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CREATION OF AN INTERACTIVE MAP OF ENVIRONMENTAL POLLUTION IN THE RECREATION AREAS OF AN INDUSTRIAL CITY

The current ecological situation in Ukraine can be described as the most critical, which was formed over a long period due to the neglect of the objective laws of development and reproduction of the natural resource complex and in connection with current events. The level of pollution by various substances exceeds the norm not only in the so-called "work zones" and war zones, but also in sleeping areas and recreational areas. The cities of industrial zones of Ukraine, in particular the cities of its eastern part, are most prone to risk.

Recreational zones are created in order to provide people with the opportunity to rest and reduce the burden on the human body from the urbanized atmosphere of cities. But practice shows that the situation in recreation areas is also not satisfactory, and in some cases even more dangerous than in other places of the settlement. The most unfortunate thing is that most people do not even suspect that these places are as dangerous as, for example, work areas.

The main goal of our research is to confirm the hypothesis regarding the high level of atmospheric air pollution in the city of Kramatorsk and to create a tool for notifying the population of this information. That is why the task of creating a convenient, accessible, functional, accurate interactive map of the state of environmental pollution in the city's recreation areas, which could enable residents to choose the least polluted recreation areas at the current moment, is urgent.

On the basis of the analysis of the existing literature and the conducted research, a complex mathematical model was developed for the assessment of atmospheric air pollution in the recreational areas of the city of Kramatorsk, which consists of determining the exact distance between the source of pollution and the recreational area, forecasting the level of concentration of a separate substance in the recreational area, and determining the general state of pollution, which is expressed by a certain color of the corresponding recreation area on the interactive map. A software product in the form of an interactive map was developed to inform the population about the predicted level of atmospheric air pollution in the recreational areas of the city of Kramatorsk.

Key words: *air pollution, OpenStreetMap, API, interactive map, recreation zone, PM, substance, monitoring, environmental safety, emissions into the atmosphere.*

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СТВОРЕННЯ ІНТЕРАКТИВНОЇ МАПИ ЗАБРУДНЕННЯ НАВКОЛИШНЬОГО СЕРЕДОВИЩА В ЗОНАХ ВІДПОЧИНКУ ПРОМИСЛОВОГО МІСТА

Нинішню екологічну ситуацію в Україні можна охарактеризувати як максимально кризову, що формувалася протягом тривалого періоду через нехтування об'єктивними законами розвитку і відтворення природно-ресурсного комплексу та в зв'язку з сьогоденними подіями. Рівень забруднення різноманітними речовинами перевищує норму не тільки у так званих «зонах праці» та зонах бойових дій, а і у спальних районах, та рекреаційних зонах. Найбільш схильні до ризику міста промислових зон України, зокрема міста східної її частини.

Рекреаційні зони створюються для того що би надати можливість людям відпочити та зменшити навантаження одержуване організмом людини від урбанізованої атмосфери міст. Але практика демонструє, що ситуація в зонах відпочинку також не є задовільною, а в деяких випадках навіть більш небезпечною ніж в інших місцях населеного пункту. Найбільш прикрим є те, що більшість людей навіть не підозрюють, що ці місця є такими ж небезпечними як і, наприклад, робочі зони.

Основною метою нашого дослідження є підтвердження гіпотези щодо високого рівня забруднення атмосферного повітря у місті Краматорськ та створення інструменту для оповіщення населення цією інформацією. Саме тому задача створення зручної, доступної, функціональної, точної інтерактивної мапи стану забруднення навколишнього середовища у рекреаційних зонах міста, яка могла б дати змогу мешканцям самим обирати найменш забрудненні зони відпочинку на поточний момент часу, є актуальною.

На підставі аналізу існуючої літератури та проведеного дослідження була розроблена комплексна математична модель для оцінювання забруднення атмосферного повітря у рекреаційних зонах міста Краматорськ, яка складається з визначення точної відстані між джерелом забруднення та рекреаційною зоною, прогнозування рівня концентрації окремої речовини в рекреаційній зоні та визначення загального стану забруднення, що виражається певним кольором відповідної рекреаційної зони на інтерактивній мапі. Був розроблений програмний продукт у вигляді інтерактивної мапи для інформування населення щодо прогнозованого рівня забрудненості атмосферного повітря у рекреаційних зонах міста Краматорськ.

Ключові слова: *забруднення повітря, OpenStreetMap, API, інтерактивна карта, зона відпочинку, PM, речовина, моніторинг, екологічна безпека, викиди в атмосферу.*

Introduction

The current environmental situation in Ukraine can be described as the maximum crisis, which was formed over a long period due to the neglect of objective laws of development and reconstruction of the natural resource complex of Ukraine. There were structural deformations of the national economy, in which preference was given to the development of raw-mining, the most environmentally dangerous industries in Ukraine. The level of contamination with various substances exceeds the norm not only in the so-called "work zones", but also in residential areas and recreational areas. Cities in industrial zones of Ukraine, in particular in the Eastern part of Ukraine, are most at risk. Recreational areas are created in order to allow people to relax and reduce the load received by the human body from the urbanized atmosphere of cities. But practice shows that the situation in recreation areas is also not satisfactory, and in some cases even more dangerous than in other places of the settlement. The most annoying thing is that most people do not even suspect that these places are as dangerous as, for example, work areas.

All this information, first of all, is often placed somewhere on the websites of local environmental departments, but not on the main pages of popular Internet resources of the city. enough to talk about creating targeted software that should be available to every resident of the city at hand. And, secondly, most often this information is presented in the form of dry figures with the specified maximum permissible concentration (MPC), and is not interpreted in any convenient way for the average user, and even more so does not report the possible consequences of the influence of exceeding the concentration of a substance on the human body.

Research field, main questions

Usually, cartography is defined as the science and art of creating and using maps. Arthur Robinson [11] defined the philosophy of the "Golden age of cartography" as follows: functional design or scientific creation of the principles of cartographic design, which is based on the perceptual and cognitive limitations of the target map user. This approach to map research has given rise to a communication model that describes the map as a conduit through which messages can be conveniently transmitted from the map creator to its user [2; 5; 12]. Also, some of the main views for cartography were supplemented during visual communication with advertising, art, education, and psychology in order to create specific recommendations for designing maps to avoid inconveniences during the transmission of these messages. Despite the fact that the communication model did not bring significant benefits through some differences in terms of practical, applied, critical, and social theory [10; 8], the basic principles of design and use that took root in this era remain the basis of the modern cartographic curriculum to this day [6; 7].

For geoinformative systems that include interactive maps, the interaction with them or how the user manipulates the map is central. Maps can be divided into two large groups: "dynamic" and "static", but instead of the concept of "dynamic", that is, those that can constantly change, the concept of "interactive" will be used in order to distinguish between the so-called "update" of the map that was caused by the system (animation, image shape, etc.) and what was caused by the user (opening the menu, entering any additional information). The digital revolution and the information age in general, with the advent of new features, together prompted changes in the direction of how maps are created and used. Interactivity is one of the most important features of this kind [4; 9].

To create a digital interactive map, it was decided to use public services with tools for creating and publishing custom maps. OpenStreetMap (OSM) was selected among all available services [1]. As noted in their reviews Gorchakov and Wagner [14], OSM uses the same principles that formed the basis for the creation of Wikipedia. All the information on these maps was collected by a very large number of volunteers who provided data from street panoramas, satellite images, aerial photos, videos, and data from GPS trackers for this project. And despite its review of this service, it was concluded that for the city Kramatorsk, OSM maps contain more detailed and relevant information than all other services. The API documentation is also very convenient and freely available.

But despite all this, when choosing a mathematical model for predicting the level of air pollution, we must rely on our current standards, since the technological processes and cleaning technologies at enterprises in Ukraine are also very outdated and do not meet modern European requirements. Suffice it to say that one of Kramatorsk's enterprises, a metallurgical plant, uses cleaning technologies from the 19th century. Therefore, to assess the state of air pollution in recreational areas, taking into account existing data, the calculation methods were used, described in detail in the works of Cherkesov [3], Vetoshkin [13].

Research results

To get records from the database for a certain date, we need to use the function shown in Figure 1–2. It accepts the date that the user selected as a parameter. In order to pull out a record for a certain time, taking into account the possible error of a few seconds/minutes, we make a time interval of ±20 minutes, which will be specified as a query parameter in the database. In order to make a correct query, we also need to convert the received dates to the "American" format "MM-DD-YYYY" by working with an array of characters. Next, this function connects to the database, dynamically generates a query depending on the selected date, and writes the corresponding data to the variables of the "Air" object, processing an exception if it is not possible to connect to the database.

```
public int GetValues(DateTime date, int id)
    {
        int id_predict = 0;
        string lowdate = date.AddMinutes(-20).ToString();
        string highdate = date.AddMinutes(20).ToString();

        char[] bufstring = lowdate.ToCharArray();

        char[] lowstring = lowdate.ToCharArray();
        lowstring[0] = bufstring[3];
        lowstring[1] = bufstring[4];
        lowstring[3] = bufstring[0];
        lowstring[4] = bufstring[1];

        bufstring = highdate.ToCharArray();

        char[] highstring = highdate.ToCharArray();
```

Fig. 1. Function for requesting data from the database regarding the predicted maximum concentrations in recreational areas for a certain date

For better visual perception, a function was created to determine the color of the recreational area on the city map (from green to red) in RGB format, which is shown in figure 3. The color is calculated depending on the concentration of the harmful substance corresponding to the MPC and the hazard class, according to the integrated assessment of air pollution (formulas 1–3).

$$grad\phi = \left(\sum_{i=1}^{n} \frac{C_p}{\text{ПДК}_{\text{м.р.}}} \cdot k_h \right) / \, n \quad (1)$$

Acknowledgements

$grad\phi$ – The calculated coefficient for the gradient;
k_h – Coefficient for calculating the force of exposure of a substance depending on its hazard class;
C_p – Predicted maximum concentration of a substance in a recreational area;
$\text{ПДК}_{\text{м.р.}}$ – Predicted maximum concentration of the corresponding substance in the recreational area;
n – The number of substances measured in the recreational area.

```
highstring[0] = bufstring[3];
        highstring[1] = bufstring[4];
        highstring[3] = bufstring[0];
        highstring[4] = bufstring[1];

        lowdate = new string(lowstring);
        highdate = new string(highstring);

        OleDbCommand selectCommand = new OleDbCommand();
        DataTable table = new DataTable();
        try
        {
            OleDbConnection objConnection = new OleDbConnection("Provider=Microsoft.Jet.OLEDB.4.0; Jet OLEDB:Engine Type=5; Data Source=F:\\Downloads\\BD.mdb");
            selectCommand.CommandText = "SELECT TOP 1 Prediction.id_prediction, Prediction.prediction_CO, Prediction.prediction_NOx, Prediction.prediction_O3, Prediction.prediction_PM10, Prediction.prediction_SO2 FROM Prediction WHERE Prediction.id_rz = " + id.ToString() + " AND Prediction.date_time BETWEEN #" + lowdate.Replace('.', '/') + "# AND #" + highdate.Replace('.', '/') + "# ORDER BY id_prediction DESC;";
            selectCommand.Connection = objConnection;
            selectCommand.CommandType = CommandType.Text;
            OleDbDataAdapter adapter = new OleDbDataAdapter(selectCommand);
            adapter.Fill(table);
            table.PrimaryKey = new DataColumn[] { table.Columns["id_prediction"] };
            id_predict = Convert.ToInt32(table.Rows[0][0]);
            CO.Value = Convert.ToDouble(table.Rows[0][1]);
            NOx.Value = Convert.ToDouble(table.Rows[0][2]);
            O3.Value = Convert.ToDouble(table.Rows[0][3]);
            PM10.Value = Convert.ToDouble(table.Rows[0][4]);
            SO2.Value = Convert.ToDouble(table.Rows[0][5]);
        }
        catch (OleDbException exc)
        {
            table = null;
            MessageBox.Show(exc.Message, "Помилка", MessageBoxButtons.OK, MessageBoxIcon.Error);
        }
        finally
        {
            selectCommand.Connection.Close();
        }
        return id_predict;
    }
```

Fig. 2. Continuation of the database data query function with respect to the predicted maximum concentrations in recreational areas for a certain date

The color for the fill is defined in the RGB model (red, green, blue), where red, green, and blue are integer values from 0 to 255 for the red, green, and blue colors in the model, respectively.We introduce an additional modified coefficient for the gradient and values for colors in the RGB model.

$$grad\phi_m = \begin{cases} (1 - grad\phi) / k, grad\phi < 1 \\ (grad\phi - 1) / k, grad\phi \geq 1 \end{cases} \quad (2)$$

When $grad\phi_m > 1$ we accept $grad\phi_m = 1$.

$$COL_{RGB} = \begin{cases} (255 - 255 \cdot grad\phi_m, 255, 0), grad\phi < 1 \\ (255, 255 - 255 \cdot grad\phi_m, 0), grad\phi \geq 1 \end{cases} \quad (3)$$

Acknowledgements

$grad\varphi$ – Is the calculated coefficient for the gradient;
$grad\varphi_m$ – Modified coefficient for the gradient;
k – Coefficient for expanding the gradient with a small amplitude of values;
COL_{RGB} – Ready color for painting in the RGB model.

```
private Color DefinePolygonColor()
    {
        double level = ((Air.ValueCO.Value / Air.ValueCO.MPC) * Air.ValueCO.Hazardclass + (Air.ValuePM10.Value / Air.ValuePM10.MPC) *
Air.ValuePM10.Hazardclass + (Air.ValueSO2.Value / Air.ValueSO2.MPC) * Air.ValueSO2.Hazardclass + (Air.ValueNOx.Value / Air.ValueNOx.MPC) *
Air.ValueNOx.Hazardclass + (Air.ValueO3.Value / Air.ValueO3.MPC) * Air.ValueO3.Hazardclass) / 5;
        Color color;
        if (level < 1.0)
        {
            level = (1.0 - level) / 0.4;
            if (level > 1.0) level = 1.0;
            color = Color.FromArgb(150, Convert.ToInt32(255 - (255 * level)), 255, 0);
        }
        else
        {
            level = (level - 1.0) / 0.4;
            if (level > 1.0) level = 1.0;
            color = Color.FromArgb(150, 255, Convert.ToInt32(255 - (255 * level)), 0);
        }
        return color;
    }
```

Fig. 3. Function for determining the color of the recreational area in accordance with its level of pollution

To work with polygons on the interactive map, we created functions for creating and updating polygons, which are shown in figure 4, and which will already be painted in the appropriate color for the level of pollution. Polygons belong to an object of the "GMapPolygon" type, and are stored in it as a layer that belongs to a collection of layers.

```
public void UpdatePolygon(GMapPolygon polygon)
    {
        polygon.Fill = new SolidBrush(DefinePolygonColor());
        polygon.Stroke = new Pen(Color.Black, 1);
        polygon.IsHitTestVisible = true;
    }
    public TextBox CreateDisplayData()
    {
        TextBox textbox = new TextBox();
        textbox.Name = name;
        textbox.Multiline = true;
        textbox.Location = new Point(1010, 150);
        textbox.Size = new Size(160, 126);
        textbox.Visible = false;
        textbox.Font = new Font("Calibri", 15);
        textbox.Text = Air.ValuePM10.Value.ToString() + " / " + Air.ValuePM10.MPC.ToString() + Environment.NewLine +
Air.ValueCO.Value.ToString() + " / " + Air.ValueCO.MPC.ToString() + Environment.NewLine + Air.ValueSO2.Value.ToString() + " / " +
Air.ValueSO2.MPC.ToString() + Environment.NewLine + Air.ValueNOx.Value.ToString() + " / " + Air.ValueNOx.MPC.ToString() +
Environment.NewLine + Air.ValueO3.Value.ToString() + " / " + Air.ValueO3.MPC.ToString() + Environment.NewLine;
        return textbox;
    }
```

Fig. 4. Functions for creating and updating polygons on the map

For drawing on the map the logos of pollutant sources with relevant information about ground-level concentrations, was created a function for creating of "markers" that are stored as a marker layer that belongs to a collection of layers. The function is shown in figure 5. The logo of a plant or other source of pollutants is set as a marker, and information about ground-level concentrations is set as text that is displayed when the mouse hovers over the marker.

To determine the exact distance between the source of emissions and the recreational area, was created a function to determine the distance, depending on the geographical coordinates of objects, shown in figure 6. The function makes calculations using the formula 5. Only two pairs of geographical coordinates are needed as parameters for this function: sources of pollutants and recreational areas. The radius of the earth is set by a constant.

```
    public void SetLogo(GMapOverlay overlay) {
        GMapMarker marker = new GMarkerGoogle(
        new PointLatLng(xcoord, ycoord),
        new Bitmap(logo, bitmapX, bitmapY));
        marker.Tag = name;
        marker.ToolTipText = name + "\n\n Розрахункові приземні концентрації:\nCO: " + CO.Value.ToString() + " мг/м3\nNOx: " +
NOx.Value.ToString() + " мг/м3\nSO2: " + SO2.Value.ToString() + " мг/м3\nO3: " + O3.Value.ToString() + " мг/м3\nПил: " + PM10.Value.ToString() + "
мг/м3";
        marker.ToolTipMode = MarkerTooltipMode.OnMouseOver;
        overlay.Markers.Add(marker);}
```

Fig. 5. Function for creating a marker for a pollutant source

```
...
{
        const int EarthRadius = 6372795;
        const int defaultRadius = 5000;
        double lat1 = xcoord * Math.PI / 180;
        double lat2 = x1 * Math.PI / 180;
        double long1 = ycoord * Math.PI / 180;
        double long2 = y1 * Math.PI / 180;
        double cl1 = Math.Cos(lat1);
        double cl2 = Math.Cos(lat2);
        double sl1 = Math.Sin(lat1);
        double sl2 = Math.Sin(lat2);
        double delta = long2 - long1;
        double cdelta = Math.Cos(delta);
        double sdelta = Math.Sin(delta);
        double y = Math.Sqrt(Math.Pow(cl2 * sdelta, 2) + Math.Pow(cl1 * sl2 - sl1 * cl2 * cdelta, 2));
        double x = sl1 * sl2 + cl1 * cl2 * cdelta;
        double ad = Math.Atan2(y, x);
        double dist1 = ad * EarthRadius;
...
}
```

Fig. 6. Function for calculating the distance between the recreational area and the emission source by geographical coordinates

To calculate the maximum concentration of harmful substances in recreational areas, we need to take into account the number of harmful substances that are the main sources of pollution in the city, for this we will use the formula (Fig. 7) calculation of maximum surface concentrations at emission sources (formula 4).

$$C_Z = \frac{A \times M \times F \times m \times n}{H^2 \times \sqrt[3]{V_1 \times \Delta T}} \qquad (4)$$

Acknowledgements

A – Coefficient, which depends on the temperature stratification of the atmosphere that defines the terms vertical and horizontal dispersion of pollutants in the atmosphere ($C^2\ /^3 \times \text{mg} \times \text{grad}^1\ /^3\ \text{g}$). The coefficient A is calculated for adverse weather conditions observed in summer during the daytime with an intensely developed vertically turbulent climate. For Ukraine this coefficient is equal to 200;

M – The amount of harmful substance that is released into the atmosphere (g/s);

H – The height of the pollution source above ground level (in our case, the height of the pipes) (m);

V_1 – Volume of the gas-air mixture (m^3/s);

ΔT – The difference between the temperature levels of the exhaust gas-air mixture and the ambient temperature in degrees Celsius;

F – A dimensionless coefficient that takes into account the rate of precipitation of particles in the atmosphere – for sterny gas 1, for dust cleaning with an efficiency of at least 90 % – 2;

M – The dimensionless coefficient that takes into account the conditions of the gas-air mixture output in our conditions is taken as 1;

N – Dimensionless coefficient, which takes into account the conditions of the gas-air mixture output in our conditions, is taken as 1.

```
public void FactoryConcentration(Substance.Name name, double tempout)
    {
        if (name == Substance.Name.CO) concCO = (160 * CO.Value * 0.9) / (Math.Pow(sourceheight, 2) * Math.Pow(airvolume * (temperature - tempout), 1 / 3));
        if (name == Substance.Name.NOx) concNOx = (160 * NOx.Value * 0.9) / (Math.Pow(sourceheight, 2) * Math.Pow(airvolume * (temperature - tempout), 1 / 3));
        if (name == Substance.Name.O3) concO3 = (160 * O3.Value * 0.9) / (Math.Pow(sourceheight, 2) * Math.Pow(airvolume * (temperature - tempout), 1 / 3));
        if (name == Substance.Name.PM10) concPM10 = (160 * PM10.Value * 2.5 * 0.9) / (Math.Pow(sourceheight, 2) * Math.Pow(airvolume * (temperature - tempout), 1 / 3));
        if (name == Substance.Name.SO2) concSO2 = (160 * SO2.Value * 0.9) / (Math.Pow(sourceheight, 2) * Math.Pow(airvolume * (temperature - tempout), 1 / 3));
    }
```

Fig. 7. The function of calculating the maximum ground level concentrations from emission sources

In figure 8 is the function for predicting the maximum possible concentrations in recreational areas, taking into account current concentrations, maximum surface concentrations near emission sources, distance from the source to the recreational area, and wind direction, using the example of PM10 dust.

```
{
...
        predictedConcentrationPM10 = Math.Round(back_pm10 / 1000.0 + (pm10_1 * isFarther1 / defaultRadius * wind_fac1) + (pm10_2 * isFarther2 / defaultRadius * wind_fac2) + (pm10_3 * isFarther3 / defaultRadius * wind_fac3)
            + (pm10_4 * isFarther4 / defaultRadius * wind_fac4) + (pm10_5 * isFarther5 / defaultRadius * wind_fac5) + (pm10_6 * isFarther6 / defaultRadius * wind_fac6), 6);
...
}
```

Fig. 8. Function for predicting maximum possible concentrations in recreational areas

Interface Elements of the interactive PC map "CleanKramatorsk"

The software package "CleanKramatorsk" is an interactive map of the city Kramatorsk, which shows the main sources of emissions of pollutants into the atmosphere in the form of logos of these sources, the main recreational areas of the city in the form of painted planes in the color corresponding to the overall level of pollution (from green – the lowest to red-the highest) and interface elements for interaction with the map user.

The interface with the main elements is shown in figure 9.

Explanation of interface elements:

- 1– logos of sources of pollution with harmful substances;
- 2 – information about ground-level concentrations of harmful substances (appears when hovering over the logo with the mouse);
- 3 – recreational areas of the city;
- 4 – wind rose, which shows the current wind direction (the part painted in red);
- 5 – menu for selecting the date for which data will be displayed on the map. It includes a calendar for selecting a specific day of the year, an element for selecting a specific measurement hour (only even-numbered hours are selected), a "select date" button for checking the availability of data for the selected date, and a "update map" button for displaying data for the selected date (becomes active if the data check is successful);
- 6 – buttons for switching map mode: satellite and topographic;
- 7 – information about concentrations and the name of the recreational zone that the user is currently viewing (changes when the mouse hovers over a specific recreational zone);
- 8 – "set default position" button, which sets the default coordinates and scale when clicked;
- 9 – button for calling help;
- 10 – interactive map.

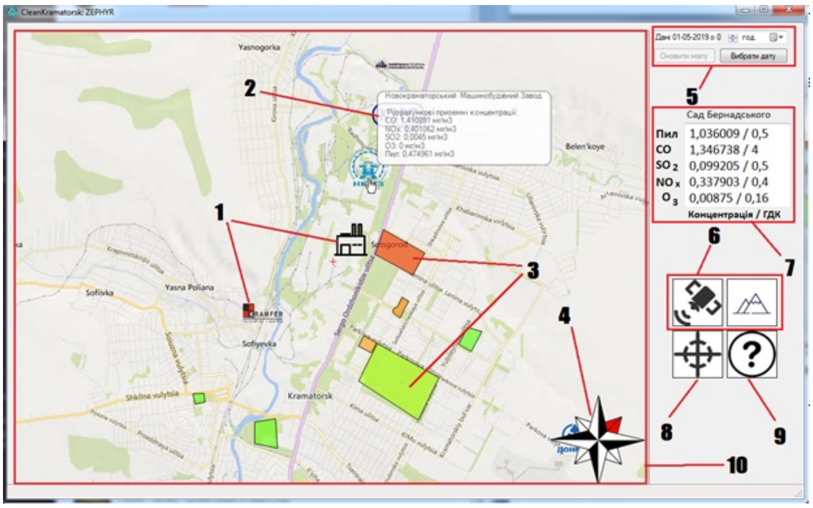

Fig. 9. Interface elements of the «CleanKramatorsk» interactive PC map

Conclusions

Based on the analysis of the existing literature and the conducted research has developed a comprehensive mathematical model for the assessment of air pollution in recreational areas of Kramatorsk, which consists of determining the exact distance between the pollution source and recreational area, forecasting the level of concentration of individual substances in the recreational area and determining the overall state of pollution, resulting in a specific color corresponding of the recreation area on an interactive map. A software product was developed in the form of an interactive map to inform the people about the projected level of air pollution in recreational areas of the city Kramatorsk. Based on the obtained forecast data, the hypothesis about the increased level of environmental pollution in the city Kramatorsk can be considered confirmed.

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