2023 年臺灣國際科學展覽會
優勝作品專輯

作品編號 **180018**

參展科別 **地球與環境科學**

作品名稱 **STUDY OF ATMOSPHERIC AIR POLLUTION OF POLTAVA REGION**

得獎獎項 **三等獎**

國　　家 **Ukraine**

就讀學校 **National center "Junior Academy of Sciences of Ukraine" under the auspices of UNESCO**

指導教師

作者姓名 **Nazar Oliinyk**

關鍵詞

作者照片

INTRODUCTION

Topicality. Ukraine as a whole, as well as Poltava Region in particular, have a problem with the state of atmospheric air pollution, because the vast majority of motor vehicles and industrial, energy, and mining enterprises are not equipped with proper cleaning filters.

A clear confirmation of the ineffectiveness of Ukraine in matters of monitoring the condition and protection of the atmosphere, in comparison with European countries, was the scandal with the manipulation of exhausts of the Volkswagen concern (Dieselgate). Diesel engines use a catalyst with injection of a urea solution (AdBlue), or a catalytic converter built on the principle of accumulation of nitrogen oxides on a metal surface made of barium compounds . Synthetic urea in automotive catalysts transforms dangerous nitrogen oxides into harmless nitrogen and water . However, due to the software, during everyday use of the VW engines in question, this function remained disabled and the catalytic converter was simply removed. However, we see such cars, along with others, even more morally and technically outdated, on the roads of Ukraine every day.

The practice of burning stubble in spring and autumn also leads to extreme consequences of air pollution.

The morally outdated system of monitoring the state of the atmosphere, which has remained in Ukraine since Soviet times, is not able to show the real state of pollution, and the lack of proper control on the part of the state leads, in general, to the worsening of the situation every year. Environmental problems in the country in general, and in Poltava Oblast in particular, are the cause of the spread of cancer and high human mortality.

Almost 80,000 people die of oncology in the country every year. According to 2020 data, the mortality of the population of Poltava Oblast from non-communicable diseases exceeds the average indicators for Ukraine: Ukraine – 1,597 people per 100,000 population, Poltava Oblast – 1,793 people per 100,000.

Therefore, the relevance of the problem raised is extremely high, and it is necessary to start with monitoring air pollution and raising the problem at the national level, because most of the country's residents do not even know what kind of air they breathe at home and on the street.

The goal of the work: to conduct its own annual survey of the state of atmospheric air pollution in the Poltava region, to systematize information about the most typical types of pollution for Poltava Oblast, the causes of their appearance , the most polluted areas of the region, through practical experience gained in the EU countries, to outline possible perspectives and directions for improving its monitoring and condition.

Object of research: atmospheric air of Poltava region.

Subject of study: analysis of the state of atmospheric air in Poltava Oblast, the main types of its pollution, the quality of the conducted monitoring and finding ways to improve it.

Research methods:

1) analysis of scientific literature, periodicals, information from Internet resources ;
2) scientific observation;
3) summarizing observations, outlining the problem;
4) finding ways to improve the situation through the acquired European experience.

Scientific novelty consists in conducting scientific research for the reasoned outline of the problem of atmospheric pollution in the Poltava region. I conducted my research not only through the Windy program, but also tested my own invention at work - a device for measuring the quality of air pollution at home, which will be convenient to use, affordable, and will provide an opportunity for Ukrainians to conduct their own air quality monitoring.

My personal contribution consists in the experimental study of atmospheric air pollution in Poltava Oblast, the analysis of the obtained results, the outline of ways to improve the quality of atmospheric air, and its monitoring based on the experience gained in European countries.

Structure of the work: the work consists of an introduction, three chapters and subsections, conclusions, figures (7), tables (1), diagrams (3), a list of used literature, including electronic resources, appendices (3). The work is experimental.

SECTION I

ECOLOGY OF THE ATMOSPHERE

1.1 Anthropogenic impact on the air basin of the world

Air is the main component of the vital activity of all living things on Earth. It forms a gas shell around the globe more than 1000 km thick and consists of nitrogen (78%), oxygen (20%), a small amount of carbon dioxide, hydrogen and various impurities, including solid ones, the amount of which depends on the process of absorption and scattering of emitted light.

Atmospheric air pollution is the main reason for disruption of the planet's ecosystem today. There is a saying that atmospheric air is never clean. If we take the purity of the atmospheric air above the ocean level as a unit, then in rural areas the pollution will be 10 times higher, in small towns – 35 times, in large cities – 150 times, and in large industrial centers – a thousand times higher.

Due to the intensive development of technology, industry, which has been observed for the last 100 years, and other branches of human economic activity, a large number of pollutants enter the atmosphere. As a result, it affects the health of all living things on the planet.

Gradual pollution of the Earth's atmosphere occurs both naturally and through human activities - anthropogenic.

The global economy annually emits more than 15 billion tons of carbon dioxide, 200 million tons of carbon monoxide, more than 500 million tons of hydrocarbons, 120 million tons of ash, etc. into the atmosphere. The total volume of emissions of pollutants into the atmosphere is more than 19 billion tons [EP3] The main pollutants that enter the atmosphere during fuel combustion are solid particles (ash, soot), sulfur oxides (SO2 and SO3), nitrogen oxides (NO and NO2). Carbon oxides (CO), hydrocarbons of the CH4, C2H4 type, polycyclic aromatic hydrocarbons, benzopyrene (C20H12), as well as vanadium pentoxide (V2O5) can accumulate in gaseous emissions. The last two compounds belong to the class of extremely dangerous. Dioxide (SO2) and trioxide (SO3) of sulfur are the main components of environmental pollution during fuel combustion.

Industrial dust is formed as a result of mechanical processing of various materials — crushing, grinding, blasting, filling, leveling; thermal processes — burning, roasting, melting.

For example, after the traditional large-scale festival of lights was held in New Delhi, India, and its suburbs on November 5, 2021, a sharp deterioration of the atmospheric air was recorded. Residents complain of worsening health. The city was shrouded in thick smog. The Air Quality Index (AQI) in New Delhi has reached 451, a reading above 300 is life-threatening. In particular, schools were closed in the city, all construction work was stopped, and trucks were prohibited from entering the city. To avoid a

jump in the number of cases and victims, the authorities imposed a lockdown in New Delhi. ndtv.com writes about it.

It is known that burning fuel produces a huge amount of gaseous compounds — oxides of sulfur, nitrogen, carbon, heavy and radioactive metals. Reduction reactions are also a source of gaseous pollutants, for example, production of coke, hydrochloric acid from chlorine and hydrogen, ammonia from atmospheric nitrogen.

The most widespread and dangerous atmospheric pollutants include: NO2 (nitrogen dioxide), SO2 (sulfur dioxide), CO (carbon monoxide), CH2O (formaldehyde), O3 (surface ozone), PM1, PM2.5, PM10 (atmospheric dust, ash, soot).

Nitrogen dioxide, NO2, is a red-brown gas with a characteristic pungent smell, which is quite poisonous when inhaled, and is considered one of the biggest pollutants of the atmosphere [ВЛІ6]. The biggest sources of NO2 emissions are internal combustion engines and thermal power plants. Nitrogen dioxide is also formed as a result of nuclear tests, it is clearly visible by the red-brown color of the mushroom, and during a thunderstorm, as a natural source of pollution.

Sulfur dioxide, SO2, is a colorless gas with a pungent odor. The largest emissions of sulfur dioxide are caused by power plants that burn coal and oil, and when they burn, sulfur is released, which reacts with oxygen to form sulfur dioxide. In large quantities, the gas can cause inflammation of the lungs and shortness of breath in humans.

Carbon monoxide, CO - carbon monoxide is colorless and odorless, so it is particularly dangerous because it cannot be felt. It burns with a blue flame and is formed as a result of incomplete combustion of natural gas, during the combustion of coal, coke, oil. It is part of the smoke produced during a fire. When a person receives a large dose of poison, hypoxia occurs, which leads to death.

Formaldehyde, CH2O, is a colorless gas with a pungent odor that can poison all living things and cause cancer. The source of formaldehyde entering the atmosphere is road transport, enterprises that use formaldehyde in their work.

Ground-level ozone, O3, is a harmful gas that is a strong air pollutant and can destroy plant cells. Ground-level ozone is a component of smog in cities. It causes headache, suffocation, manifestations of asthma and allergies in humans.

Atmospheric dust, PM1, PM2.5, PM10 – small solid particles suspended in the air with a diameter of 1 μm, 2.5 μm, 10 μm (finely dispersed particles that are not visible to the naked eye), which, when inhaled, have a harmful effect on the human respiratory tract , causing inflammation and compaction of lung tissue. For comparison, the thickness of a human hair is 100 μm, so up to 40 finely dispersed

particles can be placed on a cross-section of a hair. Most of them consist of various types of dust of anthropogenic origin, which is formed as a result of the friction of car wheels and other human economic activities. It has microscopic dimensions, so when inhaled, it easily enters the lungs and blood and poisons the body. As a result of constant poisoning, irreversible processes are started in the human body, which lead to chronic diseases and fatal diseases. Dust of natural origin does not have a harmful effect on living organisms.

The smog that hangs over the million-strong cities of the world contains a large number of particles PM1, PM2.5, PM10, formaldehyde, etc.

Today, there are no regions in the world safe from pollution: the ice at the poles contains sulfur, lead and mercury, brought by the winds from factories located thousands of kilometers away.

Combustion of gasoline and coal is accompanied by quite harmful emissions. Some of these gases, such as sulfur oxide, produce "acid rain." More than 100 million tons of them fall out every year. Every year we produce 25 billion tons of carbon dioxide, which can lead to harmful climate change. Burning coal causes respiratory diseases, which are very common in cities.

Chemical production emits a significant amount of gases. Thus, the emission of carbon dioxide heats the atmosphere, which can accelerate the melting of glaciers. CHP plants produce electricity from coal and liquid fuel. The combination of combustion products with water, in the process of a chemical reaction, forms very toxic compounds.

Gasoline and oil supplied to Ukrainian markets by Russia contain sulfur, the excess of which has a detrimental effect on human health. For example, you can look at the stop "Zygin Square" in the city of Poltava, where the walls of residential buildings closely adjacent to the highway are covered with a dark coating.

Even freezers and aerosols are harmful to the atmosphere: releasing the gas into the atmosphere destroys the ozone layer, which, for the most part, protects us from ultraviolet rays.

Nuclear reactors are also a potential hazard. The explosion of a nuclear reactor in Chernobyl, which caused radioactive poisoning of a large area, demonstrated that such cases are likely in the future.

The international organization Eco Experts compiled a list of the most polluted cities in the world, providing monitoring of pollutants that have the greatest impact on the situation in cities:

1. Cairo, Egypt. According to the WHO, the emission of nitrogen dioxide into the atmosphere over Cairo, which is the greatest danger to health, reaches record levels in Cairo and may even be listed in the "Guinness Book of Records". The concentration of heavy industry enterprises within the city limits, the

poor technical condition of the capital's car fleet, household and industrial waste, which is accumulated in huge quantities right on the city territory, overcrowding, intense heat, lack of rain and wind, as well as sand from the surrounding desert make Cairo the city with the worst ecology in the world.

2. Delhi, India. Like many other big cities, Delhi's air suffers from pollution. The largest percentage of harmful emissions enters the air through transport - 67% of the total amount of emissions, or 3,000 tons per day. Another 25% is contributed by 125,000 industrial enterprises and the city's three coal-fired thermal power plants.

3. Beijing, China. Today, this metropolis has one of the highest levels of air pollution in the world in terms of PM1, PM2.5, PM10, and formaldehyde. Smog envelops the city like a blanket made of dirty cotton wool, and local residents do not go outside without cotton-gauze bandages. Smog in China is caused by emissions from industrial production and transport and coal burning. Most often, the consequences of this are visible in winter, when a sharp drop in temperature leads to an increased demand for electricity.

4. Moscow, Russia. A high level of atmospheric air pollution was recorded near highways and industrial zones, especially in the eastern and southeastern parts of the city. The highest level of air pollution in Moscow is observed in the districts of Kapotnya, Lublino, and Marino. Smog mainly depends on meteorological conditions. In windless periods and with low atmospheric pressure, harmful substances accumulate in the lower layer of the atmosphere, concentrations of impurities in the air can increase sharply - smog occurs.

5. Guangzhou, China. In the city of Guangzhou, the population is about 12 million people, who live in extremely dangerous conditions of air pollution. In some periods, pollution levels become higher than in Beijing. Industry in the region is developing at a tremendous speed, which instantly increases the number of cars in the city and its inhabitants.

6. Shanghai, China. According to the results of the latest research, the air in China turned out to be the most polluted in the world. Smog envelops skyscrapers in all major cities of the country. The rate of development of the Chinese economy is surprising with its speed. The country's authorities are trying to take measures against air pollution, but the general forecasts are not too optimistic. Scientists predict that air pollution in China will only increase in the future.

7. Buenos Aires, Argentina. The metropolis of Buenos Aires faced numerous environmental problems. Although smog does not last long in the city due to relatively windy weather, significant air pollution is observed in various areas of the city as a result of industrial and transport emissions. This leads to an increase in the number of lung cancer patients. The situation with air pollution in the city is exacerbated by the high intensity of street traffic.

8. Paris, France. The problem of air pollution is quite acute for Paris, and air pollution indicators regularly violate EU standards. Severe air pollution in winter is associated with an increase in the volume of exhaust gases from cars and smoke from burning coal, as well as with windless weather and a lack of rain.

9. Los Angeles, USA. In terms of air pollution, Los Angeles ranks first in the United States. Experts say that 166 million of all Americans, or 52.1% of people living in the US, live in counties with unhealthy levels of air pollution.

10. Kyiv, Ukraine. The problem of air pollution also exists in the capital of Ukraine - the city of Kyiv. According to Iqair, Kyiv is consistently in the top 10 most polluted cities in the world in terms of air quality.

1.2 Correlation between the state of atmospheric pollution air and morbidity

The correlation between the state of atmospheric air pollution and the morbidity of living organisms has been scientifically confirmed. The World Health Organization (WHO) states that air pollution leads to an increase in morbidity and mortality in the world. According to the same organization, atmospheric air pollution is a priority risk factor for public health, while more than 80% of diseases to one degree or another depend on air quality.[EP4] Every year, millions of people die prematurely from air pollution in the world. Several billion more are forced to breathe air saturated with dust and poisonous compounds every day. Today, in general, about 90% of children live in cities where
the air is polluted by various harmful substances. [EP13] WHO experts note that particularly serious problems due to air pollution are observed in the vast majority of cities in poor countries.

Such a phenomenon as the unsatisfactory quality of urban air did not escape the European continent. But the countries of Central and Eastern Europe, including Ukraine, suffer the most from this. For example, specialists of the Central Geophysical Observatory named after Boris Sreznevskyi calculated that in the first half of 2020, a high level of air pollution was observed in 13 Ukrainian cities. The leaders were Mariupol, Odesa, and Lutsk. Another nine cities had a high content of harmful substances in the air. And compared to last year, the concentration of substances dangerous to health in the air of Ukrainian cities has even increased.

It was found that along with the increase in the concentration of harmful substances in the atmospheric air, there was an increase in the level of morbidity of the population, including diseases of the respiratory system, circulatory systems, and diseases of allergic origin. A strong direct correlation was found between the degree of air pollution with dust and the general incidence of bronchial asthma ($r = 0.88$), circulatory system ($r = 0.91$), ischemic septal disease ($r = 0.89$), for allergic rhinitis ($r = 0.72$).

In Ukraine, about 17 million people, or 34% of the entire population, are negatively affected by atmospheric pollution. Malformations of children in cities with environmental pollution occur 3-4 times more often than in relatively clean ones, respiratory diseases are registered twice as often, the general level of morbidity in the population is 25-40% higher, the level of allergic, oncological, cardiovascular diseases is also higher. , genetic and other diseases.

Sources of environmental emissions, Table 1.1

Industry	Type of emissions	Harmfulness
Coal, metalworking, paper	Emissions that contain particles of sand, rocks and other mechanical impurities	They can disrupt natural ecosystems, sanitation, silt the bottom and shore
Machine-building factories, enterprises of the chemical industry	Emissions resulting from the neutralization and treatment of wastewater	The environment is polluted by salts of heavy metals, cyanides, acids, toxic organic and inorganic compounds
Ore beneficiation, coal beneficiation, tanneries	Pollution that contains micro and macro elements	Pollution of the environment with an excessive amount of micro- and macro elements, in some cases by pathogens; (tanneries)
Alcohol, sugar, starch and molasses and other plants	Pollution that contains organic compounds of plant and animal origin	Environmental pollution with organic compounds that rot easily can cause infectious diseases

The development of road transport has led to an increase in atmospheric pollution with heavy metals and toxic hydrocarbons. The atmosphere is polluted by almost all types of modern transport, the number of which is constantly increasing in the world. Emissions from internal combustion engines contain carbon monoxide, nitrogen oxide and sulfur. When the amount of emissions becomes too high, the gases form an acidic environment when they come into contact with air. It has been observed that the use of unleaded gasoline makes it possible to reduce poisoning.

According to the latest research by the International Association of Automobile Manufacturers, in 2015, 947 million passenger cars and 335 million commercial vehicles were used in the world. In Ukraine in 2018, there were: 6,566,000 passenger cars, 250,000 buses, and about 840,000 motor vehicles.

Analysts estimate that the number of cars will double by 2050. In the next 30 years, 1 billion 200 million cars will appear in the world, and they will be concentrated mainly in the countries of the Asia-Pacific region.

The toxicity of the exhaust gases of gasoline engines is determined mainly by the content of carbon monoxide and nitrogen dioxide, and of diesel engines by nitrogen dioxide and soot. One of the ways to reduce the negative impact of transport on human health and the environment is to convert

transport engines to gas. Gas mixes with air better than gasoline, so it burns more completely in engines, while fewer harmful substances are released into the atmosphere.

In order to control the amount of harmful emissions into the atmosphere, with the aim of reducing them, systems for controlling emissions of combustion products are installed in developed countries, despite the high cost of such systems. Control over the content of exhaust gases is being strengthened, treatment facilities are being installed at power plants and other industrial enterprises, and flue gas desulfurization technologies are being introduced. Installation of catalytic converters on gasoline automobile engines allows reducing the volumes of emissions of nitrogen oxides, carbon monoxide and hydrocarbons into the atmosphere by more than 75%.

It should be noted that in order to reduce emissions into the atmosphere in developed countries, systems for controlling emissions of combustion products are constantly being installed, despite the high cost of such systems. Control over the content of exhaust gases is being strengthened, and a fine is imposed for exceeding the norms. The installation of water treatment facilities at power plants and other industrial enterprises gives results. The introduction of flue gas desulfurization technology at coal-fired thermal power plants allows to significantly reduce the content of sulfur dioxide in the smoke. The combined use of heat and energy in industrial plants means that the heat, instead of "going to the wind" and dissipating in the atmosphere, will heat the premises.

The specific weight of various branches of world industry and transport in the total amount of atmospheric pollution is (in %): thermal energy — 25.7; ferrous metallurgy — 23.4; oil production and petrochemical — 13.7; transport — 11.6; non-ferrous metallurgy — 11.1; mining — 7.1; enterprises of the construction complex — 3.4; mechanical engineering — 2.8; other industries — 1.2.

1.3 Consequences of pollution of the Earth's atmosphere

The atmosphere has self-healing properties. This ability of hers has been thoughtlessly exploited by man for a long time. Production waste was thrown into the air with the expectation that it would be neutralized and processed by nature itself. It seemed that no matter how large the total mass of waste was, compared to the restorative properties of the atmosphere, it was insignificant. However, the process of pollution is rapidly progressing, and it is becoming obvious that natural self-cleaning systems will sooner or later not be able to withstand such an onslaught.

The most well-known consequences of atmospheric pollution are the greenhouse effect, acid rain, the ozone hole in the atmosphere, and smog.

The greenhouse effect is a phenomenon in the atmosphere of the Earth and other planets, in which the energy of the sun's rays, reflecting off the surface, cannot return to space, because it is trapped by the molecules of various gases, which leads to an increase in the temperature of the surface. Without the

greenhouse effect, the Earth's surface temperature would be estimated to be about 33° lower than it actually is, at -18°C. The greenhouse effect is also significant on Mars and, especially, on Venus. The strengthening of the greenhouse effect is primarily related to the increase in the content of man-made carbon dioxide in the atmosphere through the burning of fossil organic fuels by energy companies, metallurgical plants, and automobile engines. The amount of man-made CO2 emissions into the atmosphere increased significantly in the second half of the 20th century. The main reason for this was the dependence of the world economy on fossil fuels. Industrialization, urbanization and the rapid growth of the planet's population led to an increase in the global demand for electricity, which is met mainly by burning fossil fuels.

Nowadays, the possibility that the greenhouse effect may greatly increase and lead to global warming as a result of human activity is of great concern. The UN Environment Program predicts that a possible increase in the average temperature of the Earth by 1.5 °C by 2025 will cause a rise in the level of the world ocean by 25 cm due to the melting of ice near the poles.

The main cause of acid precipitation is the release of sulfur and nitrogen compounds into the atmosphere during the burning of fossil fuels in stationary installations and transport engines. Acid precipitation damages buildings, monuments and metal structures, causes digression and death of forests, reduces the yield of many agricultural crops, worsens the fertility of soils that have an acidic reaction, and the condition of water ecosystems. Rainwater in clean air has a pH of 5.6. The lower the pH value, the higher the acidity. If the acidity of the water is below 5.5, the precipitation is considered acidic. Acid rain is formed as a result of the reaction between water and pollutants such as sulfur dioxide (SO2) and various nitrogen oxides (NOx). These substances are emitted into the atmosphere by road transport, as a result of the activities of metallurgical enterprises and power plants, as well as during the burning of coal and wood. Entering into a reaction with atmospheric water, they turn into solutions of acids: sulfuric, sulfurous, nitric and nitric. Then, together with snow or rain, they fall to the ground.

In aquatic ecosystems, acid precipitation causes the death of fish and other aquatic inhabitants. Acidification of water in rivers and lakes seriously affects land animals as well, because many animals and birds are part of food chains that begin in aquatic ecosystems. Along with the loss of lakes, the degradation of forests also becomes evident. Acids destroy the protective wax coating of leaves, making plants more vulnerable to insects, fungi and other pathogenic microorganisms. During a drought, more moisture evaporates through damaged leaves. The leaching of biogens from the soil and the release of toxic elements contribute to slowing down the growth and death of trees. It can be assumed that what happens to wild species of animals when forests die. If the forest ecosystem is destroyed, soil erosion begins, clogging of reservoirs, flooding and deterioration of water supplies become catastrophic. Acidification of the soil by nitric acid rains stimulates the development of forest pests. As a result of acidification in the soil, there is a dissolution of nutrients vital to plants; these substances are carried out

by rains into the groundwater. At the same time, heavy metals are leached from the soil, which are then assimilated by plants, causing serious damage to them. Using such plants for food, a person also receives an increased dose of heavy metals along with them. When the soil fauna degrades, yields decrease, the quality of agricultural products deteriorates, and this, as we know, causes the deterioration of people's health. Under the action of acids, aluminum is released from rocks and minerals, as well as mercury and lead, which then enter surface and groundwater.

Aluminum can cause Alzheimer's disease, a type of premature aging. Heavy metals entering natural waters have a negative effect on the kidneys, liver, and central nervous system, causing various oncological diseases. The genetic consequences of heavy metal poisoning can manifest themselves after 20 years or more, not only in those who use dirty water, but also in their descendants.

Acid rain corrodes metals, paints, synthetic compounds, destroys architectural monuments. Many sculptures and buildings in Rome, Venice and other cities, monuments of architecture, such as the Parthenon in Athens, the Cologne Cathedral and others, have received much more damage in the last few decades than in the entire previous time. More than 50,000 sculptures of the rock "City of Buddhas" near Yunnan in China, built 15 centuries ago, are under threat of complete destruction as a result of acid rain. Acid rain is most characteristic for industrialized countries with highly developed energy. They caused the greatest loss to the forests of Central Europe, in particular, 35% of Germany's forests (covering an area of more than 2.5 million hectares) were damaged by them[EP4]. The damage from acid rain to European forests is estimated at 118 million m3 of wood per year (of which about 35 million m3 is in the European territory of Russia).[EP4] Agricultural plants are affected to a lesser extent by acid rain, as soil acidification here can be controlled with agrochemicals. To combat acid rain, it is necessary to direct efforts to reduce emissions of acid-forming substances by coal-fired power plants.

Smog - "smoke fog" - an aerosol consisting of smoke, fog and dust, is one of the types of air pollution in large cities and industrial centers. Intense smog causes allergic reactions, irritation of the mucous membrane, attacks of bronchial asthma, damage to vegetation, buildings, structures.

The history of the great smog that enveloped London on December 5, 1952 and dissipated only by December 9 should be well remembered. This event became a real ecological disaster, as a result of which 12,000 people died. It is believed that the Great Smog became the starting point of the modern nature protection (ecological) movement.

At the beginning of December 1952, a cold fog descended on London. Because of the cold, the townspeople began to use coal for heating in larger quantities than usual. Around the same time, the process of replacing city electric transport (trams) with buses with a diesel engine was completed. Locked in by a heavier layer of cold air, combustion products in the air reached an extraordinary concentration in a matter of days. The fog was so thick that it prevented the movement of cars. Concerts were cancelled,

film screenings were stopped, as smog easily penetrated the premises. The audience sometimes simply did not see the stage or the screen. At first, the reaction of the townspeople was calm, since fogs are not uncommon in London. However, in the following weeks, statistical data collected by the city's medical services revealed the deadly nature of the disaster - the number of deaths among infants, the elderly and those suffering from respiratory diseases reached four thousand people. Another eight thousand people died in the following weeks and months.

I will try to explain why this happened on the example of my own research in the next section.

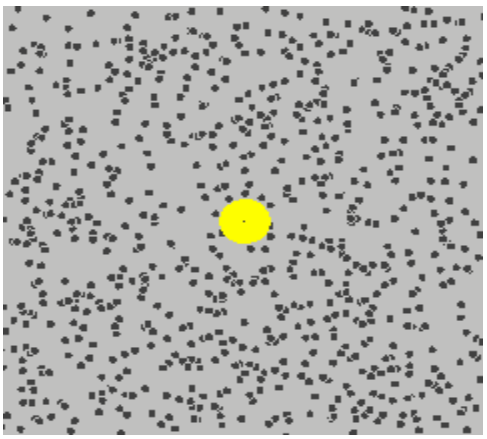
1.4 Smog. Chaotic movement of Brownian particles

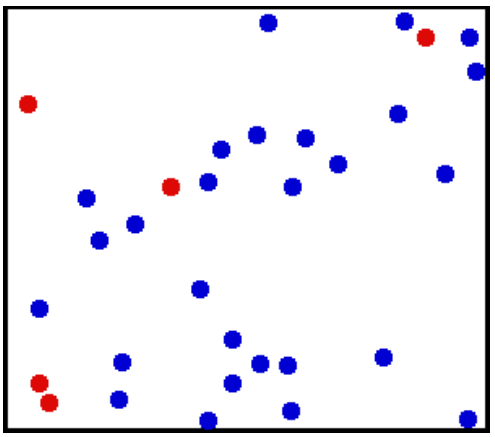
According to the Air Quality Index, smog has the highest concentration of pollutants PM 2.5 and PM 10 (dust with a size of 2.5 to 10 nanometers). It is a mixture of inorganic ions, small water droplets, metals, and hydrocarbons. Very small particles (about 1 nm or less) are gas molecules. For example, the diameter of water and oxygen molecules is 0.30 nm, nitrogen is 0.32 nm, and hydrogen is 0.25 nm. The behavior of such small bodies is very different from PM2.5 particles.

According to WHO data, the contribution of the main sources to the total anthropogenic emission of primary PM2.5 and PM10 in cities is distributed as follows: motor vehicles - 10-25%, fuel burning at stationary installations - 40-55%, technological processes in industry - 15-30 %, long-distance transfer from sources located outside the city limits - 26-34%. At the same time, the main source of PM2.5 is road transport.

Heavy PM10 particles "fall" to the ground over time (black snow near a factory or on both sides of a highway), while light PM2.5 practically does not settle. It is more difficult for them to overcome the resistance of the environment, in addition, they are also characterized by Brownian motion (Fig. 2.1;2.2).

Fig. 2.1 and 2.2





Brownian particles, like molecules, are in chaotic motion. They are subject to all gas laws.

The distribution function of molecules under the action of the field of external forces (depending on their potential energy) was found by Boltzmann.

The pressure difference at levels that differ by a high Δh is equal to:

$\Delta p = \rho g \Delta h = -mng\Delta h$, where m is the mass of one molecule, n is the concentration of molecules.

Moving on to the infinitely small, we have:

$$dp = -mngdh .$$

On the other hand, according to the main equation of the molecular-kinetic theory of gas, $p = nkT$, from which we find:

$$dp = kTdn .$$

So,

$$kTdn = -mgdh$$

or

$$\frac{dn}{n} = -\frac{mgdh}{kT} .$$

We potentiate and get:

$$n = n_o e^{-\frac{mqh}{kT}} .$$

In general, the energy distribution of molecules in the potential field will be as follows:

$$n = n_o e^{-\frac{W}{kT}}$$

This is Boltzmann's law, which shows that at a given temperature T , the concentration of particles n increases with a decrease in their energy W , that is, that particles are concentrated in places with lower potential energy - that is, in places of stable equilibrium. But with an increase in T at a constant energy W , the difference in the concentration of n and $n_{o\ is}$ smoothed out. In this way, the field forces "try to hold" the particles throughout the volume. At $T \to 0$, atmospheric molecules would fall to Earth.

Boltzmann's law characterizes the distribution of particles in any force field and is used for electrons in an electric field in metals, semiconductors, etc. Therefore, it can be used to describe pollutants PM 2.5 and PM 10 (dust from 2.5 to 10 nanometers in size).

The average kinetic energy of one Brownian part is equal to the average kinetic energy of molecules at a given temperature (2.1).

$$\overline{E_k} = \frac{3}{2}kT = \frac{3}{2}\left(\frac{R}{N_A}\right)T \qquad 2.1$$

At 20 ^{0}C E_k = 6.1*10 $^{-23}$ J, and at 0 ^{0}C – 5.7*10 $^{-23}$ J. At a higher temperature, PM2.5 particles are in the atmosphere for a longer time.

Therefore, indoors and in the warm season, the harmful effect of PM2.5 particles is much greater (table 1.2).

The concentration of dust particles suspended in the air is described by the Botsman distribution (2.2).

$$n_h = n_0 \exp\left(-\frac{3mgh}{2\overline{E_k}}\right) \qquad 2.2$$

Table 1.2

Diameter, μm	Sedimentation speed, m/s	Displacement, m
0.1	8.71×10^{-7}	3.70×10^{-5}
0.2	2.27×10^{-6}	2.01×10^{-5}
0.4	6.85×10^{-6}	1.30×10^{-5}
1.0	3.49×10^{-5}	7.43×10^{-6}
Diameter, μm	**Sedimentation speed, m/s**	**Displacement, m**
2.0	1.29×10^{-4}	5.06×10^{-6}
2.5	1.98×10^{-4}	……
4.0	5.00×10^{-4}	……
10	3.03×10^{-3}	……
20	2.20×10^{-2}	……
40	4.71×10^{-2}	……
100	2.47×10^{-1}	……

As can be seen from the table, the settling speed for PM2.5 particles is 15 times lower than for PM10, and is approximately 0.2 mm/s. This value is compensated even by a slight upward air flow. And for PM1 particles (with a diameter of up to 1 μm), the Brownian motion completely prevails over the sedimentation rate. Therefore, this smallest fraction of particles may never settle at all.

PM1, PM2.5 and PM10 particles can be considered as a permanent air pollutant. Migration and elimination are extremely slow due to the small size of the particles. They can be captured by filters based on the diffusion process. The only sure way to change the number of indoor particles is to control the sources of the particles, namely, -removal or limited use of potential sources of particles.

The atmosphere of any large city in our country contains a sufficient amount of negative PM2.5 particles. Therefore, if we at least clean the air in the rooms where we spend most of our lives while sleeping and working, then the average daily dose of negative particles inhaled during the day will significantly decrease. And you need to start by improving the composition of the air environment directly in your office, apartment or house. Only in this way is it possible to insure yourself against many of the diseases listed above. To clean the air, it is best to use an air purifier with a HEPA filter, which will effectively remove particles up to 0.3 microns in size from the air.

SECTION II

ECOLOGY OF THE ATMOSPHERE OF POLTAVA REGION

2.1 Research on the level of air pollution in the Poltava region

The situation with air pollution in the world is similar to the situation in Ukraine, and the most polluting cities are Mariupol, Kryvyi Rih and Kyiv. Ten years ago, Poltava region was considered an ecologically clean region. What is the current situation? In order to find out about the level of atmospheric pollution over the Poltava region, I conducted my own scientific research.

Every day throughout the year, with the help of the Windy program, I conducted my own research on the level of atmospheric pollution in Poltava Oblast.

Windy is a Czech company that provides interactive weather forecasting services around the world. The services take all the information from the Earth's meteorological satellites.

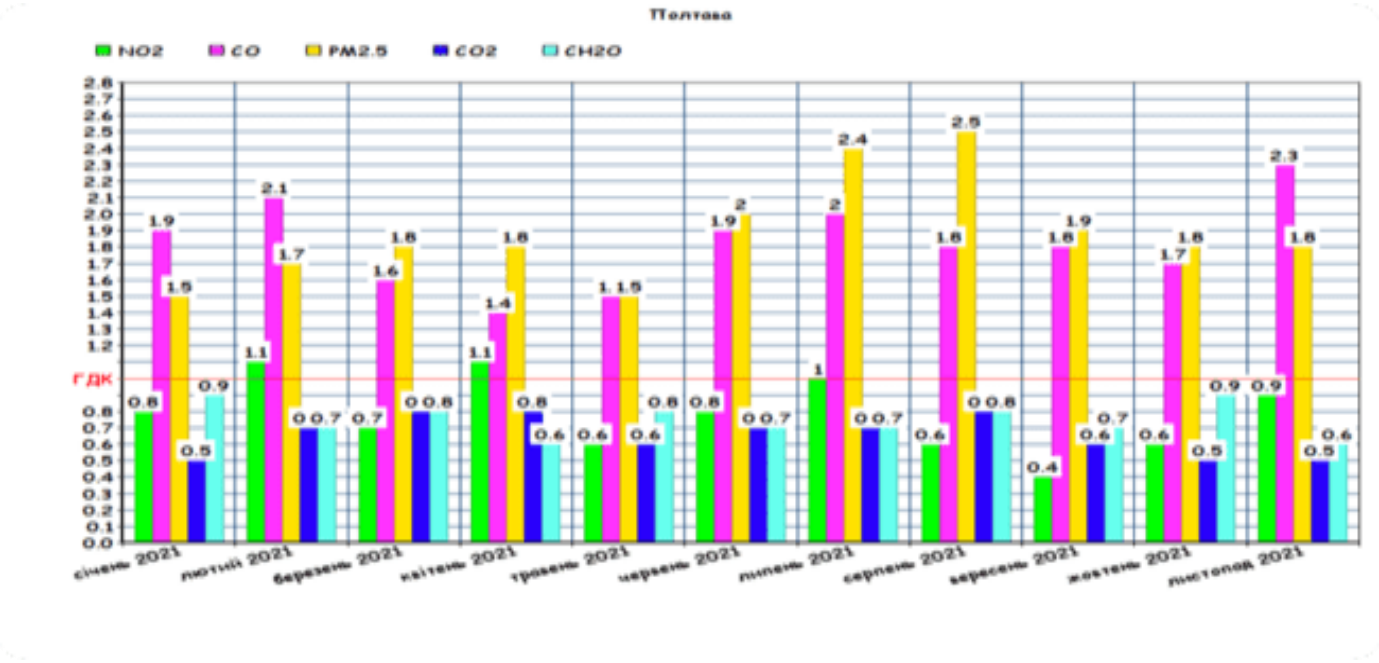
Meteorological satellites are artificial satellites of the Earth, whose work program includes photographing cloud cover and other observations of the state of the lower atmosphere.

There were three cities in the field of vision - Poltava, Kremenchuk, Horishni Plavni. Based on daily observations, I derived the average pollution index for each month in the dimension of MPC (maximum permissible concentration).

Maximum permissible concentration (GDC)– the maximum amount of a harmful substance per unit volume or mass in water, air or soil environments.

POLTAVA (Atmospheric air pollution in Poltava)

Diagram 2.1



According to my research, Poltava constantly has dirty air. It is especially logical that the greatest concentration of pollutants is concentrated on the Makuhiv landfill. The concentration of formaldehyde, nitrogen oxide and carbon monoxide is above the norm. Nearby settlements and the people who live there are subject to constant poisoning. Immune diseases are common, including incurable ones.

According to my own device installed in Poltava, the city also has problems with PM2.5 pollution, in my opinion, this situation is due to the large number of cars. (diagram 2.1)

July and August 2021 became critical, because solid particles remain in the atmosphere for a longer time due to the increase in atmospheric temperature. Such a situation, which has a permanent place, is a real threat to people's lives and health.

October and November 2021 were distinguished by a high deviation from the norm according to the CO (carbon monoxide) indicator. This situation became possible due to the burning of leaves and dry matter (Fig. 2.1)

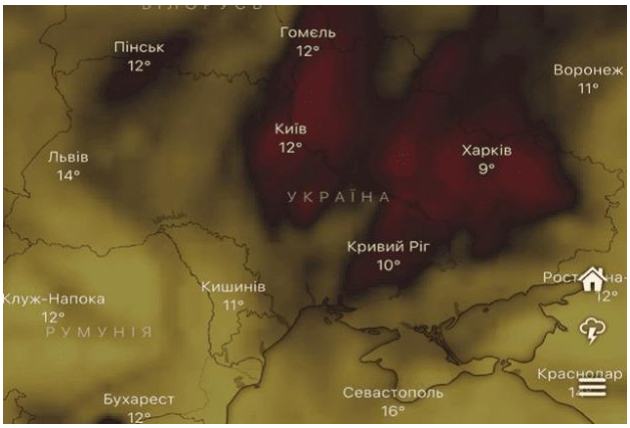
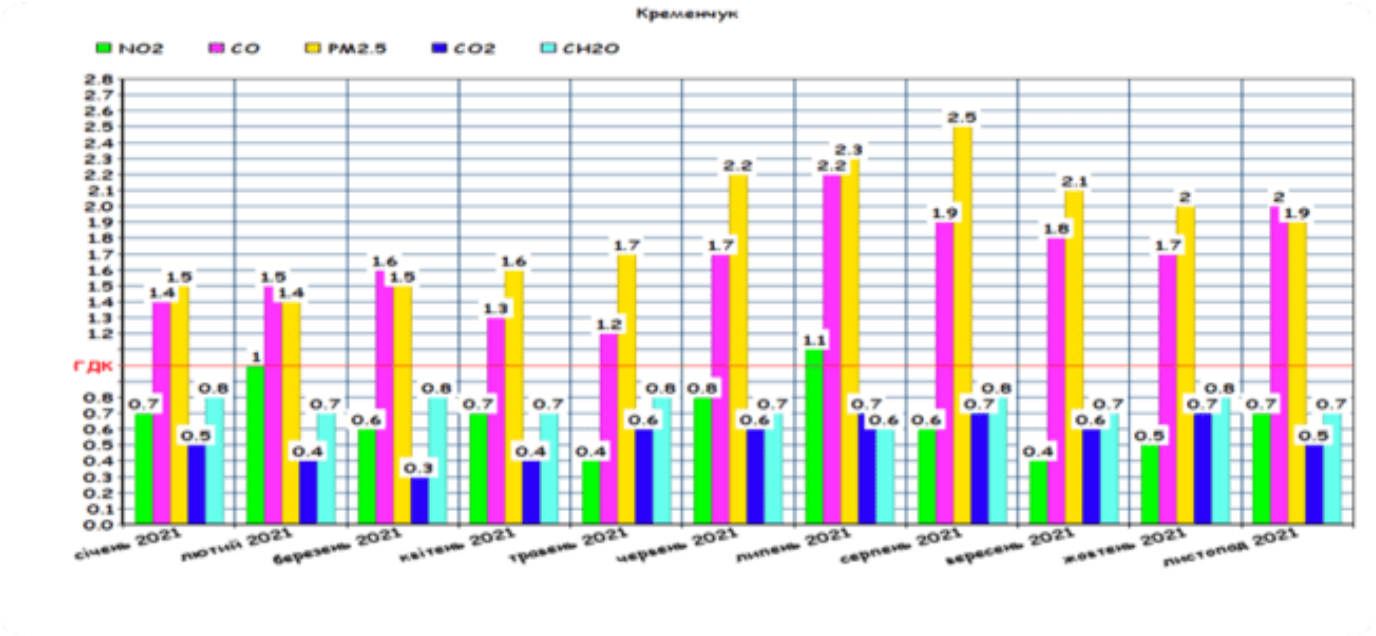


Fig. 2.1
The sky over Ukraine on October 27, 2021
Exceeding the norm of CO by 4-5 times

Kremenchuk (Atmospheric air pollution in Kremenchuk)

Diagram 2.2



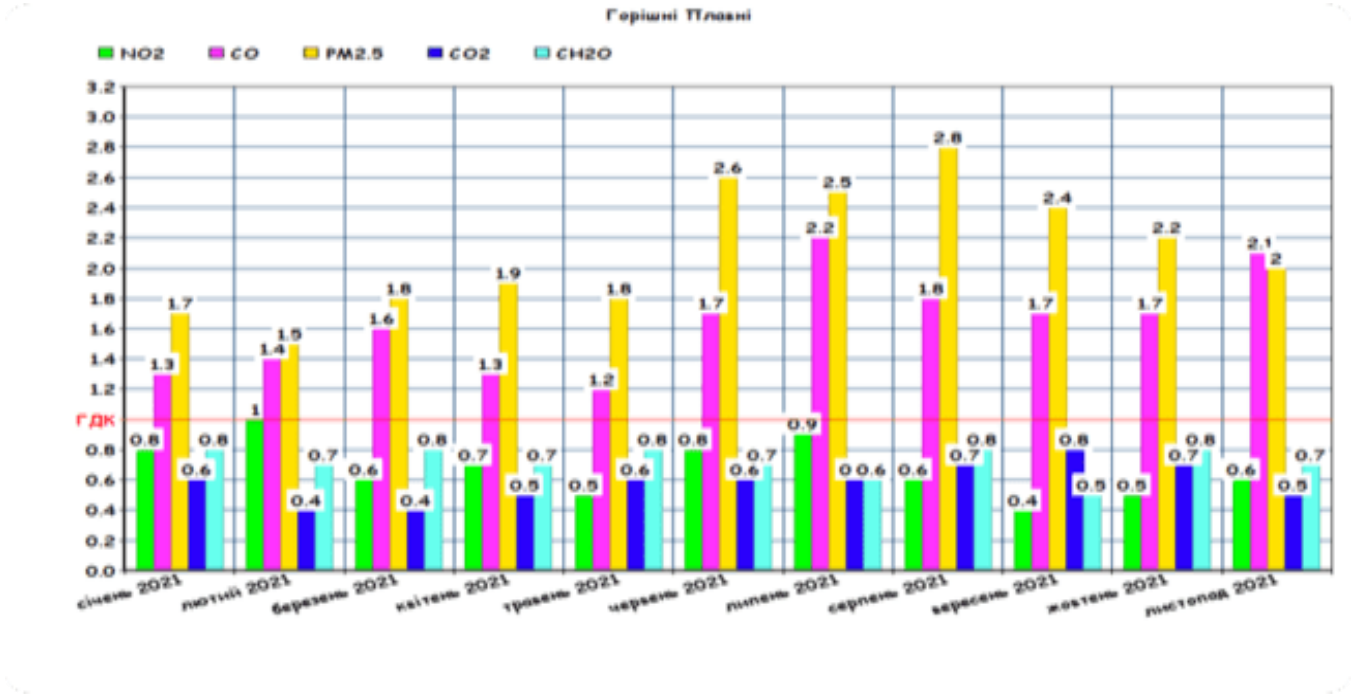
KREMENCHUK

The city of Kremenchuk with its industry represented by machine-building, petrochemical, energy, construction, light and food industries is a source of environmental pollution in the Kremenchuk region. Today, 86 industrial enterprises operate in the city. About 95% of emissions from enterprises are accounted for by 9 of them: JSC "Ukrtatnafta", JSC "Kremenchutsk Technical Carbon Plant", Kremenchutsk Thermal Power Plant, JSC "Kremenchutsk Wheel Plant", HC "AvtoKrAZ", JSC "Steel Plant", concern "Kryukiv Wagon Building Plant" ", OJSC "Kredmash".

From the inquiries about cleaning filters, I can state with confidence that no company is equipped with cleaning filters. Some of them have outdated filters. Kremenchuk is a critically dangerous city for people's lives. Nitric oxide and carbon dioxide constantly exceed the norm
(diagram 2.2), carbon monoxide, fine dust particles, sulfur dioxide and formaldehyde.

Horishni Plavni(Atmospheric air pollution in the city of Horishni Plavni)

Diagram 2.3



The mining industry is the economical basis of Horishni Plavni, which accounts for 96.4% of the total volume of sales of industrial products in the city.

Mining activity is the cause of air pollution in Horishni Plavni. A characteristic excess of PM2.5 fine particles in the air, which is constantly observed (diagram 2.3)

So, according to my research, PM2.5 and CO (carbon monoxide) particles exceed the pollution standards the most. If we calculate the average excess for 3 cities according to these two indicators, then we will get:

(20:11+18.3:11+18:11)/3= 1.7 – the average excess of the norm for carbon monoxide

(20.7:11+20.7:11+23.2:11)/3= 1.95 – the average exceedance of the norm for small particles PM2.5

2.2 State influence on environmental problems in Ukraine

Ukraine's intention to develop relations with the European Union, confirmed by the Association Agreement with the EU, gave Western colleagues the right to familiarize themselves with the state and methods of monitoring air pollution in Ukraine.

"Today, there is very little reliable information about air quality in Ukraine. The organization and methodology of pollution monitoring do not meet EU standards. Suspended particles of PM10 and PM2.5

and a number of aggressive substances are not monitored: ozone, benzene, arsenic, mercury. There is no data on pollution in the entire territory of the country, the available information is relevant only for the points where measurements are made. Monitoring is not carried out all the time, but a maximum of 4 times a day. Hygienic standards are outdated. There is no system of informing the population about the quality of atmospheric air, as well as a system of pollution control" - the verdict of the conducted monitoring.

In accordance with Ukraine's obligations under the association agreement with the EU, the system of all-Ukrainian state monitoring, which would collect data specifically on fine dust, was to be implemented in 2018. But the lack of funds became an obstacle, because one stationary device for measuring fine dust costs 330 thousand euros. For work, you also need to have calibration and chemical laboratories, which together cost more than 1 million euros. According to the Ministry of Energy of Ukraine, about 100 million hryvnias have been allocated for the year 2020 to install modern air monitoring systems in the most polluted cities of Ukraine. However, the plans were affected by the coronavirus pandemic, and funds were diverted to other needs.

I have prepared and sent a request to the Ministry of Internal Affairs of Ukraine and the State Emergency Service regarding the placement of air pollution monitoring points in Ukraine at the request of the European Union. The response received (Appendices A.2, A.3, A.4) did not satisfy my expectations regarding the improvement of affairs and Ukraine's progress on the way to overcoming the problem.

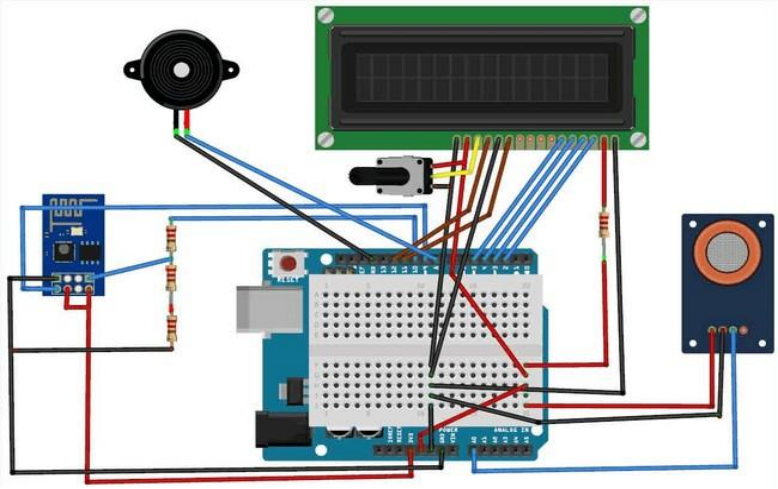
2.3 Own innovative development - portable air monitoring station at home "UNIVERSE"

In Ukraine, there is no practice of informing the population about the days of the greatest atmospheric air pollution. Ukrainians are little aware of the current state of air pollution over Ukraine.

My idea was to invent a modern device for measuring air pollution at home, because often, it is at home due to low-quality furniture, modern repairs, in the process of which not quite ecological materials are used, the air in people's homes is quite polluted with chemical impurities. I managed to create the device thanks to my studies in the section of experimental physics. It is compact and inexpensive, so it is affordable. My device, through personal observation, will teach every Ukrainian to understand the problem of air pollution and take care of their health. Own device for measuring the level of air pollution at home is designed to measure the following parameters: CH2O; CO2; PM 1; PM 2.5; PM 10. To make the device, **I purchased the following parts:**

Fig. 2.3 Arduino Uno board Fig. 2.4 MQ-135 gas sensor (NO2, CO2, CO, CH2O)

Project scheme of the device



Principle of operation of the MQ-135 sensor

MQ-135 sensors belong to semiconductor devices. The principle of operation is based on the change in the resistance of the layer of tin dioxide SnO2 upon contact with the molecules of the determined gas. The sensitive element of the sensors consists of a ceramic tube coated with Al2O3 and a sensitive layer of tin dioxide applied to it. A heating element passes inside the tube, which heats the sensitive layer to the temperature at which it begins to vaporize the specified gas.

Technical characteristics of the MQ-135:

- supply voltage: 5V;
- warm-up time: about 1 minute;
- current consumption: 130-150 mA;
- operating temperature range: -10 ... 45 ° C;
- output signal: TTL level;
- dimensions: 35 x 20 x 21 mm;
- weight: about 10 g.

Process and work results

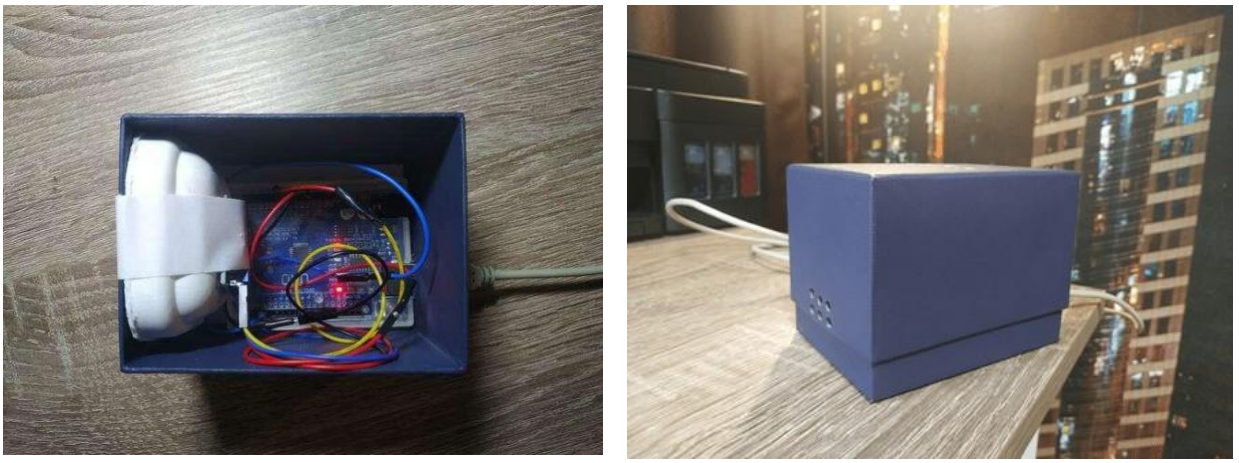


Fig. 2.5 Device (internal view)

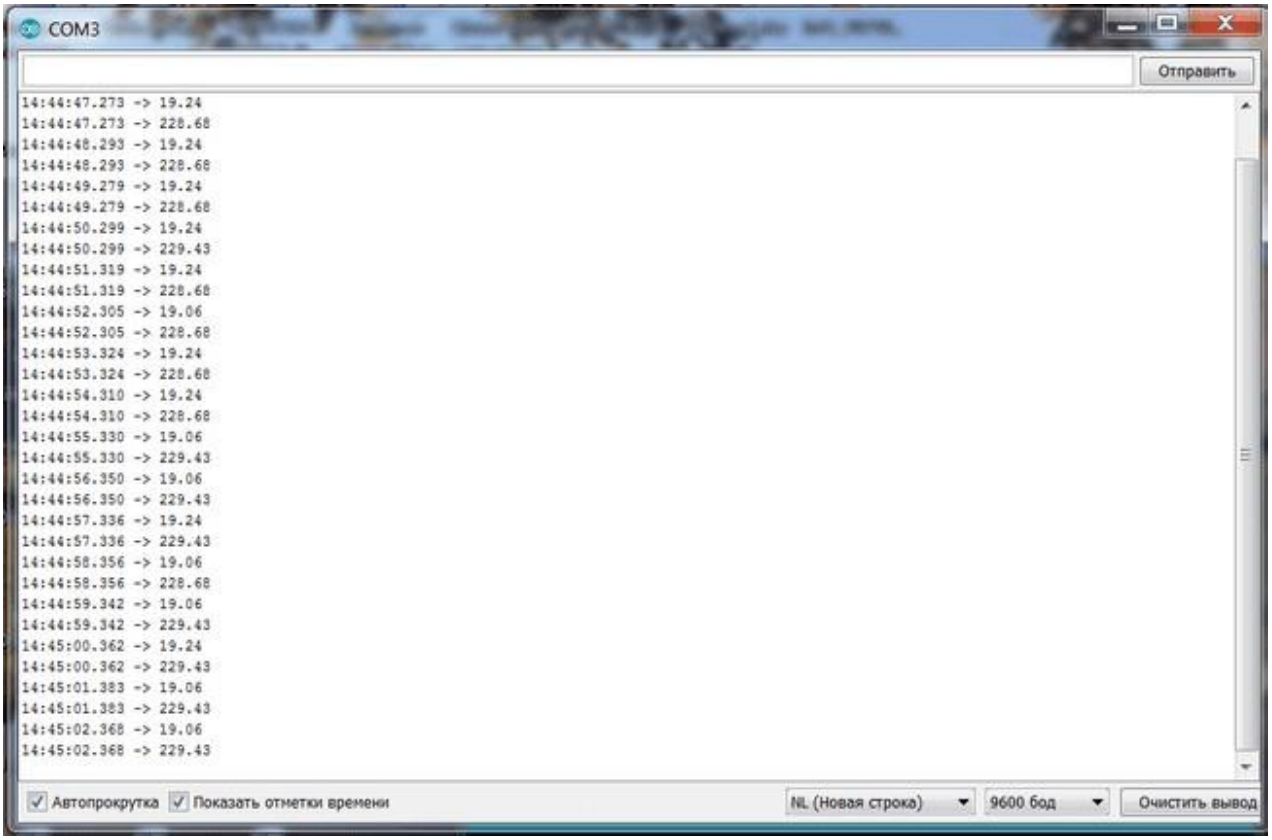


Fig. 2.6 Display of information on the monitor screen

The device (Fig. 2.5) displays total pollution information on the monitor, finding the average number of pollutants: NO2, CO2, CO, CH2O. The measurement takes place using conventional units from 0 to 1000, where 0 to 420 is a normal indicator of pollution. Data is updated every second (Fig. 2.6).

The result of the work: in my opinion, the work carries a scientific novelty, which consists in conducting a scientific study for the reasoned delineation of the problem of atmospheric pollution in the region and in the development of an own device that will provide an opportunity to independently measure its pollution.

The developed own device for measuring air pollution is compact and inexpensive. Each person at home will be able to observe the level of air pollution, know about problems and look for solutions.

CHAPTER III

EUROPEAN WAYS TO OVERCOME THE ENVIRONMENTAL CRISIS

3.1 European Earth observation program "Copernicus"

Member states of the European Union use the Copernicus observation program for high-quality, continuous monitoring of atmospheric air pollution (Fig. 3.1).

Copernicus is an Earth observation program coordinated and managed by the European Commission in partnership with the European Space Agency (ESA), EU Member States and EU agencies.

It is aimed at achieving global, continuous, autonomous, high-quality, wide-range Earth observation. Providing accurate, timely and easily accessible information is used to improve environmental management.

Fig. 3.1 Central Office of the European Space Agency (ESA). Work according to the observation program "Copernicus"

Rice. 3.2 Screenshot of Windy

The goal is to use the vast amount of global data from satellites and ground, air, sea measurement systems to produce timely and quality information, services and knowledge, and to provide autonomous and independent access to information in the fields of environment and security at the global level to help service providers, government bodies and other international organizations to improve the quality of life

of European citizens. In other words, the system combines all the information received by the Copernicus satellites, air and ground stations and sensors to provide a comprehensive picture of the "health" of the Earth.

One of the advantages of the Copernicus program is that the data and information generated by the program are freely available to all users and the public, thereby enabling the development of the following fields.

The services offered by Copernicus cover six main areas that influence each other: atmosphere, water, land, climate, emergencies and security. The services developed and operated by Copernicus are open to its users and the public.

There are other developments of scientists in the form of services: WeatherRadar, Doppler, Ventusky, Windy (Fig. 3.2).

I used the latter program for my own research. Windy is a Czech company that provides interactive weather forecasting services around the world. The services take all the information from the Earth's meteorological satellites (Fig. 3.3).

Meteorological satellites are artificial satellites of the Earth, whose work program includes photographing cloudiness and other observations of the state of the lower atmosphere[6]. The images from space clearly show the of pollution above industrial centers, their movement, structural features, which allows us to judge the concentration of impurities and the height of their spread. Smoke plumes from factories, sea vessels and smog spots of industrial pollution can be clearly seen by cosmonauts, but their systematic study is possible only through space photographs, which clearly record all sources of pollution.

Fig. 3.3 Meteorological satellites of the Earth

3.2 On passing environmental practice in Spain

On September 1-9, 2021, at the invitation of the Spanish side, I had the opportunity to study and gain practical experience in the field of ecology. I had the opportunity to familiarize myself with the Spanish experience in the fight against atmospheric air pollution.

As part of the Erasmus youth exchange, we studied the goals of sustainable development of the European Union. The goals of sustainable development in terms of ecology include 5 areas - clean drinking water, use of renewable energy sources, fight against climate change, preservation of marine and terrestrial ecosystems. All these problems are inherent in Spain.

In the 1990s, Spain hopelessly lagged behind the economically developed countries of Europe in terms of environmental protection. Now it is inferior only to Switzerland, Luxembourg, Australia, Singapore, the Czech Republic and Germany, ahead, in turn, of more than 170 countries. And every year,

more and more laws and regulations are adopted here, aimed at protecting rare species of trees and animals, as well as improving the ecological situation in large and industrial cities. At the moment, there are about twenty national laws aimed at protecting the environment in Spain.

Recently, close attention has been paid to the problem of air pollution in Spain, where Barcelona and Madrid suffer the most. To do this, in many Spanish cities, they are trying to convince local residents to use public transport or to switch to bicycles, which rental agencies are available in all large settlements. The Spanish authorities have introduced new restrictions on the movement of old cars, aimed at reducing air pollution by 40%. "Tough" measures include a complete ban on the movement of old cars. In addition, owners of all old cars will have to test the emissions of their cars. Drivers whose cars are subject to a traffic ban will be forced to pay a fine of 90 euros.

3.3. Studying the experience of the Republic of Cyprus on the way to ecological stability

On November 21-27, under the Erasmus program, I visited Cyprus and had the opportunity to familiarize myself with the country's environmental situation. The government pays considerable attention to the cleanliness of the island's environment.

In April 2021, a waste processing plant began operating in the city of Limassol. Task No. 1 for the Government of Cyprus is the organization of the full functioning of household waste collection points. The republic plans to switch to efficient waste management and a cyclical model of industrial development, which paves the way for the secondary use of raw materials. The government of Cyprus is working to completely eliminate waste burial on the island.

The opening of the waste processing plant completely solved the problem of air pollution in Cyprus. The pollution indicators of my device did not exceed the norm.

CHAPTER IV

PRACTICAL ASPECTS OF SCIENTIFIC WORK

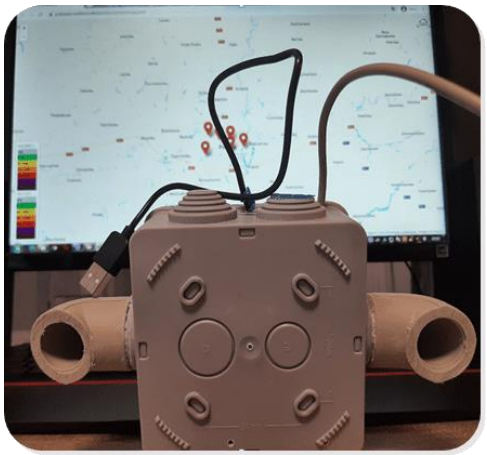
4.1. The work of the scientific laboratory "POLTAVA AIR CONDITION"

Last year, while working on a research paper, I made an air quality monitoring device. He measured CH2O, CO, NO2. The device had to be improved for more accurate monitoring and ease of use. Based on last year's project (Fig. 4.1), adding a larger number of sensors and changing the Arduino Uno board to an ESP-8266 Wi-Fi module, I, together with the students of the Academy of Medical Sciences, made the monitoring much more accurate and convenient.

Now the device can measure PM2.5, and this is very important, because these particles dominate the process of air pollution and are extremely dangerous for human health. The new monitoring station was made on the basis of last year's UNIVERSE station.

Fig. 4.2 Observation of work stations for monitoring and adjusting their work by the Windy program

Fig. 4.1 First version "Universe" monitoring stations (Arduino Uno, MQ-135)



The new station is made of the following sensors: **Waveshare PM2.5 sensor, MQ-135 (NO2, CO2, CO), ZE08 – CH2O sensor.** Autonomous operation is provided by the **Wi-Fi module ESP8266.** Currently, there are 6 such stations.

A website was also developed, where online information is displayed, which is taken from monitoring stations located in various districts of Poltava. Currently, there are 8 such stations. In the future, it is planned to install a larger number of stations. You can familiarize yourself with the site by following the link:

poltavaaircondition.online

Telegram bot was also developed for more convenient use:

@POLTAVAAIRCONDITIONBOT

The following sensors are installed in the updated monitoring stations:

- MQ – 135 (NO2, CO, CO2);
- SDS – 011 (PM2.5, PM10);
- DHT – 11 (humidity and temperature);
- ZC08 (CH2O).

The device was adjusted using the Windy program and telegrams of the SaveEcoBot bot (Fig. 4.2).

Annual monitoring was based on the indicators of three sources: the Windy program, SaveEcoBot and monitoring stations of the Poltava Laboratory of the National Academy of Sciences.

The approximate error of the stations is 3%.

CONCLUSION

1. Information on the factors and consequences of anthropogenic influence on the air basin of the world, the correlation between the state of atmospheric air pollution and human morbidity, and climate changes that are currently occurring have been studied and summarized.

2. The most common types of atmospheric air pollution are singled out, including:

NO_2 (nitrogen dioxide), SO_2 (sulfur dioxide), CO (carbon monoxide), CH_2O (formaldehyde), O_3 (surface ozone), PM1, PM2.5, PM10 particles.

3. An annual monitoring of the state of air pollution in Poltava Oblast was carried out through the Windy program. It was found that the most characteristic types of atmospheric pollution for Poltava Oblast are CO (carbon monoxide) and PM2.5 particles.

4. It has been proven that microscopic Brownian PM2.5 particles, when inhaled, easily enter the lungs and blood, gradually poisoning the body. As a result of constant poisoning, irreversible processes are triggered in the human body, which lead to chronic diseases and the development of fatal diseases. The main source of these harmful substances is transport.

5. The principle of atmospheric pollution monitoring, which consists in the use of a system of sensors integrated into a global network, is considered.

6. Comparative information on Ukrainian and European methods of monitoring the state of atmospheric air was elaborated and summarized, noting the EU standards for the organization of air pollution measurement, existing global services and the European "Copernicus" program as the best experience.

7. The "POLTAVA AIR CONDITION" scientific laboratory was created, new portable air quality monitoring stations were made based on the "UNIVERSE" monitoring station, which are combined into one network and systematically display indicators on the developed site (telegram bot).

USED BOOKS:

1. Shvydenko A.N., Rudenko V.P., Evdokymenko V.K. Ecological foundations of nature management. Kyiv, 1999, pp. 130-135 Perelman Ya. Interesting physics / Yakov Perelman., 2016. – 496 p. – (Educational project).

2. I.R. Stakhiv Kyiv National University named after Taras Shevchenko, Kyiv The influence of the polluted air environment on the health of the population in 2001-2010. Hida T. Brownivsky movement / Takeyuki Hida., 1987. – 304 p.

3. "Wikipedia" is a free encyclopedia. page 355.

4. Law of Ukraine "On Protection of Atmospheric Air".

5. Article 79 of the Code of Ukraine "On Administrative Offenses".

6. Ambient air quality monitoring to assess the impact on human health WHO Regional Publications. European series. No. 85. - Published by WHO, 2001. - 293 p.

7. Borodin A. M. Handbook of Brownian motion. Facts and formulas / Andriy Mykolayovych Borodin., 2016. – 704 p.

8. A. Lichtenberg. Dynamics of particles in phase space / A. Lichtenberg.,
1972. – 304 p.

9. Levi P. Stochastic processes and Brownian motion / P. Levi, 1972. - 375 p.

ELECTRONIC RESOURCES:

1. World Air Quality Report - 2020 [Electronic resource]. – 2021. – Resource access mode: file:///C:/Users/user/AppData/Local/Temp/world-air-quality-report-2020-en.pdf

2. TOP-10 megacities with the most polluted air [Electronic resource]. – Mode of access to the resource: https://mind.ua/news/20190474-top-10-megapolisiv-z-najbilsh-zabrudnenim-povitryam

3. Ukraine ranked 8th in Europe and 43rd in the world in terms of air pollution in 2020 [Electronic resource]. – 2021. – Mode of access to the resource: https://www.pravda.com.ua/news/2021/03/16/7286775/.

4. Material from Wikipedia - the free encyclopedia. [Electronic resource]. – 2021. – Mode of access to the resource: https://uk.wikipedia.org/wiki/.

5. Mode of access to the resource: mk.dsp.gov.ua

6. Who most pollutes the air of Ukraine: top-20 enterprises [Electronic resource] / Bohdan Petryshyn // Today. – 2019. – Mode of access to the resource: https://rubryka.com/ru/infographics/hto-najbilshe-zabrudnyuye-povitrya-ukrayiny-2018/ .

7. Encyclopedia of modern Ukraine [Electronic resource] / V. A. Dyachuk // Atmosphere. – 2001. – Mode of access to the resource: http://esu.com.ua/search_articles.php?id=44601 .

8. Physical pollution of the environment - types, sources, examples, characteristics [Electronic resource] / Mykola Svitalinskyi. – 2020. – Mode of access to the resource: https://nrv.org.ua/fizychne-zabrudnennya-navkolyshnogo-seredovyshha-vydy-dzherela-pryklady-harakter ystyka/ .

9. Library for MQ-135 [Electronic resource] - Resource access mode: https://github.com/GeorgK/MQ135 .

10. Air pollution monitoring system based on Arduino [Electronic resource] / admin-new. – 2020. – Resource access mode: https://microkontroller.ru/arduino-projects/sistema-monitoringa-zagryazneniya-vozduha-na-osnove-arduino/ .

11. Wikipedia. Free encyclopedia [Electronic resource] - Mode of access to the resource: https://uk.wikipedia.org/wiki/%D0%93%D0%BE%D0%BB%D0%BE%D0%B2%D0%BD%D0%B0_%D1%81%D1%82%D0 %BE%D1%80%D1%96%D0%BD%D0%BA%D0%B0 .

12. Chemical, bacteriological and toxicological air pollution and impact on non-infectious morbidity of the adult and children population - 2021 - [Electronic resource] - Resource access mode: https://slavska-gromada.gov.ua/news/1643010356/

13. Public health issues - 2020 - [Electronic resource] - Mode of access to the resource: http://cgz.vn.ua/problematika-gromadskogo-zdorovya/problematika-gromadskogo-zdorovya_455.html

14. Air - [Electronic resource] - https://slide-share.ru/povitrya-5400

【評語】180018

A year-round air quality analysis was conducted in three Ukrainian cities using portable and simple air quality monitors. The results show that the seasonal changes are quite obvious. It is worth exploring the relationship between seasonal variation and environmental conditions and sources of pollution. The monitoring principle of the monitor and the significance of air quality indicators should be thoroughly understood.