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## THE STUDY OF THE ATMOSPHERIC PRECIPITATIONS ACIDITY IN THE KYIV CITY DURING WINTER PERIOD

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***Purpose***. To investigate the acidity of solid atmospheric precipitations level in Kyiv territory during winter period and define the possible negative impacts on the environmental components. ***Methodology.*** To define the pH level of snow cover during winter period a series of snow samples we have taken in four different locations in the central area of the city of Kyiv during winter periods of 2016-2017 and 2017-2018. The samples were taken in park areas to avoid the impact of the secondary sources of pollution. The atmospheric precipitations acidity level was defined at melt samples with the help of the universal water tester AMR-210. ***Results.*** The Kyiv city posses a significant industrial complex, producing emissions of acid-creative compounds due to not efficient energy and resources management at industrial facilities and intensive traffic. The biggest sources of acid precursors emissions are Kyiv power generating facilities. The analysis of meteorological factors has showed that eastern industrial territories of Ukraine can significantly influence the acid precipitations in Kyiv, as well as transboundary air pollution. So, the experimental results have showed the pH level of precipitation in Kyiv have tendency to decreasing. The acid rains were observed in 31.25 %, 50 %, 72 % and 50 % cases by each sampling points. The first months of winter periods are characterized with the highest rate of acid precipitations manifestation. ***Originality.*** We have conducted the analysis of snow precipitations acidity in Kyiv over the last two winter periods and defined the potential consequences for buildings, structures and monuments, aquatic ecosystems, soils and phytocenosis at the study area. ***Practical value.*** We have developed recommendations for the control and mitigation of acid precipitations impacts on the components of urban ecosystem, including soils and biota. *References 17, tables 2, figures 0.*

**Keywords**: acid precipitations, impacts mitigation, emissions, meteorological conditions, transboundary air pollution.

## ДОСЛІДЖЕННЯ КИСЛОТНОСТІ АТМОСФЕРНИХ ОПАДІВ У МІСТІ КИЄВІ В ЗИМОВИЙ ПЕРІОД

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У статті досліджується проблема кислотних дощів, зокрема інтенсивність випадання такого типу атмосферних опадів на території України. Встановлено, що особливою гострою ця проблема є для західного та центрального регіону країни. Розглянуто загальні умови формування кислотних опадів та метеорологічні фактори, що впливають на їх перерозподіл та осадження. Визначені основні джерела викидів речовин-прекурсорів кислотних опадів на території міста Києва, зокрема основні підприємства забруднювачі та роль автотранспорту, що з кожним роком збільшує свою відносну частку впливу. Оцінено внесок у даний процес транскордонних переносів атмосферних забруднень із Західної Європи. Проведено відбір проб снігового покриву у центральній частині міста протягом зимового періоду 2016-2017 та 2017-2018 років. Встановлено загальну тенденцію до слабкого підкислення опадів протягом останніх років. Проаналізовано потенційні наслідки випадання твердих кислотних опадів для екосистеми міста, зокрема ґрунтового покриву, рослинних асоціацій, водних об'єктів та споруд і будівель. За результатами аналізу статистичної інформації виявлено прояв наслідків впливу кислотних опадів у формі хронічного підкислення водних об'єктів та ґрунтового покриву міста. Запропоновано заходи для мінімізації негативних наслідків для міської рослинності та ґрунтів: регуляторні обмеження, внесення хімічних засобів, які здатні зв'язувати кислотні компоненти у ґрунті, а також введення до складу рослинних асоціацій видів, що відрізняються стійкістю до впливу кислот. Запропоновано здійснювати регулярний моніторинг стану ґрунтового покриву для виявлення негативних змін у рівнях кислотності.

**Ключові слова:** кислотні опади, пом'якшення впливів, викиди, метеорологічні умови, транскордонне забруднення повітря.

PROBLEM STATEMENT. Modern urban environment creates a series of problems threatening human health and biota in general. Among the most pressing and important issues it is the increased level of air pollution and consequently transformation of chemical composition of atmospheric precipitations.

Growing intensity of emissions into the atmosphere of Kyiv city during recent years has been provoked by the insufficient level of nature protection technologies application in economy, using inefficient types of fuels, rapid growth of vehicles quantity, including those which are old. These lead to formation of dangerous atmospheric processes, especially, acid rains and smog.

In the late XX and early XXI century acid precipitations became significant components of the atmosphere. Such precipitations are widely distributed in European countries, and also in major metropolitan areas in Asia and Americas [1]. The main reason of acid rains formation is emissions of sulfur and nitrogen compounds during the combustion of fossil fuels at stationary facilities and motor vehicles, but till now significant scientific evidences of this are still not

available. By their essence acid precipitations are all types of atmospheric water: rain, snow, hail, fog, rain and snow with the acidity lower than normal, i.e. below 5.5 [2].

The basic components of acid rains are $SO_2$ ,NOx, volatile organic compounds (reactive alkanes – 50% (propane and butane), olefins – 23% (ethylene, propylene, etc.), aromatic hydrocarbons – 18% (benzene, xylene and others)) and specific halogen containing components (HCl, $Cl_2O_7$, HF and phosphates) [3].

Directly or indirectly acid precipitations damage the components of environment, especially waters and soils. Ecosystems located within 100-200 km from the source of acidic emissions are said to undergo the biggest influence [4]. Moreover, acid rain is not fixed to the region, where its sources are located. Prevailing winds can transport chemicals in the atmosphere for hundreds or even thousands of kilometers, not accounting state and other administrative borders. For instance, compounds from the industry in China can potentially be deposited in the U.S. Midwest [4]. For this reason, acid rains are considered a global problem.

Acid precipitations cause acidification of soil and surface waters, which are also the sources of water supply. Negative impacts of acid precipitations are also reflected on the condition of forests, especially on beech and pine [2]. Acid rains damage protective cover of leaves, as a result, the plants become more vulnerable to insects, fungi, and other pathogens. At the same time, they cause negative impact on buildings and structures, which is especially dangerous for architectural and sculptural monuments and metal constructions. Thus, the relevance of studying acidity of atmospheric precipitations in such huge populated and urbanized city as Kyiv is quite rational.

The *aim of the work* is to investigate the acidity of solid atmospheric precipitations level in Kyiv territory during winter period and define the possible negative impacts on the environmental components. The choice of solid precipitations is conditioned by the fact of their long lasting influence, as they are accumulated over a certain period and gradually release acidic solution in the process of melting. The concentration of acids may even increase, due to evaporation of water and intrusion of additional pollutants. Thus, the acidity of the melt water is ten times higher than the acidity of rain. Such waters entering the soil can cause acidification of whole profile of soil, and often acidified ground waters [3].

EXPERIMENTAL PART AND RESULTS OBTAINED. *The intensity of acid rains in Ukraine*. During the last 50-60 years increasing atmospheric precipitations acidity through all over the world is observed. The biggest volume of acid falls in the countries of Scandinavia [2, 4]. In Ukraine acid rains often occur in Sumy, Cherkasy, and Rivne regions, mostly due to transboundary pollution from the Western Europe [5, 6], while local sources of pollution are responsible for the formation of the acid rains in the Crimea, Donetsk, Odessa and Kiev regions. Alkaline precipitations are observed in the east part of country (in industrial areas) and in the Kiev region [7].

The acidity of precipitations is tested at 54 monitoring stations in Ukraine. The results obtained during the period from 2012 to 2015 show that in most cases reaction of the precipitations is normal or moderately alkaline (Table 1).

In winter period of 2013-2014 monitoring of the chemical composition of snow cover was also conducted at 54 meteorological stations. According to the observations the content of sulfate was within 1,00-185,70 mg/dm$^3$, ammonia nitrogen - 0,07-1,57 mg/dm$^3$, nitrates – <0,01-40,00 mg/dm$^3$, chlorides – <0,01-9,96 mg/dm$^3$. The pH of snow was mostly neutral, but at 9 stations slightly acid reaction of rainfall was recorded. During the next period (2015-2016) the level of pollution of snow cover with the chemicals, including the content of sulfates, nitrates, chlorides and metals, has increased [7].

Table 1 - Characteristics of the precipitations reaction in Kyiv city

| Year | Percentage of the samples with corresponding reaction | | | | |
|---|---|---|---|---|---|
| | Alkaline | Slightly alkaline | Normal | Moderate-ly acidic | Acidic |
| 2012 | 0.07 | 23.64 | 66.31 | 9.76 | 0.22 |
| 2013 | 0.11 | 26.22 | 65.97 | 7.46 | 0.24 |
| 2014 | 0.03 | 24.31 | 68.60 | 6.83 | 0.23 |
| 2015 | 0.1 | 21.49 | 68.80 | 9.54 | 0.07 |
| 2016 | 0.05 | 24.21 | 67.22 | 8.34 | 0.18 |

Note: Data by the Central Geophysical Observatory.

The analysis of the intensity of acid precipitations in the capital is based on the information, provided by the Central Geophysical Observatory on the official request by the authors. So, the reaction of atmospheric precipitations during the winter seasons of 1993-2015 is above the threshold for acidic precipitations (5.6) and tend to reach normal pH level for neutral medium (pH=7). It is important to note that during the first half of the investigated period (1993-2004), the occurrence of slightly acidic precipitations was higher (average value of precipitations pH level per year is equal to 6.57) than during the period of 2005-2015 (average pH level during year – 6.95). In the first case precipitations are closer to pure rains. The acidity of snow cover during 2000-2009 experienced fluctuations within the range from 5.8 to 6.8.

Summarizing all above information it is not possible to conclude that there is tendency to decreasing pH level of the atmospheric precipitations in Kyiv and the nearest regions. This trend is observed only in specific cases, the reasons are various, and the most important are variation of industrial activity intensity and combination of meteorological factors.

*Sources of acid oxides emission in Kyiv*. During last years the list of main pollutants and volumes of its emission into atmosphere of the Kiev city remained almost unchanged. Thus in 2015 in city atmosphere was found the following concentration of such pollutants as carbon monoxide – 109051.2 tons; volatile organic compounds – 23878.3 tons nitrogen compounds – 22283.5 tons; substances in the form of suspended

solids – 4677.0 tons; sulfur dioxide and other sulfur compounds – 9428.7 tons [7].

Among stationary sources of atmosphere pollution the biggest share is contributed by the enterprises of power generating sector: JSC «Ekostandart» (Dniprovsky district of Kyiv, – 17.7 thousand t of gaseous emissions a year), CHP-5 «Kyivenergo» (Holosiivskyi district), CHP-6 «Kyivenergo» (Desnyansky district), «Energia» - waste incineration plant. Gross emissions of the listed enterprises in 2016 were accounted as 45.2%, 12.5 %, 9.2 % and 2 % respectively in accordance to total emissions of stationary sources in the city [8].

Despite this the biggest source of acid rains precursors emissions in Kyiv is automobile transport [9]. Vehicles emissions are the biggest by gross value and penetrate into the air almost directly in the area of human breathing. Increasing level of air pollution is formed due to low operating performance of vehicles and low quality of fuel, low capacity of major highways but high traffic. According to statistical data by 2016 emissions from mobile sources were recorded as follows: dioxide and other sulfur compounds – 12358.8 tons, nitrogen compounds – 7628.4 tons, non-methane volatile organic compounds – 5738.3 tons which in combination with emissions from stationary sources is a significant factor promoting formation of acid rains. The trend of the average level of air pollution in recent years was characterized with increased concentration of nitrogen and sulfur dioxides and average density of emission in Kyiv during the last 5 years was over 4550 t/km$^2$ [10]

*The analysis of meteorological preconditions of atmosphere pollution.* Such factors as atmosphere condition, enterprises and sources of air pollution location, territory peculiarities, physical and chemical characteristic of pollutants, sources height and other technical features have crucial impact on the process of emissions distribution.

According to the meteorological data on the territory of Kyiv air flows come from the Atlantic, Arctic and Eurasia. During a year in Kiev and around the capital west wind is prevailing (17.7%), a bit lower is frequency of north and northwest winds (13.6% and 13.5% respectively). The average frequency of calm during a year is 13 % [11]. In the city center the average annual wind speed is 2.7 m/sec, the value for areas outside the city – 4.2 m/sec [5]. The highest average wind speed is observed in February (in the city – 3.2 m/sec, in the countryside – 5.1 m/sec), the lowest – in August (in the city – 2.2 m/sec, in the countryside of 3.2 m/sec) [5]. Low speed of winds is observed due to a large density of city buildings.

In winter in Kyiv city (15.1 %, 17.5 %, 14.0 % in appropriate winter month) the predominant wind direction was South-East, which allows to assume that this air mass can bring the pollutants and atmospheric precipitations from the industrial areas of the central and eastern part of Ukraine, while the Kyiv acidic emissions are transported further to the north-west and precipitate in Polissya region of Ukraine and Belarus [11].

An important aspect contributing to the distribution of air emissions is such phenomena as temperature inversions: they affect the development of various atmospheric processes, especially can hinder the development of ascending air currents and the uplift of transport emissions [12]. According to the investigation performed by O.G. Shevchenko [11] during calm wind regime the frequency of cases with low concentrations of sulfur dioxide in separate posts of atmospheric air vary within 40,0-66,7 %, average in the city – 55.6 %. For nitrogen dioxide repentance of cases of low level contamination average in the city is 57.1% cases and ranges from 57.1% to 59.0%. Cases of surface and upraised inversions were considered separately in order to assess their impact on air quality. The obtained results indicate that the presence of surface inversion in the atmosphere of the city does not necessarily lead to high levels of air pollution. For sulfur dioxide concentrations during surface inversions on most observation posts is low and varies between 37.3-41.1%. For nitrogen dioxide the repeatability of cases of increased concentration is slightly higher and varies within 47.4−50.8%. Such repeatability value is higher by 10% as compared to sulfur dioxide [5, 11].

Higher frequency of cases with increased levels of nitrogen dioxide is observed due to the reception of such pollutant substance by the atmosphere from automobile transport (57%), emissions of which belong to low and cold sources, while input of sulfur dioxide (78%) is performed due to emissions provided by high industrial pipes of different companies [11].

Thus, according to the above information the presence of inverse atmospheric layers in Kyiv city does not always lead to deterioration of air quality. The frequency of cases with high pollution with sulfur and nitrogen dioxides during upraised inversion is low. Such situation is observed due to the fact that raised inversions lead to increased levels of air pollution in urban areas, where pollutants come mainly from high sources, Kyiv does not belong to such areas. Also Kyiv is characterized with rapid destruction of inversions, thus pollutants do not have time to accumulate in the surface layer up to dangerous concentrations.

*Transboundary pollution with acid precipitations*.

Acid precipitations in Ukraine appear under the influence of both national and transboundary sources of pollutants emissions. Nearly 25-30 % SO2 and 15-25 % NOx are transferred by winds from the enterprises located in EU and Post-Soviet countries. The balance of transboundary emissions of sulfur and nitrogen dioxides from EU countries into Ukraine shows that Poland, Germany and Hungary are providing surplus of emissions to Ukraine, while the exchange with Romania, Czech Republic, Moldova and Bulgaria are more or less compensated either by excessive output of nitrogen or sulfur oxides [6]. Sulfur and nitrogen oxides, transferred by air masses to the distance up to 1000 km, stay in the atmospheric air no more than 5 days. During this time these compounds are converted into appropriate acids and with precipitations penetrated into soil and surface waters. For Europe the share of nitric acid in precipitations is 10–20 %, for Ukraine – 35– 50

% [6]. In general volume of transboundary exchange of precipitations with all neighboring countries, Ukraine has correlation for sulfur dioxide – 1:3, and for nitrogen oxide – 1: 2.

*Methods and materials*. To define the pH level of snow cover during winter period a series of snow samples were taken in 2016-2017 and 2017-2018. The samples were taken according to grid sampling method at the park areas to avoid possible secondary pollution of snow cover; also we tried to avoid places untypical for the area (depressions, ravines, etc.). It is also important in terms of direct snow samples collection to avoid any impurities and foreign objects which can be represented with mud, plan residuals, and garbage. Sampling was conducted in four different locations in the central area of the city of Kyiv (Solomyansky district): Lebedev-Kumach Street, 2/6; two points in different parts of park «Vidradny»; and the fourth – at Nizhynska Street, 20.

To define the atmospheric precipitations acidity level the water obtained by melting the snow under room temperature was analyzed with the help of the universal water tester AMR-210. The preparation of the samples eliminated the need to add corrections by temperature of the sample and its low salinity typical for atmospheric precipitations and has provided the high accuracy of the obtained values.

*Results and discussions*. Analysis of precipitations acidity was carried during period from 13.10.16 (first snow fall of the studied period) to 27.03.18 (last snow fall) – total number of samples is 64 – 4 samples from 16 snowfalls during the period of 2016-2017, and 168 – 4 samples from 42 snowfalls during the period of 2017-2018. Obtained results show that for the entire period of samples collection none of the samples meet either the appropriate normal acidity level for clean rains (pH=5.6) or the level of neutral medium (pH=7). Average pH level of samples varies between values of 5.35 and 5.8 in 2016-2017 and 5.8 and 5.96 in 2017-2018. Such acidity is tending to be claimed as normal.

Sampling point 1 and 4 during winter season of 2017 was characterized with the lowest level of acidity equal to 4.5. Data collected from the sampling point 1 show that the lowest pH value (pH=5) was recorded 2 times, the lowest for the sampling point 2 (pH=4) – ones, the lowest for the third point of sampling (pH=5) – 7 times and the same value of the lowest acidity of precipitations for the point 4 (pH=4.5) was recorded just ones.

Separately by each sampling point the acidity level lower than 5.6 was observed as follows: point 1 – 41.25% samples, point 2 – 45.6 %, point 3 – 72 %, point 4 – 48.1 %. Samples selected from the third point are the most acid. From the possible reasons we should account close location of the road as a source of the secondary pollution and peculiarities of wind mode in park ecosystem. Obtained results state that not only anthropogenic sources of atmosphere pollution can lead to acid precipitation formation, but the impact of weather condition nowadays becomes significant in term of pollutants distribution.

Average values of precipitation acidity per winter month are given in Table 2. December is the month with the most frequent repeatability of acid precautions. In all other cases precipitation is close to normal.

As it was described before acid precipitations directly or indirectly deteriorate the quality of all components of environment. Taking into account significant area of the city of Kyiv – 83.6 mln hectares and number of current population – 2929029 persons, it is understandable that manifestation of negative impacts of acid rains can cause tremendous variety of environmental problems [8].

Kyiv as a developed city of Europe possess cultural and environmental heritage (3905 sites), which can undergo negative impacts of acid precipitations. Also the territory of city includes 54.4 mil hectares of green plantations [8]. Objects of Nature protection fund of the city are represented with parks, water objects, city forests, and parks-monuments of landscape art of national and local importance. The level of snow acidity defined in the study may cause the degradation of green plantations quality by affecting root system, acidification of soil, leaching of nutrient chemicals, increasing level of heavy metals mobility, pollution of aquatic ecosystems, corrosion of buildings and monuments, and health disorders.

Table 2 – Average value of the sampled precipitations' acidity

| № | Month and number of snowfalls sampled | Point 1 | Point 2 | Point 3 | Point 4 |
|---|---|---|---|---|---|
| 2016-2017 winter period | | | | | |
| 1 | October (1) | 6 | 6 | 5 | 6 |
| 2 | November (2) | 5.5 | 5 | 5.5 | 5.5 |
| 3 | December (4) | 6.25 | 5.5 | 5.5 | 5.6 |
| 4 | January (5) | 5.9 | 5.5 | 5.6 | 5.8 |
| 5 | February (3) | 5.8 | 5.6 | 5.5 | 5.6 |
| 6 | March (1) | 5.5 | 5 | 5 | 5.5 |
| 2017-2018 winter period | | | | | |
| 1 | November (3) | 5.5 | 5.5 | 5.5 | 5.5 |
| 2 | December (6) | 6 | 5.5 | 5.5 | 6 |
| 3 | January (8) | 5.8 | 5.5 | 5.5 | 6.1 |
| 4 | February (14) | 5.8 | 6 | 6.5 | 6.2 |
| 5 | March (11) | 6 | 6.5 | 6.5 | 6 |

For example, predominant types of trees in the park «Vidradny», included into the study, are deciduous trees - mostly linden, maple, birch, which are not very tolerable to acidic reaction of the environment. There is also an artificial lake in the park. Thus, plant biocenosis and aquatic ecosystem of this territory could suffer from the acid rains: it may lead to gradual changes the plant species structure and damage fish. Thus, according to / J. Baker and S. Christensen pH=6.5-9 has no effect on fish, 6.0-6.4 - can be harmful when $CO_2$ level in water is very high; 5.0-5.9 is not especially harmful, but 4.5-4.9 is harmful to the eggs of salmon and trout species (salmonids) and to adult fish; 4.0-4.4 is harmful to adult fish of many types which aren't adapted to low pH; 3.5-

3.9 is lethal for salmonids; and at bpH=3.0-3.4 most fish dies within few hours [13].

As for the plants, the way that acid precipitations damages plants is very subtle. Over time, the acidic water alters the pH of the soil where plants are growing, binding and dissolving vital minerals and carrying them away.

Acid deposition can alter the properties of soil, binding and dissolving vital minerals (calcium and other base cations) and carrying them away. As soils lose nutrient base cations, which are critical in neutralizing acids, they become more vulnerable to further acidification, and, as a result, trees become more sensitive to disease and stress. As the soil pH further goes down, plants display increasingly obvious symptoms, including yellowing between the veins on the leaves in spring after snow melting [14]. At the same time, snow retained on the needles of coniferous plants gradually removes the outer waxy layer of tissue that protects the plant from drying out, leading to the destruction of the chloroplasts that drive photosynthesis [14]. The damage and loss of numerous leaves/needles causes stress of this plant and attract pests and pathogenic organisms. Of course, under the level of pH=5 and higher there will be no signs of necrosis, as it was proved by the studies of B.Haines et al., however, the authors suggest that developing leaves may be more susceptible to acid rain damage than are mature leaves, which increases the potential damaging effect of acid snow on fresh leaves in early spring [15].

The increasing soil acidity causes a chain of other negative phenomena: under this condition the release of aluminum, which is a heavy metal, from the soil deteriorates living conditions for many freshwater fish species. High concentrations and extensive exposure of lakes and streams to aluminum is the main symptom of systems suffering from chronic acidification [15].

Direct impact of acid precipitations also can be reflected in corrosion processes of different subjects. The destruction of buildings, monuments and other matter caused by corrosion process is observed very often. The reason of that is an increasing hydrogen ions concentration on the metal surface, which has influence on oxidation processes. In suburban areas the rate of corrosion is equal to several micrometers per year and in the cities – more than 100 micrometers [16]. Corrosion causes damage to bridges structures, reservoirs, power lines, machinery and transport.

Monuments and sculptures of sandstone and limestone are the most vulnerable to acid precipitations because the potassium carbonate contained in those materials is easily soluble in water and can be converted to calcium sulfate (gypsum), which is then washed away by rainwater [17].

Similar effect is observed in case of materials surface cover resistance. Most paints and latexes are permeable to gases and moisture, thus during diffusion hydrometric and oxidational transformations of surfaces are possible leading to the changes of their strength and fragility. Acid snow, penetrating into the contact area of paint with surface, accelerates the process of peeling.

Marble, limestone, and sandstone can be easily dissolved by acid precipitations. Metals, paints, textiles, leather, rubber and ceramic can easily be corroded. Man-made materials slowly degrade under the influence of any humidity, but acid rain accelerates the process. Acid rain causes carvings and monuments in stones to lose their features.

The repairs of building and monuments can be quite costly. In Westminster, England, up to ten million pounds was spent on removing damage from by acid rain. In 1990, the United States spent thirty-five billion dollars on paint damage. In 1985, the Cologne Cathedral cost the Germans approximately twenty million dollars in repairs. The Roman monuments cost the Romans about two hundred million dollars [4].

Reduced visibility also is the result of air pollution with sulfur and nitrogen oxides, along with othe anthropogenic pollutants, such as volatile organic compounds, soot and dust. The mechanism of their action is different: sulfur dioxide, converted into sulphates form the fine particles, suspended in the air and forming visual obstacle; nitrogen oxides adsorb blue spectrum of light and produce the yellowing [4].

The acidification as an environmental process is classified in two forms:

1. Episodic acidification – short-term intensive acidic events. For example, winter snowmelt brings large volumes of acids to the environment over short period of time. These can have significant biological effects that include the loss of biodiversity and changes in community structure;

2. Chronic acidification is generally typical for water objects and soils that have lost their ability to neutralize acids due to loss of base nutrients such as calcium, potassium, and magnesium, This can make the system more vulnerable to episodic acidification and form chronic surface water acidity [17].

Comparing obtained results with the general tendency for atmospheric precipitations acidity described above, it should be mention that with time passing precipitations become more acidic (precipitations over the period of 1993-2015 only in several cases were claimed as acid) [11]. The results of investigation state that frequency of acid precipitation is growing.

In order to avoid such negative situation it is necessary to implement a plan of measures for the protection against acid precipitations and mitigation of their impacts. Thus, many countries provide regulations aimed at reduction of acid pollutants emission. Also city administration may conduct liming of vegetation and aquatic ecosystems. It is also necessary to plan urban greenization with those plants, which are stable to the influence of acids. As for the soil, it is recommended to conduct soil testing every six to 12 months to prevent the problems by adding extra minerals, nutrients or lime when it is necessary.

CONCLUSIONS. The main reason of acid rain formation is emission of sulfur and nitrogen compounds into the atmosphere during the combustion of fossil fuels in stationary facilities and on transport, as well as the natural process activity. Acid precipitations are not

limited to the region of acidic emissions formation, thus it can cause significant negative environmental impact at long distances. In Ukraine acid rains often occur in Sumy, Cherkasy, Odesa, Kyiv and Rivne regions.

The capital of our country possess a significant industrial complex, producing emissions of acidic compounds due to inefficient energy and resources management, absence of modern manufacturing technologies. In term of movable sources of emission the main reasons are low operating performance of vehicles and low quality of fuel. Among all meteorological factors which have impact on atmosphere pollution in the city of Kyiv the most important is wind mode (in Kiev and capital area the west winds prevail, subjecting the eastern territories to acid precipitations.

The results of snow testing during the winter period of 2016-2018 have showed the tendency to decreasing the pH level of precipitation in Kyiv. Specifically, slightly acidic reaction of snow samples was defined in 40-72% cases. The negative impacts of acid precipitations in Kyiv are possible for all components of environment, especially, for green plantations, soils, water bodies and numerous monuments.

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## ИССЛЕДОВАНИЕ КИСЛОТНОСТИ АТМОСФЕРНЫХ ОСАДКОВ В ГОРОДЕ КИЕВЕ В ЗИМНИЙ ПЕРИОД

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В статье рассмотрены общие условия формирования кислотных осадков и метеорологические факторы, влияющие на их перераспределение и осаждение. Определены основные источники выбросов веществ-прекурсоров кислотных осадков на территории города Киева и оценен вклад в данный процесс трансграничных переносов атмосферных загрязнений. Проведен отбор проб снежного покрова в центральной части города в течение зимнего периода 2016-2017 и 2017-2018 годов. Выявлено общую тенденцию к слабому подкисление осадков в течение последних лет. Проанализированы потенциальные последствия выпадения твердых кислотных осадков для экосистемы города, в частности почвенного покрова, растительных ассоциаций, водных объектов, сооружений и зданий, а также предложены меры по их минимизации.

**Ключевые слова**: кислотные осадки, смягчения воздействий, выбросы, метеорологические условия, трансграничное загрязнение воздуха.

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