteorological observations; data of the Intergovernmental Panel on Climate Change (IPCC) regarding the increase of global temperature of the Earth’s surface; statistics on the amount of urban population and the results of meteorological research of Central Geophysical Observatory of Ministry of Emergency Situations of Ukraine on the temperature changes in Kiev during the last century were used for this investigation; the mechanisms of the greenhouse effect, in particular, the interaction of molecules of greenhouse gases with infrared radiation of the Earth’s surface aree proposed.

The **Presentation of the Basic Material.** The main reasons that cause the climate change, include the geometry and orbital variability of our solar system due to solar flares, solar wind and storms, the eccentricity of the Earth's orbit, and rising concentrations of greenhouse gases due to human activities.

The Sun with its surface temperature 6000 K emits the shortwave radiation with wavelengths in the range 200-5000 nm and peak at about 500 nm.

The Earth's surface acts as a blackbody with its own temperature of 288 K. Thus, this blackbody emits the longwave infrared radiation with wavelengths in the range 4-50 μm and peak at about 10 μm.

Human activity leads to increasing atmospheric gases such as CO_2, N_2O, CH_4, CFCs. The specific peculiarity of these gases is their ability to absorb optical radiation in infrared part of spectrum. The infrared radiation of the Earth's surface is absorbed by the atmospheric gases and clouds and doesn't escape to space. The atmospheric gases usually have nonlinear molecular structure, possess electric dipole and absorb longwave radiation of the Earth.

The temperature at which solar radiation equals outgoing infrared radiation, is called *radiative equilibrium temperature* which is 255 K or -18^0 C [11. The average ground-level air temperature is 15^0 C that is more than 30^0 C higher than the radiative equilibrium temperature as soon as the greenhouse gases absorb infrared radiation (Fig. 1). The radiation that is warming the lower atmosphere called the *greenhouse effect.*

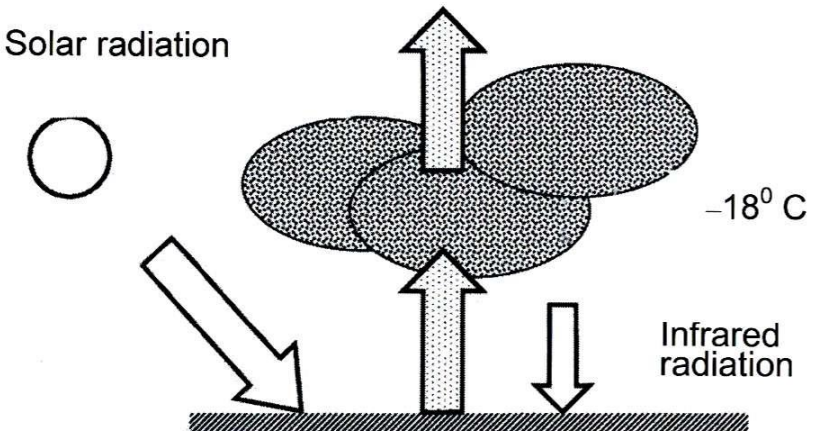

Fig. 1. **Infrared radiation that is directed dawnward by greenhouse gases [11]**

Thermal long-wave radiation is absorbed by the Earth's atmospheric gases; it plays the role of window glass in the greenhouse [7].

Molecules of greenhouse gases are characterized by a dipole moment, which is determined by the spatial displacement of electric charges and makes possible the absorption of optical radiation by these molecules.

Electric dipole is a system consisting of two identical opposite point charges (+*q*,–*q*), which are located at some distance *l* from each other. The displacement vector $\vec{l}$ is directed along the axis of the dipole from the negative to the positive charge; its modulus is equal to the distance between them.

The main characteristic of the electric dipole is its moment $\vec{p}$, which is equal to the product of the charge and the displacement vector pointing from the negative charge to the positive charge $\vec{p} = q\vec{l}$.

Such asymmetric molecules as H_2O and O_3 have an electric dipole moment and can absorb optical radiation.

The non-polar diatomic molecules such as nitrogen and oxygen, devoid of electric dipole moment due to their linear structure even during the ocillations of atoms; therefore they do not participate in the process of absorption of electromagnetic radiation.

The carbon dioxide molecule is linear and centrosymmetric, that’s why the molecule has no electrical dipole. But several vibrational bands are observed in the infrared spectrum – an asymmetic stretching mode and a bending mode (Fig.2).

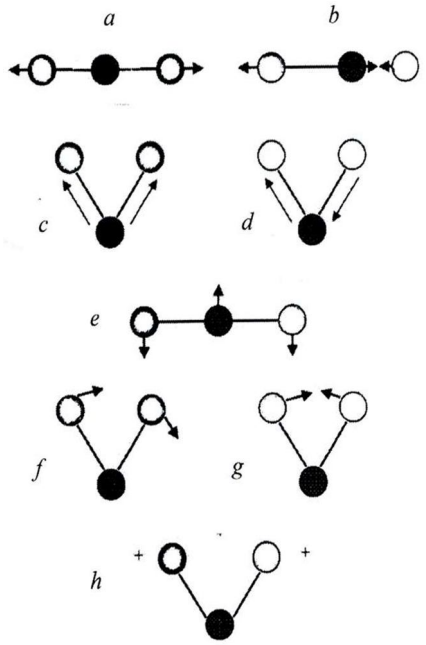

Fig. 2. **The main types of molecular vibrations**: *a* – symmetric stretching; *b* –asymmetric stretching; *c* – symmetric bond stretching; *d* – asymmetric bond stretching; *e* – bending; *f* – in-plane rocking; *g* – in-plane scissoring; *h* – out-of-plane wagging

In methane CH_4 which demonstrates the central symmetry, the dipole moment also occurs due to stretching and bending vibrational modes. The spatial displacement of electric charges induces the electric dipole moment of this molecule.

As a whole, molecules of typical atmospheric gases are characterized by the following values of the electric dipole moment (in Debye): nitrogen (0), oxygen (0), ozone (0.53), carbon monoxide (0.112), oxides of nitrogen (0.17), water vapor (1.85).

The greenhouse gases provide temperature 15^0 C, which is comfortable for the inhabitants of the Earth. However, the concentration of these gases increases and leads to the disruption of thermal balance, increase of global temperature of the Earth's surface and corresponding climate change.

The global temperature of the Earth's surface increased to $0{,}74^0$ C ± $0{,}18^0$ C during 1906-2005 according to the The Intergovernmental Panel on Climate Change (IPCC) [3].

The IPCC Fourth Assessment Report (2007) proposed six possible scenarios which characterize carbon dioxide emissions in the 21th century (Fig. 3) [11].

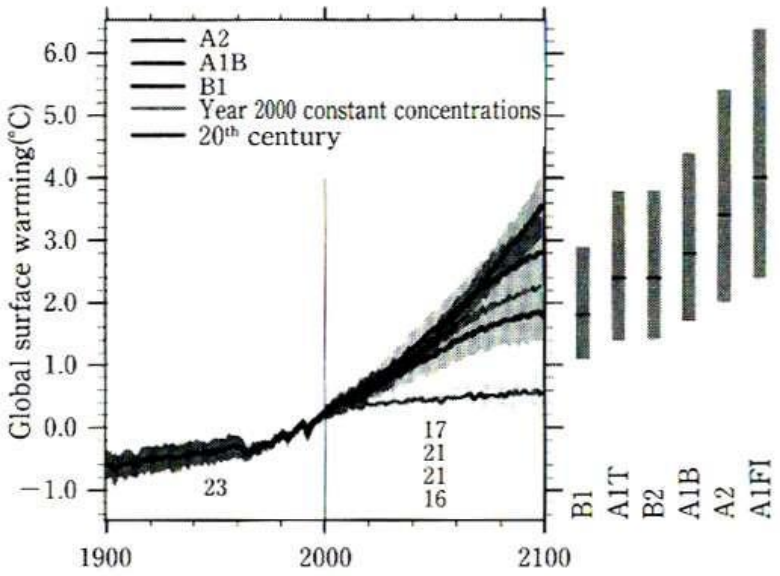

Fig.3. **Four possible scenarios which characterize carbon dioxide emissions in the 21th century[11**

B1 is the “sustainable development society scenario," which reconciles environmental conservation and economic growth worldwide; B2 is the "regional coexistence society scenario", which has somewhat low economic growth, and wherein solutions to environmental problems are pursued within each locality; A1 is divided into A1F1, which is dependent on fossil fuels, A1T, which emphasizes non-fossil fuels, and A1B, which strives toward a balance of energy sources. Of the six scenarios, A2 and A1FI have high CO_z emissions, which at the end of the 21st century are assumed to be about three times those at the close of the 20th century [12]. The B1 scenario has the lowest CO_2 emissions, which would increase up to about 2040, but then decline and reach about 60% of current emissions at the end of the 21st century.

The predictions of the changes of temperature during 100 years are: 2^0 C according to the B1 scenario; 3^0 C – A1B scenario; 4^0 C – A2 scenario.

The temperature rise leads to the melting of polar ice. Sea ice is formed when ocean water freezes. This process occurs for salty seawater at minus $1,8^0$ C. Glacier melting reduces the size of the Arctic region. Prediction of climate change in the

Arctic region suggests the lack of ice in the Arctic Ocean in summer period between 2060 and 2080, or in 2030 according to other estimations.

In addition, the release of methane from permafrost zones is quite possible due to the global warming.

Observations from satellites have shown that the loss of ice mass increased from 137 Gt/yr to 286 Gt/year for the period 2002-2009 with an average speed 30 Gt annually.

The area of ice cover decreased by 42% and volume by 40% during 2005-2008; the loss of ice was about 6300 km^2.

The ice cover in summer season will reach a minimum at the end of the XXI century. Abnormal reduction of ice cover in the Arctic in 2007 is a clear evidence of the need to develop accurate and reliable models of climate prediction.

Loss of terrestrial ice sheets of Greenland and Antarctica is very likely (> 90%) induced the sea level rise in the period 1993-2003. Increasing global temperature leads to thermal expansion of the ocean volume and imminent sea level rise with an average annual rate of 18 cm in 1961-2003 and 31 cm in 1993-2003. So, the main factor, responsible for sea level rise, is the thermal expansion of sea water as a result of global heating.

The temperature rise provokes the floods in the areas that are inhabited by hundreds of millions of people, coast erosion, flooding, inhibitiion of the processes of formation of primary production, changes in the quality of surface and groundwater, increasing the duration of seasonal thawing of soil, the deterioration of forests located in the permafrost zone. Global warming is the cause of such disasters as hurricanes, tsunami and droughts. Climate change may lead to population migration [8].

Ukraine also suffers from the effects of global climate change, which are characterized by increasing temperature and warming. The experts of the Ukrainian Research Hydrometeorological Institute stated that a general tendency to increase of air temperature about 0.3-0.7^0 C was observed in Ukraine in the twentieth century [1].

It is necessary to mention 43 years of drought in Ukraine during XX century, the shortening and warming of the winter seasons, more frequent events of flooding

(especially in the South of Ukraine), floods (in Transcarpathian region), significant icing (in central and southern regions). The Black Sea rise will provoke the degradation of deltas of such rivers as Danube, Dnieper, Dniester.

Global warming is the cause of floods. So, torrential rains and hurricanes in Central and Eastern Europe, which began on July 22, 2008, led to a sharp rise of the water level in the rivers Dniester and Prut and devastating floods in Ukraine, Moldova, Romania, Slovakia, and Hungary. About 25 thousand inhabitants of Lviv, Zakarpattia, Ivano-Frankivsk, Ternopil, Chernivtsi, Vinnytsia regions (the western regions of Ukraine) were forced to leave their homes due to the flooding. In general, water flooded about 523 Ukrainian towns and more than 24 thousand hectares of farmland. Nine thousand houses, 360 roads and 560 pedestrian bridges were destroyed. Western Ukraine losses from the disaster were estimated at 650-870 million dollars according to the UN News Center.

The number of towns and villages of Ukraine with constant displays of flooding (raising the water level to dangerous levels) doubled during the last 20 years – from 265 to 541. The total flooded areas in these settlements increased from 88.6 thousand to 196.2 thousand hectares. Extremely acute problem of flooding of lands was in the Kherson, Nikolaev, Zaporozhye, Dnepropetrovsk, Donetsk, Lugansk, Odessa regions and Crimea during recent years, especially in winter 1998.

In June 1992 at the UN Conference on the Environment (Rio de Janeiro, Brazil) 155 countries, including Ukraine, signed the UN Framework Convention on Climate Change. The Kyoto Protocol – an international agreement, which coordinates international efforts to limit emissions of gases that cause global warming, was signed in December 1997.

Currently, the Kyoto Protocol is ratified by more than 160 countries, including Ukraine (February 2004). These countries must reduce the total average emissions of six types of gases (CO_2, CH_4, N_2O, SF_6, hydrofluorocarbons HFCs and perfluorocarbons PFCs) between 2008-2012 compared with the level of 1990 by 5.2%.

Ukraine can throw into the atmosphere each year about 925 million tons of greenhouse gases according to this document. However, this volume of industrial

emissions was carried out last time in 1990, when it fell twice after the collapse of the USSR. Ukraine can realize this unused portion of quota which will exceed 2.2 billion tons in 2008-2015.

But although Ukraine actively involved to solve climate problems and inspite of the fact that greenhouse gases emission decreased significantly, it should be noted that the real reason for this reduction is a sharp fall of industrial production in Ukraine, limited energy resources, outdated technological equipment and deformed industrial infrastructure.

The implementation of the Kyoto Protocol mechanisms in Ukraine is the prerogative of the National Environmental Investment Agency of Ukraine. However, the activity of Ukrainian government is one-sided according to the opinion of social experts [6].

The United Nations Climate Change Conference in Copenhagen, Denmark took place from 7-19 December 2009 [5]. The objective of this meeting was the adoption of new agreement to replace the Kyoto Protocol in 2013. But negotiations delayed due to the reluctance of committing and reduced greenhouse gas emissions.

However, although the number of countries announced intention to reduce greenhouse gas emissions, the official position of Ukraine foresees the increase of emissions in 2020 by 70% compared to 2008 [9,10].

Global climate change observed on the Earth, could not avoid Kiev also. The temperature level in Kiev during last decade exceeds the global temperature of the Earth's surface. Available information shows that the average annual temperature of air in Kiev was 7.1^0 C in 1881-1960; 7.7^0 C in 1961-1990, and 8.6^0 C in 1991-2007 [9].

The results of measuring air temperature in Kiev during 40 years are presented in Fig. 4.

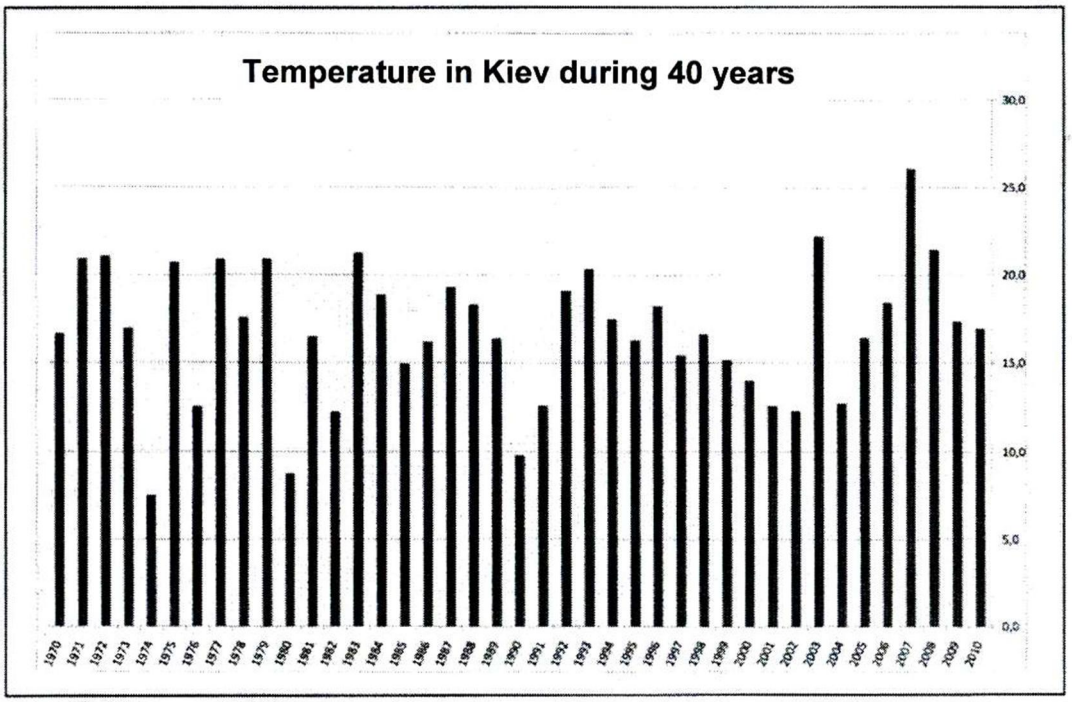

Рис.4**. The change of the air temperature in Kiev during 40 years**

The magnitude and spatial distribution of temperature depends on such factor as urbanization, that is accompanied by the growth and development of urban settlements and increasing the proportion of the urban population. Analysis of statistical data shows that the urban population in Ukraine increased from 45.7% in 1959 to 67.2% in 2001, while the rural population decreased from 54.3% in 1959 to 32.8% in 2001 [2].

The average population of the city in January-October 2012 included 2,823,328 inhabitants (recall that 626,000 people lived in Kiev in the early twentieth century, and 2,786,518 people in the early twenty-first century according to the Central Statistical Office in Kiev) [4] .

The temperature regime of Kiev is influenced by city topography (width and orientation of the city streets, the structure and heterogeneity of buildings), the presence of artificial surfaces (asphalt, paving, concrete), green areas, the water reservoirs, character of aerodynamic profile (speed and direction), the interaction of the solar radiation with the surface of the city, purity or contamination of urban air.

Typical for Kiev situation is related with the formation of so-called “heat islands” – zones of increased concentration of industrial and construction sites,

buildings and population. Temperature in these areas throughout the year is a few degrees higher than in the surrounding areas.

Let's consider the perspectives of further increase of air temperature in Kiev. Suppose that the temperature rise 3^0 C over the next 100 years will correspond to scenario A1B.

Consider the typical character of air temperature in Kiev (lower curve in Fig. 5). The period of low (less than 0^0 C) daily temperature T> in the winter lasts 2-3 months, and high (over 20^0 C) daily temperature T> in the summer lasts 2 months. Assuming an increase of average air temperature at 3 ^{0}C, the the duration of the cold period at temperature T> + 3^0C in winter will fall to 1 month, and the duration of warm period increase of average air temperature at 3 ^{0}C, the the duration of the cold period at T> + 3^0C in summer will increase to 3.5 months (upper curve in Fig. 5).

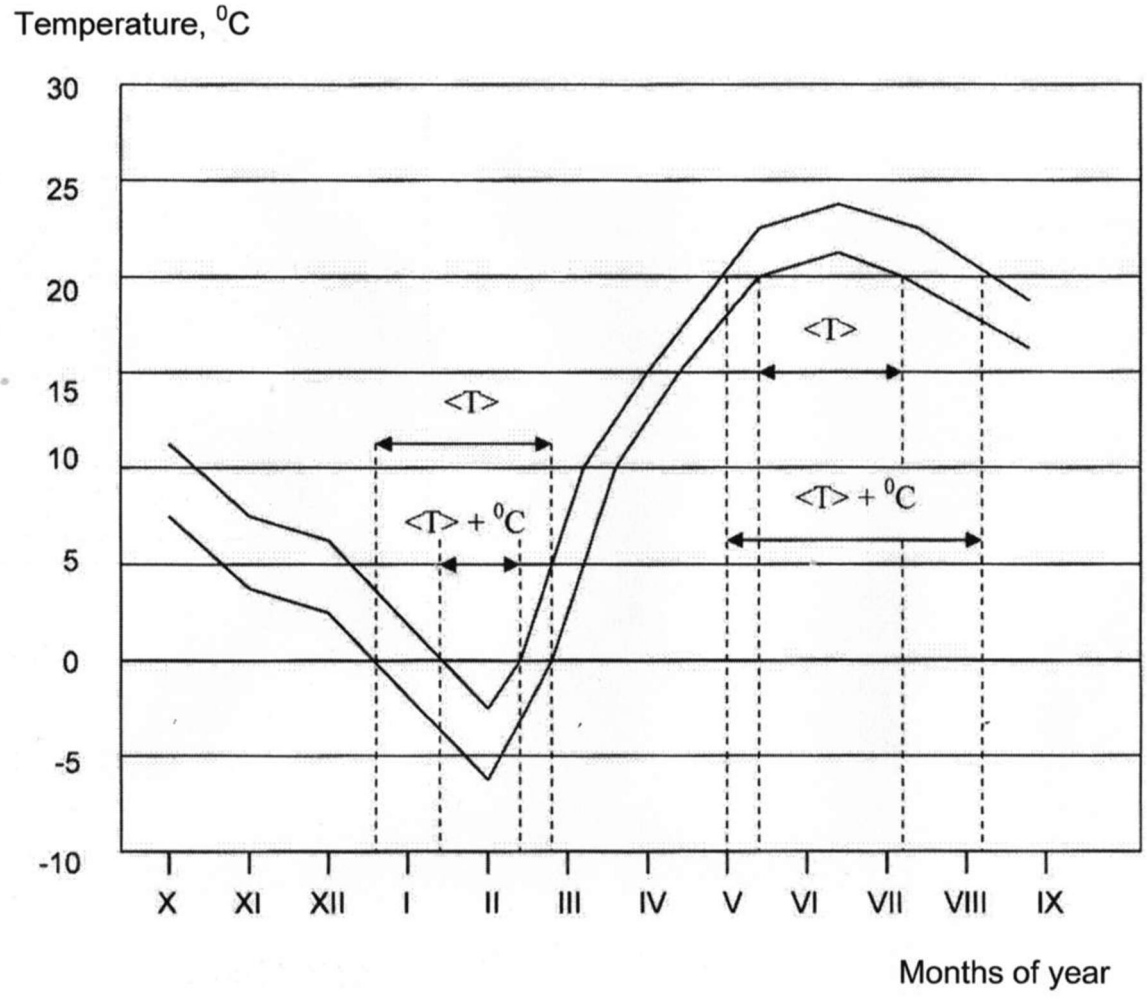

Fig. 5. **Typical character of seasonal change of daily temperature in Kiev in current period of time (lower curve) and over the next 100 years if the temperature rise 3^0 C will take place (upper curve)**

This tendency is confirmed by meteorological observations in Kiev: so, in 2008 the annual temperature rate exceeded 1,9° C the standard climatic rate which was calculated for the period 1961-1990 and was recognized by the World Meteorological Organization. This fact confirms the changes of the global climate.

Conclusions. Thus, the population growth and urbanisation are characterised with such environmental impacts as increasing release of carbon dioxide, temperature rise, global warming. Increased global temperature leads to the melting of polar ice and thermal expansion of the ocean volume that could ultimately lead to an increase in sea level. The population and environment will put at risk of flooding areas, natural disasters, economic losses and casualties.

The increase of the air temperature in Kiev during recent decades is greater than the global temperature of the Earth's surface.

It is necessary to develop and realise a national strategy for the implementation of Ukraine's commitments under the UN Framework Convention, the Kyoto Protocol and the Copenhagen resolution to prevent the impacts of climate change.

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References

1. Барабаш М. Зміна клімату при глобальному потеплінні/Барабаш М., Гребенюк Н., Татарчук О. // Водне господарство України. – 1998. – №3. – С.9-12.

2. Всеукраїнський перепис населення 2001 Результати / Кількість та територіальне розміщення населення / Графічний матеріал. http://2001.ukrcensus.gov.ua/results/total_population1/graphic/

3. Зміна клімату, 2007, четверта доповідь Міжурядової групи експертів зі зміни клімату. Fourth Assessment Report: Climate Change 2007. http://en.wikipedia.org/wiki/Intergovernmental_Panel_on_Climate_Change

4. Київ. Матеріал з Вікіпедії — вільної енциклопедії. http://uk.wikipedia.org/wiki/Київ

5. Міжнародні переговори ООН зі зміни клімату у Копенгагені 7 груня 2009 р. http://www.necu.org.ua/peregovory-cop-rozpochato/

6. Оцінка виконання Плану дій Україна-ЄС: довкілля та сталий розвиток / Під ред. Н. Андрусевич. Львів. Ресурсно-аналітичний центр «Суспільство і довкілля». – 2009. – 104 с

7. Посудін Ю.І. Моніторинг довкілля з основами метрології / Посудін Ю.І. − К.: Printline, 2012. − 432 с. http://www.ekmair.ukma.kiev.ua/handle/123456789/1568

8. Зміна клімату та екологічна міграція / Посудін Ю., Бистревська К., Вакуленко Г. та ін. 31.01.2012. http://www.ekmair.ukma.kiev.ua/handle/123456789/1284

9. Степаненко О. Захистіть клімат! Не гальмуйте міжнародні переговори!» / Степаненко О. http://www.helsinki.org.ua/index.php?print=1259873496

10. Участь України у виконанні Рамочної конвенції ООН по зміні клімату www.center.uct.ua/zbirniky/2010/Kiotskii_protokol.pdf

11. Sustainable Low-Carbon Society. F. Yoshida and Motoyoshi Ikeda, eds. Hokkaido University Press, 2010. − 201 p.

ПРИЧИНИ, НАСЛІДКИ ТА ПЕРСПЕКТИВИ ЗРОСТАННЯ СЕРЕДНЬОЇ ТЕМПЕРАТУРИ ПОВІТРЯ У СВІТІ, В УКРАЇНІ ТА КИЄВІ

Ю.І. Посудін

Розглянуто причини, наслідки та перспективи зростання середньої температури повітря у світі, в Україні та у Києві. З'ясовано, що збільшення глобальної температури спричиняє танення полярного льоду та теплове розширення об'єму океану, яке може призвести до затоплення територій, зміни тривалості сезонних процесів та стихійних лих.

Глобальні зміни клімату, які характеризуються зміною температурного режиму та потеплінням, мають місце в Україні. Особливо гостро це спостерігається у Києві внаслідок урбанізації.

Для запобігання впливу кліматичних змін потрібне серйозне виконання зобов'язань відповідно до Рамкової конвенції ООН, Кіотського протоколу та Копенгагенської резолюції.

Ключові слова: *зміна клімату, температура повітря, наслідки*

ПРИЧИНЫ, ПОСЛЕДСТВИЯ И ПЕРСПЕКТИВЫ ВОЗРОСТАНИЯ СРЕДНЕЙ ТЕМПЕРАТУРЫ ВОЗДУХА В МИРЕ, В УКРАИНЕ И КИЕВЕ

Ю.И. Посудин

Рассмотрены причины, последствия и перспективы возрастания средней температуры воздуха в мире, в Украине и в Киеве. Выяснено, что возрастание глобальной температуры приводит к таянию полярных льдов и тепловому расширению объема океана, которое может вызвать затопление территорий, изменение продолжительности сезонных процессов и стихийные бедствиям.

Глобальные изменения климата, которые характеризуются изменением температурного режима и потеплением, имеют место и в Украине. Особенно остро это наблюдается в Киеве вследствие урбанизации.

Для предотвращения влияния климатических изменений необходимо серьезное выполнение обязательств, принятых согласно Рамочной конвенции ООН, Киотскому протоколу и Копенгагенской резолюции.

Ключевые слова: *Изменение климата, температура воздуха, последствия*