# INFORMATION SUBSYSTEM FOR THE RECORD-KEEPING OF ENVIRONMENTAL PROTECTION MEASURES

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Against a backdrop of growing environmental challenges, caused by both human activity and the consequences of armed aggression, the issue of automating the recording of environmental protection measures is becoming particularly important. Effective recording, rapid analysis and reporting of environmental data enable a swift response to changes in the environment and the adoption of informed management decisions at all levels of government.

The vast amounts of information received by local authorities and government bodies make it difficult to manually process and analyse environmental measures and data on waste resulting from the destruction. This highlights the need to develop an integrated information system that will automate the entry, processing, storage and generation of reports in accordance with current legislation and the minutes of government meetings. This task is of particular relevance in light of the introduction of new reporting requirements regarding environmental protection measures, waste and operational plans, in accordance with resolutions of the Cabinet of Ministers of Ukraine, orders of the Ministry of Environmental Protection and current state environmental policy strategies. Consequently, the development of an effective information subsystem is a practically significant and timely task.

In line with the stated objective, the following tasks have been formulated: 1) to review recent research and publications in the field of 'accounting for environmental protection measures'; 2) to analyse existing information subsystems for the automated accounting of environmental protection measures; 3) to formulate the problem statement and select the means for its implementation; 4) to develop a design for an information subsystem for the accounting of environmental protection measures; 5) to implement the database and the user interface in the selected software environment. The object of the study is the information processes involved in the accounting of environmental protection measures. The subject of the study is the automation of the accounting of environmental protection measures.

For the first time, a concept for an information framework to record environmental protection activities has been proposed and substantiated to meet the practical needs of local environmental authorities; this framework provides for:

- the integration of the documentation of environmental programmes and the recording of residues from destructive processes into a single digital space, in line with the latest Ukrainian legislation and approved government directives;
- the introduction of a structured layout for information databases, brought into line with the definitions of waste components, documentation forms and classification rules established by Government Resolution No. 1073 of 27 September 2022;
- the proposed data warehouse architecture helps to eliminate redundant data and ensures data reliability when working with large volumes of records;
- the implementation of proprietary mechanisms for the automatic generation of reports, which take into account specific environmental metrics and the relevant requirements of government regulatory bodies;
- creation of visual user interface layouts that simplify data entry and analytical processing, thereby improving the efficiency of the specialist's interaction with the software suite;
- identifying the critical operational and hardware characteristics necessary for the further development and expansion of this system within regional or national environmental information networks.

Building on the results achieved, scientifically sound principles have been formulated for the design of modern information systems for recording environmental protection activities, which can serve as a foundation for the development of more comprehensive digital environmental platforms.

**1. Review of recent research and publications.** Under the Law of Ukraine 'On the Protection of the Natural Environment' (Articles 20 and 22), provision is made for the development of the State Environmental Monitoring System (hereinafter referred to as the SEM) and for the monitoring of the state of the environment, in particular the level of pollution. The performance of these functions has been delegated to the Ministry of the Environment and other central executive authorities that are participants in the State Environmental

Monitoring System, as well as to enterprises, institutions and organisations whose activities cause or may lead to a deterioration in the state of the environment.

The main principles of the SESM's activities are set out in Resolution No. 391 of the Cabinet of Ministers of Ukraine dated 30 March 1998 "On the Approval of the Regulations on the State Environmental Monitoring System".

Currently, within the State Environmental Monitoring System (hereinafter referred to as the SEM), the functions and tasks of observation and information provision are carried out by eight entities of the monitoring system: the Ministry of the Environment, the Ministry of Emergencies, the Ministry of Health, the Ministry of Agrarian Policy, the Ministry of Housing and Communal Services, the State Water Management Agency, the State Forestry Committee and the State Land Committee.

Each entity within the State Environmental Monitoring System monitors those environmental components specified in the Regulations on the State Environmental Monitoring System and in the procedures and regulations governing the state monitoring of specific environmental components.

Key regulatory acts governing the monitoring of environmental objects:

- Resolution of the Cabinet of Ministers of Ukraine No. 343 of 9 March 1999 'On the Approval of the Procedure for the Organisation and Conduct of Monitoring in the Field of Atmospheric Air Protection';
- Resolution of the Cabinet of Ministers of Ukraine No. 815 of 20 July 1996 'On the Approval of the Procedure for the Implementation of State Water Monitoring';
- Resolution of the Cabinet of Ministers of Ukraine No. 661 of 20 August 1993 'On the Approval of the Regulations on Land Monitoring';
- Resolution of the Cabinet of Ministers of Ukraine No. 51 of 26 February 2004 'On the Approval of the Regulations on Soil Monitoring on Agricultural Land' [9].

Thus, the regulatory framework for state monitoring covers the main components of the environment, ensuring a systematic approach to their observation and assessment. However, the current challenges posed by the full-scale war in Ukraine necessitate an update to monitoring approaches, particularly with regard to controlling the environmental consequences of destruction. The devastating effects of the war affect absolutely all areas, including the need to find ways to prevent and minimise the negative impact on the environment and human health of waste generated as a result of damage (destruction) to buildings and structures, unfinished construction projects, and public amenities due to hostilities, terrorist acts, sabotage or the elimination of their consequences — on the environment and human health.

The Government has proposed the relevant Procedure, approved by Resolution of the Cabinet of Ministers of Ukraine No. 1073 of 27 September 2022 (as amended). The Procedure applies during the performance of a range of restoration works to eliminate the consequences of armed aggression and hostilities during martial law and in the reconstruction period (within 90 calendar days following the cessation or lifting of martial law on the territory of Ukraine).

The management of demolition waste involves a range of organisational and technical measures and operations. These are carried out to ensure the environmentally safe collection, transport, sorting, storage, processing (recycling), disposal, removal, neutralisation and burial of such waste. These measures are coordinated by the executive body of the village, settlement or city council, or by the military administration of the settlement (settlements).

The organisation of operations involving demolition waste may be carried out in areas where active phases of hostilities are absent or have already concluded:

- by the owner/manager of the facility that has suffered damage (demolition), as a result of which this waste was generated;
- by the owner or user of the land plot on which such waste is located;
- by the authorised body — in respect of waste from destruction located on the streets and roads of settlements, public roads, in public areas such as parks, squares, open spaces, embankments, areas adjacent to buildings, beaches and cemeteries (in particular, those displaced to the aforementioned areas by a shock wave resulting from the impact of weapons, explosions, fires, etc.).

The identification and recording of demolition waste shall be organised by the competent authority on the basis of: 1) inspections of damaged (demolished) properties; 2) consideration of applications (reports) from citizens, enterprises, institutions and organisations, other legal entities, the media, central executive authorities, military formations, or receipt of information regarding the identification of demolition waste.

The recording of demolition waste is carried out directly at the site of its generation or at temporary storage sites or other waste management facilities using the specified form shown in Table 1.1.

Waste generated as a result of demolition includes: 1) main components — parts (fragments, debris) of building structures, fillings from door and window units, utility systems, plumbing fixtures and the like; 2) additional components — materials and items that were inside or near the structure at the time of damage (destruction) or during its demolition, for example, equipment, personal belongings, everyday items (furniture, household appliances), and organic compounds [7].

**Table 1.** Form for recording demolition waste

| Serial number | Names of waste components resulting from demolition | Unit of measurement | Volume | Location (temporary storage of demolition waste/other waste management facilities) |
|---|---|---|---|---|
| Notes | 1. Information shall be provided regarding demolition waste stored at a temporary storage site for demolition waste or at another waste management facility.<br>2. The names of the components of demolition waste in accordance with Annex 1 to Resolution No. 1073 of the Cabinet of Ministers of Ukraine of 27 September 2022 No. 1073 'On the Approval of the Procedure for the Management of Waste Generated in Connection with the Damage (Destruction) of Buildings and Structures as a Result of Hostilities, Terrorist Acts, Sabotage or the Conduct of Work to Eliminate Their Consequences, and on Amendments to Certain Resolutions of the Cabinet of Ministers of Ukraine'.<br>3. The volumes of waste from destruction shall be stated in tonnes or cubic metres; the relevant unit of measurement shall be indicated when completing the form. | | | |

Source: [7]

The destruction of infrastructure and residential buildings, on the one hand, generates a large volume of waste, and on the other, leads to mass population displacement. Internal displacement in Ukraine is one of the most significant humanitarian consequences of the armed conflict. According to the Ministry of Social Policy, as of 1 February 2022, over 1.4 million internally displaced persons (IDPs) had been registered in Ukraine, and during the year this figure exceeded 6.6 million. These are people who were forced to leave their homes and possessions due to threats to their lives and health.

Firstly, it is important to recognise that internally displaced persons (IDPs) face numerous difficulties and challenges in their new region, namely: 1) inadequate social and economic adaptation; 2) limited access to housing, education, healthcare, social services and justice; 3) discrimination, stigmatisation and rejection by the local population; 4) psychological distress, anxiety, depression, post-traumatic stress disorder (PTSD), suicidal thoughts and behaviour; 5) loss of a sense of purpose, self-identity, heritage and cultural values.

Given these circumstances, psychosocial support for IDPs is required, aimed at alleviating their situation, improving their psychological well-being and facilitating their social integration.

Secondly, psychosocial support, as a crucial element in the adaptation of IDPs, can be provided by various stakeholders, amongst whom non-profit organisations (NGOs) play an important role. NGOs are capable of delivering such psychosocial support to IDPs, but they are not the only ones:

- psychosocial support that NGOs can provide to internally displaced persons in their new region of residence;
- providing information on available services and resources in the new region, such as education, healthcare, social assistance, legal support and more;
- organising group and individual counselling and psychotherapy sessions for internally displaced persons suffering from stress, anxiety, depression or other psychological problems;
- creating safe and welcoming spaces for internally displaced persons where they can socialise, receive social support, pursue their interests and develop their skills;
- engaging internally displaced persons in community initiatives and voluntary work, which promotes their social integration and a sense of belonging;
- conducting training sessions and workshops for internally displaced persons on self-help, stress management, building peaceful relationships and constructive conflict resolution [25].

Given the sheer volume of such waste and the potential risk it poses to the environment, it is of the utmost importance to have a clear system for recording, sorting and managing it in accordance with current legislation. Since 1 January 2018, a ban on the landfilling of untreated (unrecycled) household waste has been in force in Ukraine. In addition, waste sorting has become a direct responsibility of every resident of Ukraine.

Particular attention should be paid to the problem of unauthorised disposal at landfills of bulky waste, waste requiring repair, and waste hazardous to the environment.

How should waste be sorted correctly? As regards recyclable materials, there are two main sorting principles: 1) Waste bins must be dry and clean; 2) All packaging must be compressed as tightly as possible.

In accordance with the law, hazardous waste must be collected, sorted and immediately handed over to specialised companies licensed to process it. Transporting this type of waste is permitted only by vehicles with special equipment. Household waste may only be disposed of at landfills or waste disposal sites specifically designated for this purpose.

Local authorities or the state administration must give priority to waste management schemes that enable higher levels of recovery or recycling to be achieved.

Waste incineration is permitted only at specialised facilities, exclusively for the generation of energy (thermal or electrical).

The law prohibits the construction and use of landfill sites for household waste where the designs do not include mechanisms to protect against groundwater contamination, as well as systems for the collection and utilisation of leachate and biogas.

Recyclable materials are generally divided into the following categories:

- Waste paper. This includes books, magazines, newspapers, paper packaging, etc. To save space, cardboard and paper items should be flattened as much as possible and then placed in a paper bag or tied with string. The following are not considered waste paper: receipts, cigarette packets, Tetra Pak cartons, products that have already been recycled, and various types of soiled or damp paper.
- Tetra Pak refers to multi-layered packaging made of polyethylene, cardboard or foil. The packaging should be thoroughly washed inside and compressed;
- polyethylene: food bags, gloves, cling film;
- plastic. There are seven types of plastic, five of which are recyclable. To determine which type a plastic item belongs to, look closely at the marking. It shows a triangle with a number from one to seven; sometimes the marking consists only of letters. If there is no marking, or if it shows the numbers 7 or 3, such items are not recyclable.
- metal: tin cans, lids, other metal items. These must be cleaned of dirt and tightly compressed;
- glass: bottles from medicines and cosmetics, drinks, etc. Broken glass is also recyclable. Porcelain and particularly tough glass (which withstands heavy impacts and high temperatures) are not recyclable;
- waste containing toxic substances: energy-saving light bulbs, mercury thermometers, batteries, solvents, paints, ABS plastic. Such waste must not be disposed of in a standard bin;
- organic waste: wood, plants, food scraps;
- residual waste: this is what remains after waste sorting (adhesive tape, ‘shur-shik’, sanitary towels and wipes, wrappers and unlabelled products, broken items). This portion of waste must be sent to a landfill. Old clothing that can still be used;

At first glance, sorting rubbish may seem like a complicated task. But if you practise and commit the above-mentioned types of waste to memory, it is easy to learn [24].

**2. Analysis of software products and alternatives.** The market offers a wide range of software solutions designed for environmental monitoring. Their functionality varies, including the collection, processing and visualisation of collected data. However, not all of them feature an intuitive interface and flexible settings tailored to individual user needs. Despite the availability of such products, information systems for monitoring environmental conditions are few in number and not widely used by internet users. The following were selected for the analysis of comparable products:

- eco.gov.ua [8];
- saveEcoBot [10];
- globalForestWatch [1];

The first example is the ‘EcoSystem’ website. The site contains information on:

- administrative services;
- registers;
- news;
- about the project;
- ecoThreat;
- e-Cabinet;
- online services: e-Exits, e-Forest, e-OVD, e-Control and others;
- Information panel on resources: water, forest fires, geological portal.

This resource was created to gather information on various activities (Figure 1).

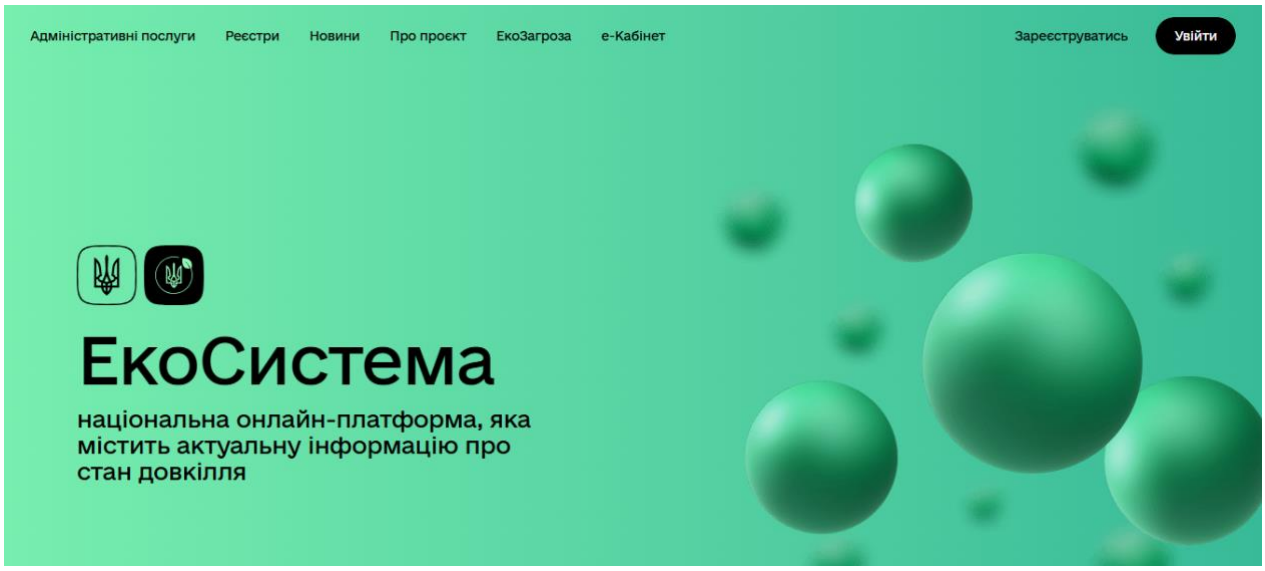


***Figure 1.*** *The 'EcoSystem' homepage*
*Source: [8]*

To view the waste data that has been entered, you must first register with the system and log in using a file key or via IDGOVUA (Figure 2). If using IDGOVUA, you can use an electronic signature: a physical token, a USB token, or cloud storage. It is also possible to use the NBU Bank ID, in which case you will need to log in via your chosen bank.

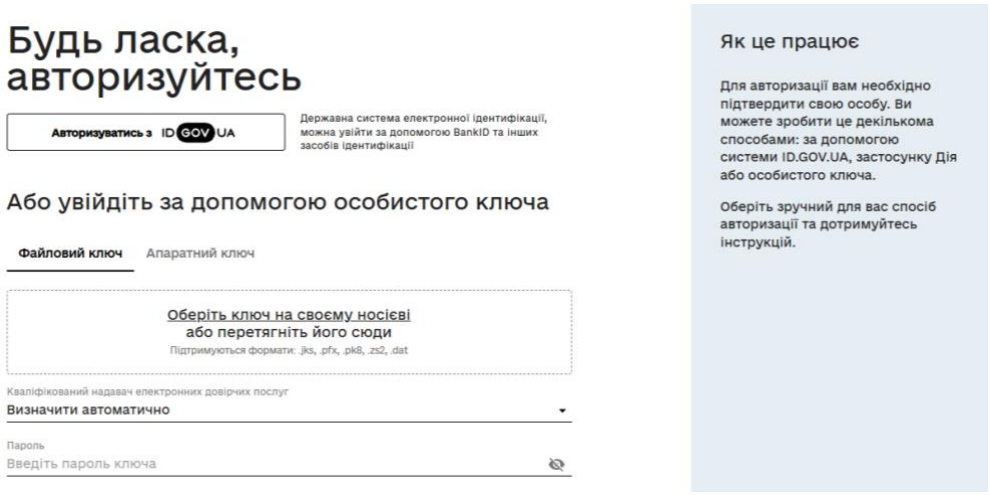


***Figure 2.*** *System login page.*
*Source: [8]*

Once registration is complete, the user is redirected to a selection page: tasks, services, registers, account. To view the waste declarations submitted by companies, go to the 'Registers' section and click 'Waste Declaration 3.0' (Figure 3).

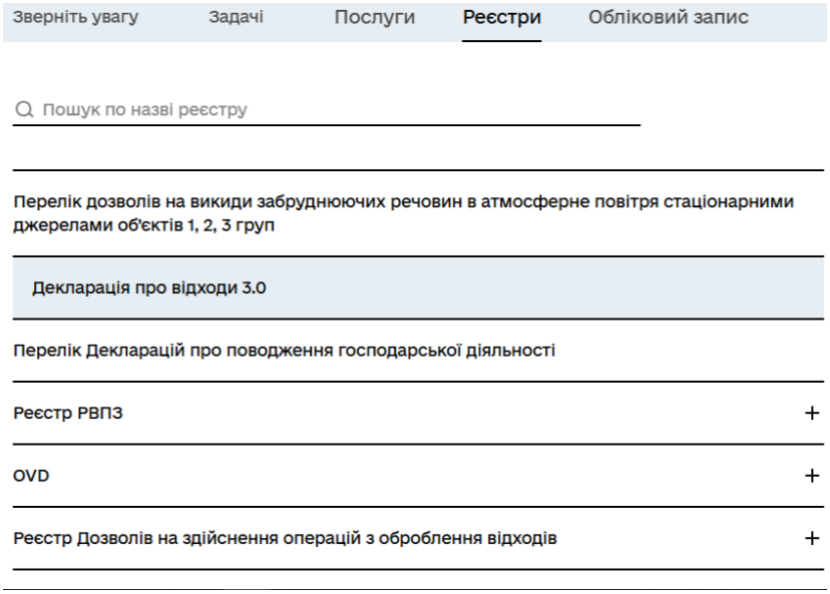


***Figure 3.*** *Registry selection webpage.*
*Source: [8]*

A separate page has been created for businesses, which ordinary users cannot access; therefore, the standard waste reporting for businesses has been revised (Figure 4). The reporting consists of:

- date of submission;
- name of the company or full name of the sole trader;
- company's EDRPOU number or sole trader's RNOKPP number;
- place of registration of the applicant;
- region of operation;
- city or district of operation;
- village, settlement or city district;
- reporting year;
- email address;
- application number;
- telephone number.

The generation of waste or the acquisition of ownership of waste is divided into:

- name of the waste (code [11] is used);
- volume of waste accumulated at the start of the reporting year, tonnes;
- details of the waste producer;
- volume of waste, tonnes;
- details of the waste producer (specify the name and country of registration of the counterparty);
- volume of waste, in tonnes;
- code under List A or B of the Basel Convention;
- notification or decision number;
- volume of waste generated by the declarant, in tonnes.

Carrying out waste treatment operations, including those involving hazardous waste. Information on waste used by the declarant for the purposes of reuse, recycling, recovery or disposal, and information on waste generated as a result of the reuse, recycling, recovery or disposal of waste by the declarant:

- name of the waste;
- volume of waste, tonnes;
- code of the planned waste operation [13];
- description of waste operations;
- name of waste;
- volume of waste, tonnes;
- number of the treatment permit and/or number of the licence decision;

- code under List A or B of the Basel Convention;
- code of the operation resulting in the generation of waste;
- description of the waste operation.

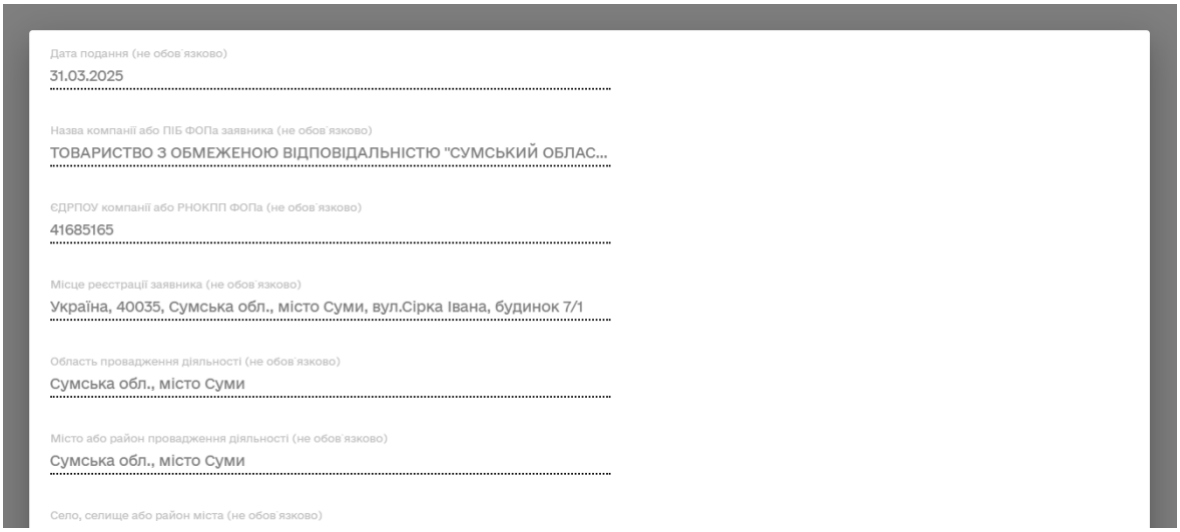


***Figure 5.*** *Waste declaration*
*Source: [8]*

Waste transfer:
- name of the waste;
- details of the producer;
- volume of waste;
- details of the producer;
- volume of waste;
- code under List A or B of the Basel Convention;
- notification number or decision number;
- name of waste;
- volume of waste remaining at the end of the reporting year, tonnes.

This report can also be downloaded or viewed in PDF format (Figure 6).

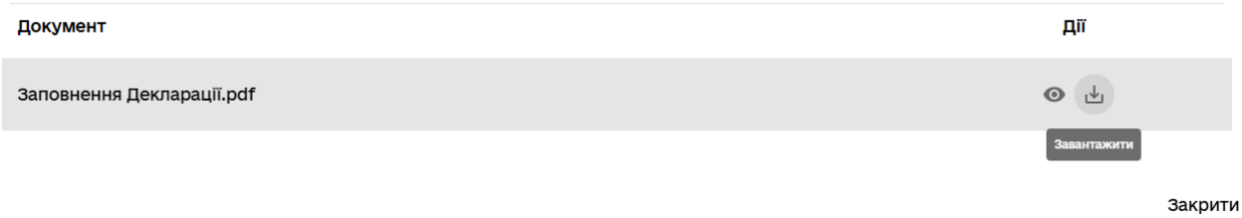


***Figure 6.*** *Download as PDF*
*Source: [8]*

General features of the EcoSystem website:

- Public access and transparency of data – data can be viewed by any user without the need to create an account or log in;
- Registry structure – the website is organised as a registry containing information on various environmental documents, permits, licences, businesses and other relevant data;
- Search and filtering – the interface allows users to search and filter data by key parameters, such as object name, region, status and other relevant criteria;
- Pagination – results are displayed in batches, with the option to configure the number of records per page (rowsPerPage) and page navigation (page);

- API-oriented – URLs contain parameters (keyId, page, rowsPerPage), indicating a REST architecture and enabling potential integration with other systems;
- Up-to-date information – information is regularly updated in line with changes made to government registers;
- machine-readability
- data is presented in the form of clearly structured tables, allowing it to be parsed, analysed and integrated with business intelligence (BI) systems or other analytical tools;

Another example of environmental monitoring is 'SaveEcoBot' – an eco-friendly chatbot and online platform designed for public monitoring of the state of the environment in Ukraine, specifically air emissions, air quality, environmental impact assessment (EIA) procedures, companies' environmental documentation, and citizens' actions (Figure 7).

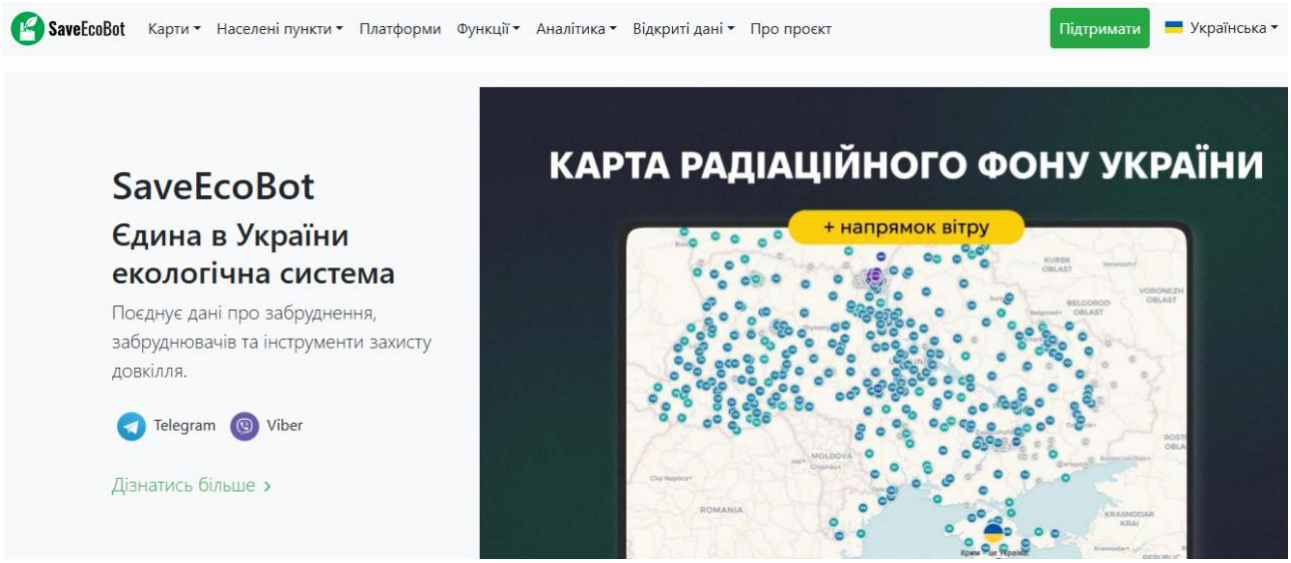


***Figure 7.*** *The 'SaveEcoBot' homepage*
*Source: [10]*

Key features and capabilities:
1. Real-time air quality monitoring:
- display of data from automatic monitoring stations;
- sources: government stations, Sensor.Community, Airly, and citizens' own stations;
- pollutants: PM2.5, PM10, $CO_2$, $NO_2$, $O_3$ and others;
- interactive map.
2. Access to environmental permits and documents:
- register of atmospheric emission permits;
- permits for special water use;
- waste management licences.
- EIA (Environmental Impact Assessment): public consultation and project archive.
3. Notifications (bot feature):
- via Telegram, Viber, Facebook Messenger or the web platform;
- subscription to companies, regions or types of environmental documents;
- notifications about new permits, changes to document status, the start of public consultations, etc.
4. Public participation tools:
- templates for submitting comments on EIA reports;
- the ability to monitor a specific enterprise (environmental threats, permits, changes);
- public pressure through appeals to the authorities.

Who is it for:
- for citizens — to monitor air pollution levels in their local area;
- for environmental activists — to monitor the activities of businesses that harm the environment;

- for journalists — a platform for accessing environmental information that is open to the public;
- for public authorities — a tool for ensuring transparency and gathering feedback from the public;
- for developers — providing data via API.

Another example of environmental monitoring is 'Global Forest Watch' – an online platform that provides open-access, satellite and analytical data on the state of the world's forests in near real time (Figure 8). The platform allows users to track deforestation, fires, degradation and other threats to forest ecosystems.

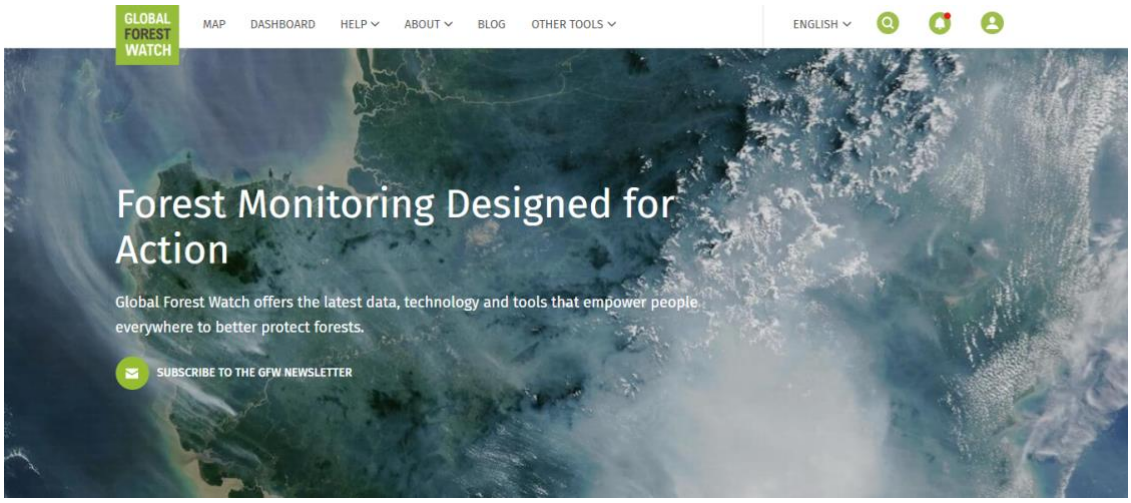


***Figure 8.*** *Global Forest Watch homepage*
*Source: [1]*

Key features:
1. Monitoring of deforestation:
- data is updated weekly or monthly, depending on the source;
- visualisation of deforestation from 2001 to the present;
- identification of illegal logging, including the intensity and scale of changes.
2. Fire detection:
- integration with NASA (MODIS, VIIRS) – fire hotspots;
- information updated several times a day;
- alerts regarding forest fires in specific regions;
3. Interactive map:
- a map with over 100 layers;
- forest cover;
- deforestation;
- humid tropical forests;
- agricultural land;
- biodiversity, legal status of territories;
- you can create your own maps, export them or share them.
4. Data downloads and API:
- Geodata can be downloaded in CSV, GeoJSON and SHP formats;
- An open API is available for automatic integration.
5. Alerts
- Creating monitoring zones: the user selects an area (e.g. their neighbourhood or a nature reserve);
- Receiving email or SMS alerts about new fires, deforestation or changes in land cover.
6. Analytics tools:
- a dashboard for each country, region or even specific area;
- statistics by year: area of forest loss/regeneration, trends, causes of deforestation;
- integration with databases on logging licences, nature reserves and commercial zones.

An analysis of the subject area has revealed that environmental monitoring plays an extremely important role in assessing and predicting changes in the environment. Current trends in its development are closely

linked to the implementation of smart technologies, such as the Internet of Things (IoT), artificial intelligence, wireless sensor networks and remote sensing. An analysis of existing software products (Ecomonitoring.hlr.ua, Monitoring.davr.gov.ua, Acres, Esri) has shown that, despite their significant functionality, most of them are either designed to address a limited range of tasks or are insufficiently adapted to the needs of local authorities. This highlights the relevance and necessity of developing a new web application that will provide a user-friendly interface, flexibility, automation and adaptability to the specificities of environmental data collection and analysis in local communities.

**3. Defining the task and selecting implementation methods.** The creation of an information subsystem for recording environmental protection measures ensures the automation and optimisation of processes relating to the collection and processing of environmental monitoring data, the register of environmental protection measures, waste from demolition works, and the implementation of operational action plans.

In accordance with job descriptions and the composition of the executive committee, the entry of this information is carried out by responsible persons entrusted with the relevant duties for implementing environmental protection measures, reporting on demolition waste and operational action plans, with the main Department of Environmental Protection and Natural Resources housing senior specialists who collect this information from local authorities.

The basis for the development of software and information systems for the purpose of preparing information for the Ministry of Environmental Protection and Natural Resources of Ukraine regarding the implementation of environmental measures, in accordance with Article 20 of the Law of Ukraine 'On Environmental Protection' and taking into account the requirements of Resolution No. 106 of the Cabinet of Ministers of Ukraine dated 16 February 2011 'Certain Issues Concerning the Accounting of Taxes, Fees, Payments and Other Budget Revenues' [5]. The data is compiled from reports on measures that have been carried out, planned or not implemented, covering areas of environmental conservation, nature conservation measures, nature conservation effects, as well as the reasons for the non-implementation of these measures. This is used for the conservation of the nature reserve fund, the protection of atmospheric air, the rational use of natural, plant and animal resources, and other activities throughout the entire period of regulatory activity. A database of environmental protection measures is established, characterising the environmental situation of local authorities. Reports are generated promptly based on overall indicators. Reporting is carried out at the following intervals: 1st quarter, half-year, 9 months, and annually. Once the measures have been recorded, the report is removed from the register and transferred to the archive.

Furthermore, in the development of the software and information infrastructure for the information system—designed to ensure compliance with the requirements of paragraph 2 of Section IV of the minutes of the meeting chaired by the Prime Minister of Ukraine, Denys Shmyhal, on 9 February 2023—the Ministry requests that monthly reports be provided on the management of waste generated as a result of damage (destruction) to buildings and structures, unfinished construction projects and public amenities as a result of hostilities, with the aim of preventing and reducing the negative impact of such waste on the natural environment and human health [15]. The data is compiled from reports on waste generated by destruction, information on damaged facilities, the management of hazardous waste, details of existing equipment or the need for such equipment, and details of operations involving the management of waste generated by destruction. This is used to monitor environmental situations that may involve hazardous materials. Tracking this data enables the identification of: the level of threat to the environment, the detection of critical environmental impacts, and the planning of measures to mitigate the consequences of destruction. Management of disposal processes: data on damaged facilities, the volume and composition of waste, the availability of disposal equipment, and information on the transfer of hazardous waste to licensed enterprises. Ensuring effective planning and response: assessments of the need for additional funding and equipment, and coordination of actions between local authorities and central government bodies. Reports are produced on a monthly basis. Once the measures have been recorded, the report is removed from the register and transferred to the archive.

Furthermore, as part of the development of the software and information infrastructure for the information system, an operational action plan has been drawn up in accordance with Order No. 312-r of the Cabinet of Ministers of Ukraine dated 7 April 2023, approving the implementation of the State Policy Strategy on Internal Displacement for the period up to 2025 during 2023–2025 [16]. The data is generated from reports on the provision of information regarding the operational action plan, including the names of measures and

tasks. This is used to develop the Strategy's plans and measures. The data is collected and processed automatically on an annual basis.

The vast volume of incoming information results in a significant time investment for carrying out this work. The automation of data entry operations within the information subsystem for recording environmental protection measures serves to improve the productivity of the relevant specialist.

This information is collected by all local authorities and by the Department of Environmental Protection and Natural Resources itself. To this end, the option is provided to receive reports automatically, using a filter of their choice; certain fields have been restricted for standard users.

The functional structure of reporting on environmental protection measures is shown in Figure 9 [22].

Description of the system's functions. The entry of data on environmental protection activities by local government bodies – code ПРИРОДОХ1 – facilitates the monitoring and management of actions taken to protect the environment and ensures effective management of the process at the level of local councils and their surrounding areas.

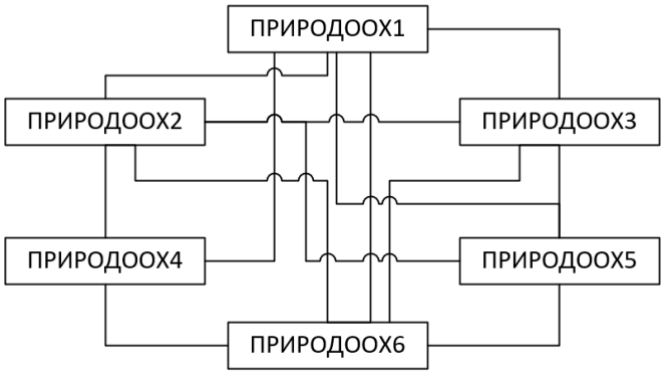


***Figure 9.*** *Diagram illustrating the interrelationships between the tasks involved in these environmental protection measures.*

Entry of reference information on environmental protection measures – task code ПРИРОДОХ2. A list of reference information on environmental protection measures is compiled, covering: environmental protection programmes, ecological initiatives, energy-saving measures, and the protection of biodiversity.

Creation of reports on planned environmental protection measures, task code ПРИРОДОХ3. A list of planned environmental protection measures is being compiled. It is presented in MS Excel table format. The list shows funding amounts and sources of funds. The information is broken down by budget items and organised by areas of work and environmental protection measures. The total funding for the planned environmental protection measure is indicated, as well as the expected environmental impact. Summaries are provided separately for each area and in total.

The generation of reports on implemented environmental protection measures, task code ПРИРОДОХ4, involves compiling a summary of the environmental protection measures carried out. This summary is generated in the form of an MS Excel spreadsheet. It contains data on funding amounts and sources. The information is structured by budget items, grouped by areas and specific environmental protection measures. It shows the total amount of actual expenditure, as well as the environmental impact achieved as a result of the environmental protection measures. Results are summarised both for each individual area and in aggregate.

The preparation of reports on planned and unimplemented environmental protection measures, task code ПРИРОДОХ5, involves the creation of a list of unimplemented environmental protection measures. This list is generated in MS Excel table format, showing funding volumes and their sources. The information is structured by budget items, grouped by areas of environmental protection activity and specific measures.

The total funding allocated for each environmental protection measure is specified, and the reasons for its non-implementation are identified. The report's findings are summarised separately for each area, as well as in aggregate.

The generation of user queries to the database is designated by task code ПРИРОДОХ6. All specified tasks are implemented in the appropriate mode with clearly defined deadlines and types of results. In addition, this database allows for the execution of certain non-standard queries:

- by period;
- by year;
- by quarter;
- by contractor's full name;
- by local authority;
- by field values in the list of areas form;
- by field values in the list of measures form;
- by criteria in the fields of the list of outcomes form;
- by criteria in the fields of the list of reasons for non-completion form;
- by adding or updating data;
- by deleting individual or all records;
- by exporting to MS Excel;
- by editing existing records;

The functional structure of reporting on demolition waste is shown in Figure 10.

Overview of the system's functions. The entry of data on demolition waste by local authorities – code ВІДХ1 – facilitates the preparation of reports on the composition, volumes and sources of waste generated as a result of demolition; it also ensures that central authorities are kept informed in a timely manner and supports decision-making in the field of environmental safety.

Entering reference information on waste from destruction (task code ВІДХ2) generates a list of reference information on waste from destruction, which includes: types of data on damaged objects, names of operations involving the management of waste from destruction, and names of components of waste from destruction.

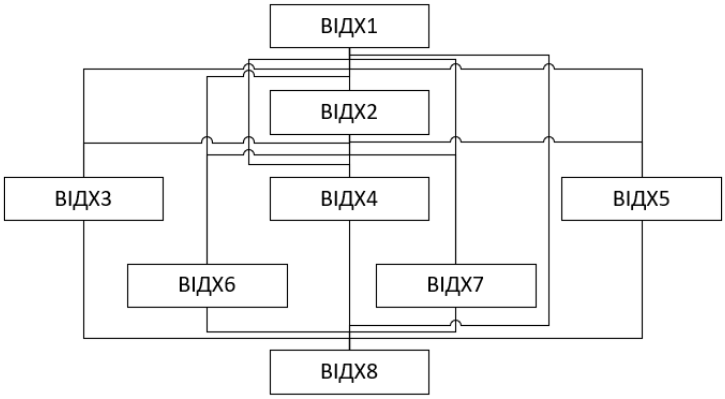


***Figure 10.*** *Functional structure of reporting on demolition waste*

Preparation of reports on the provision of information regarding demolition waste (task code ВІДХ3): a report is generated from the form for providing information on demolition waste and is presented in tabular form on the website and as a downloadable MS Excel file, showing: the names of the components generated during demolition, the volume in tonnes of the demolition waste itself, the location of the temporary storage site / other waste management facility, the address or coordinates, and the total area of the storage sites. The information is sorted by the date of reporting, as well as by district and the name of the local authority. Filtering is available for the chief specialist of the Department of Environmental Protection and Natural Resources by local authority and district, as well as by month, several months or year; for ordinary users, filtering is available by month, several months or year. The summary is based on the volume of waste from demolition in tonnes.

Generation of reports on damaged objects (task code ВІДХ4): a list is generated from data on damaged objects and presented in tabular form on the website; when downloaded to MS Excel, it displays: the type, number and volume (in tonnes) of damaged objects resulting from destruction. Filtering is available for the chief specialist of the Department of Environmental Protection and Natural Resources by local authority and district, as well as by month, several months, or year; for ordinary users, filtering is available by month, several months, or year. The summary is based on the volume of waste resulting from the destruction.

Generation of hazardous waste management reports (task code ВІДХ5): a summary of hazardous waste management data is generated and presented in tabular form on the website; when downloaded to MS Excel,

it shows: whether hazardous waste is separated from demolition waste, locations for the separate storage and disposal of hazardous waste (site for the temporary storage of demolition waste/other waste management facility, address, coordinates), the number of temporary storage sites for hazardous waste within demolition waste, whether hazardous waste is transferred to enterprises licensed to carry out economic activities involving the management of hazardous waste, and the business entity to which the hazardous waste has been transferred. The information is sorted by the date of reporting, as well as by district and the name of the local authority. Filtering is available for the chief specialist of the Department of Environmental Protection and Natural Resources by local authority and district, as well as by month, several months, or year; for ordinary users, filtering is available by month, several months, or year.

Generation of a report on existing equipment or the need for such equipment (task code ВІДХ6): a list of existing equipment or the need for such equipment is generated; this is presented as a table on the website and, when downloaded to MS Excel, displays: the type of existing waste disposal equipment, the quantity of existing waste disposal equipment, the type of equipment required, the quantity of equipment required, the expected quantity of equipment and the means of obtaining it (purchase, transfer), and proposals. The information is sorted by the date of reporting, as well as by district and the name of the local authority. Filtering is available for the chief specialist of the Department of Environmental Protection and Natural Resources by local authority and district, as well as by month, several months, or year; for ordinary users, filtering is available by month, several months, or year.

Generation of reports on waste management operations relating to demolition waste (measure code ВІДХ7): a report on waste management operations relating to demolition waste is generated in the form of a table on the website and, when downloaded to MS Excel, displays: the names of the operations, the volume (in tonnes) covered by the operation, the volume (in tonnes) remaining to be processed, the funding sources used to carry out the operation, whether there is a need for additional funding (with an approximate indication of the amount required), and whether there is a need for specific equipment (specifying the type). The information is sorted by the date of reporting, as well as by district and the name of the local authority. Filtering is available for the chief specialist of the Department of Environmental Protection and Natural Resources by local authority and district, as well as by month, several months, or year; for ordinary users, filtering is available by month, several months, or year.

User queries to the information database are identified by task code ВІДХ8. All such tasks are carried out in a regulated manner, with specified deadlines and types of results. In addition, a number of non-regulated queries can also be performed in this database: 1) by type of data on damaged objects; 2) by name of operations for the management of demolition waste; 3) by name of demolition waste components; 4) by month; 5) by year; 6) by contractor's full name; 7) by local authorities; 8) by field labels in the form for the list of names of operations for the management of demolition waste; 9) by field labels in the form for the list of names of demolition waste components; 10) by fields in the form for the list of names of demolition waste components; 11) by inserting or updating data; 12) by deleting individual or all records; 13) by exporting to MS Excel; 14) by editing existing records.

The functional structure for reporting data on operational action plans is shown in Figure 11.

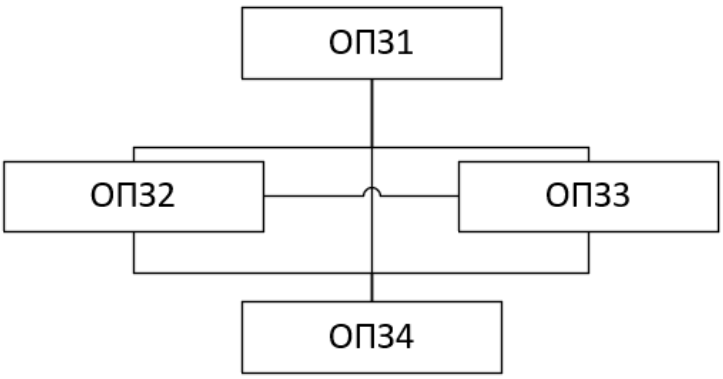


***Figure 11.*** *Diagram showing the interrelationships between tasks in operational action plans*

Description of the system's functions. Entering data on operational action plans by local authorities – code ОП31 – facilitates the implementation of action plans and tasks for internally displaced persons.

Entering reference information for operational action plans – code ОП32 – generates a list of reference information from operational action plans, which includes: task names and action names.

Generating reports on operational action plans (task code ОП33) is generated as a table on the website and, when downloaded to MS Excel, displays: task name, action name, completion deadline, and implementation status (expected outcomes, indicators). The information is sorted by the quarter in which the report is submitted, as well as by the persons responsible for its implementation. Filtering is carried out by quarter and year.

Generation of user queries to the information database – code ОП34. All the tasks listed are carried out in a regulated manner, with specified deadlines and types of results. In addition, a number of non-regulated queries can also be performed in this database: 1) by event name; 2) by task name; 3) by quarter; 4) by year; 5) by contractor's full name; 6) by local government bodies; 7) by values entered in the fields of the list of event names form; 8) by values entered in the fields of the list of task names form; 9) by inserting or updating data; 10) by deleting individual or all records; 11) by exporting to MS Excel; 12) by editing existing records.

**4. Choice of implementation tools.** Visual Studio Code (VS Code) [3] was selected as the development environment for implementing the web application. This is an open-source editor from Microsoft, chosen for the following reasons:

- Extensibility and customisation: VS Code adapts extremely easily to the needs of a project, thanks to its support for a wide range of extensions. You can easily extend its functionality by supporting various programming languages, configuring debugging, implementing version control, and integrating other developer tools. Extensions are installed via the built-in manager;
- Cross-platform compatibility: VS Code works equally well on different operating systems, including Windows, macOS and Linux. Developers can work on their preferred platform without changing their development tool. This provides convenience and flexibility during the development process;
- Integration with version control systems: VS Code has built-in support for Git and other similar systems. This allows you to conveniently manage code changes, perform revisions and collaborate with your team. Integration with GitHub, Azure Repos and other services makes developing and deploying applications significantly easier;
- Powerful debugging and testing tools: VS Code comes with built-in debugging tools that support most popular programming languages and platforms. This allows you to quickly identify and fix errors, thereby improving productivity. In addition, it offers the ability to configure an environment for automated testing;
- Speed and performance: VS Code is characterised by fast start-up and high performance. The editor's lightweight nature and optimised use of system resources ensure stable and fast operation, which is critical for large projects;
- Community and support: VS Code has a large and active user community. A wealth of resources is available, including documentation, tutorials, forums and conferences. The community's activity contributes to the tool's rapid development and improvement.

In addition, HTML (HyperText Markup Language) [21] was chosen for building the web application as a means of structuring web applications, owing to a number of advantages:

- Versatility: HTML is a universal standard for all web pages and works in all browsers. This means that web pages written in HTML open and display without any issues in any browser on any platform, whether it be a desktop computer, laptop, tablet or smartphone;
- Ease of learning: HTML is one of the easiest programming languages, making it the ideal choice for beginners. It features a simple syntax structure and does not require an in-depth understanding of programming to create basic web pages;
- multimedia support enables the use of various multimedia formats, utilising tags for images, audio and video. This makes it easy to embed images, videos and audio files directly into web applications, making them more engaging and interactive for users;
- free to use – no need to purchase specialised software to work with HTML. You can create and edit HTML files in any editor, and view them in a web browser.

JavaScript [19] was chosen to create dynamic, interactive pages, given that it allows the page to be updated in real time. The main areas of application for JavaScript are:

- Client-side development: JavaScript runs directly in the browser, enabling developers to integrate interactive components such as animations, modal windows, sliders and dynamic data loading. This significantly improves user interaction, making web pages more 'responsive';

- Server-side development (Node.js): The Node.js platform has enabled JavaScript to move to the server, allowing server-side applications to be written using a single language for both client-side and server-side components. This reduces training costs and simplifies the integration of different parts of a project;

- mobile app development: using technologies such as React Native or Apache Cordova, JavaScript enables the development of cross-platform mobile apps that run on Android and iOS;

- using tools for creating desktop applications, such as Electron, developers can build apps for Windows, macOS and Linux from a single JavaScript codebase.

Advantages of JavaScript:

- interactivity and responsiveness: JavaScript plays a key role in creating websites that respond instantly to user commands, as this gives web pages a more 'lively' feel;

- Versatility: it works on both the client-side and server-side of a project, allowing a single programming language to be used throughout the project, which minimises the complexity of the development and integration process for all components;

- A thriving developer community and a wide selection of libraries and frameworks (e.g. React, Angular, Vue) significantly simplify the process of developing complex interfaces and applications, allowing new functionalities to be implemented quickly;

- Asynchronous data processing, mechanisms such as AJAX, the Fetch API and Promises, enable efficient handling of large volumes of data without disrupting the user's interaction with the site. This is extremely important for modern web applications that require high performance;

- Easy integration with HTML and CSS; JavaScript works seamlessly with existing web technologies, making it the logical choice for creating interactive elements on existing websites;

- Regular language updates; ECMAScript standards are constantly being improved (e.g. ES6, ES7 and others), enabling developers to use modern programming approaches, thereby improving performance and code quality.

CSS [20] has been chosen for styling, as it defines how elements written in the markup language should appear on web pages. Thanks to CSS, it is possible to control the layout, positioning, colour palette, fonts, spacing and many other visual aspects, which significantly improves the user experience and makes the website harmonious and attractive. Key features and applications of CSS:

- Separation of content from presentation: CSS allows the document structure (HTML) to be separated from its visual styling. This helps keep the code clean and simplifies the process of making changes. Visual styling is controlled via one or more CSS files, which are automatically applied to all pages using these styles;

- Responsive design: thanks to CSS media queries, it is possible to develop designs that automatically adapt to the screen sizes of various devices — from mobile phones to desktop computers. This is a key aspect of modern web development, as it ensures a comfortable viewing experience regardless of the user's device;

- flexible layout methods: the use of CSS Grid Layout and Flexbox allows you to build complex layouts and provides flexibility in positioning elements on the page without the need for additional elements or complex calculations. These approaches make the creation of complex yet intuitive interfaces more efficient;

- animations and transitions: CSS enables the creation of animations, transformations and effects that add dynamism to web pages. Modern capabilities allow for smooth transitions between styles, the definition of keyframes, and the development of interactive effects without the need for JavaScript;

- Support for a component-based approach: thanks to methodologies such as BEM (Block Element Modifier), SMACSS or ITCSS, CSS becomes more organised and modular. This enables developers to create isolated components that are easy to maintain and extend in large-scale projects.

MySQL Server [4] has been selected for data storage, given its reliability and efficiency in data management:

- is renowned for its outstanding performance. It demonstrates the ability to process large datasets and provide simultaneous access for a large number of users. This makes it suitable for large-scale projects that require the processing of significant volumes of information;

- is notable for its ease of scaling, allowing the volume of data and the number of users to be flexibly adapted to the current needs of the project. You can start with a smaller database and gradually expand it as the application's functionality grows;

- offers a robust security system that provides granular control over data access at the user level. The ability to set permissions at the database, table or individual row level allows you to flexibly determine who can view or modify information;

- is open-source, allowing you to freely use and modify it. This enables you to flexibly configure MySQL to meet the specific needs of your project without licensing restrictions;

- supports a wide range of programming languages, including PHP, Java, Python, Perl and C++. This expands its potential for integration with various systems;

- is compatible with various platforms, including Linux, Windows, Mac OS and Solaris. This makes it a versatile solution that can be deployed on a variety of operating systems and servers.

PHP was chosen as the programming language for the web application [23] due to its numerous advantages, which make it the ideal choice for developing dynamic web applications:

- recognised as one of the easiest programming languages to learn;

- PHP is an extremely versatile programming language. It can be used to create a wide range of projects – from basic web pages to complex web applications – as well as for writing command-line scripts and developing applications;

- It integrates easily directly into HTML code, allowing you to combine PHP code with HTML markup;

- It supports MySQL, PostgreSQL, SQLite, Oracle and many other databases;

- PHP is open-source software. This means it is free to use and you are free to modify it to suit your requirements;

- PHP runs on most web servers and major operating systems, including Linux, macOS and Windows.

To implement the information subsystem for recording environmental protection measures, the selection of technical and software components was justified by taking the following aspects into account: functionality, stability, scalability, cross-platform compatibility, integrability, and active support from the developer community. The Visual Studio Code environment was chosen due to its adaptability; a wide range of extensions and seamless integration with HTML, CSS and JavaScript ensure a comfortable, responsive and interactive user interface. PHP was used for the server-side – a language that is easy to learn and interacts well with HTML and databases. The Microsoft SQL Server database management system ensures high performance, security, flexible access control and the ability to process large volumes of data.

5. Development of functional diagrams for the software tool. A use case diagram is an important tool in the process of system design and development [2]. The system's functionality models the services, tasks and functions it is required to perform. Interactions are defined that reflect the external entities (actors) interacting with the system, and helps to visualise how a user or another system will interact with the diagram, which aids in defining the requirements for the functional behaviour of the system under design, and the definition of boundaries, which establishes the general limits and context of the modelled domain in the early stages of design.

In this context, actors can be considered as follows:

- user: a representative of a local authority within a territorial community who uses the software product;

- administrator: a person who has extended access to the product's features and manages the system.

- Department of Environmental Assessment, Monitoring and Natural Resource Management; Department of Air Quality Standards, Water Resources, Waste Management and Air Quality Control: senior specialists within the state administration who review and compile a consolidated report based on the data submitted by users.

The creation of functional diagrams (also known as functional block diagrams or system block diagrams) is an important part of the system analysis and design process [12]. These diagrams help to visualise the interaction between the functions and components of a system. Figure 12 shows a context model of the information subsystem for environmental protection measures.

The input data for the environmental protection measures accounting information subsystem include:

- username;

- password;

- data on environmental protection measures;

- data on demolition waste;

- data on the management of operational action plans.

The input data includes:

- updated database;

- automated management of environmental protection measures;

- automated management of demolition waste;
- automated management of operational action plans.

The managed properties include:
- environmental protection guidelines;
- guidelines on demolition waste;
- guidelines on operational action plans;
- authorisation;
- input database.

These mechanisms include:
- administrator;
- end user;
- software and hardware.


***Figure 12.*** *Contextual model of the information subsystem for recording environmental protection measures*

The architecture of the information subsystem for monitoring environmental protection measures defines the structure, organisation and interaction of the components required to ensure the functionality and effective operation of the system [6].

The architectural model is designed with a focus on scalability, ensuring the reliability and uninterrupted operation of the information system, whilst guaranteeing flexible deployment in both on-premises infrastructure and cloud environments. Interaction between components is carried out via well-documented API interfaces, which facilitates the simple integration of new modules and updates without the risk of disrupting the functionality of existing parts of the system. The databases are designed with backup capabilities and fault tolerance in mind, and data exchange channels are protected by modern encryption and user authentication methods. Access rights to the system's functionality are organised according to a role-based model, allowing permission levels to be set depending on the rights of each user type, from administrators to representatives of local authorities.

The deployment diagram of the information subsystem for recording environmental protection measures illustrates the physical structure of the system, including the location of its components on a physical server, and demonstrates scenarios for their interaction (see Figure 13) [18].

This diagram clearly shows how the various elements of the system — the web server, database, file storage, processing modules and user interfaces — are situated within the physical environment, forming a coherent and interconnected structure. Interconnections between components are provided via an internal

network and the use of communication protocols, which allows for the optimisation of system response times and the maintenance of stable data exchange.

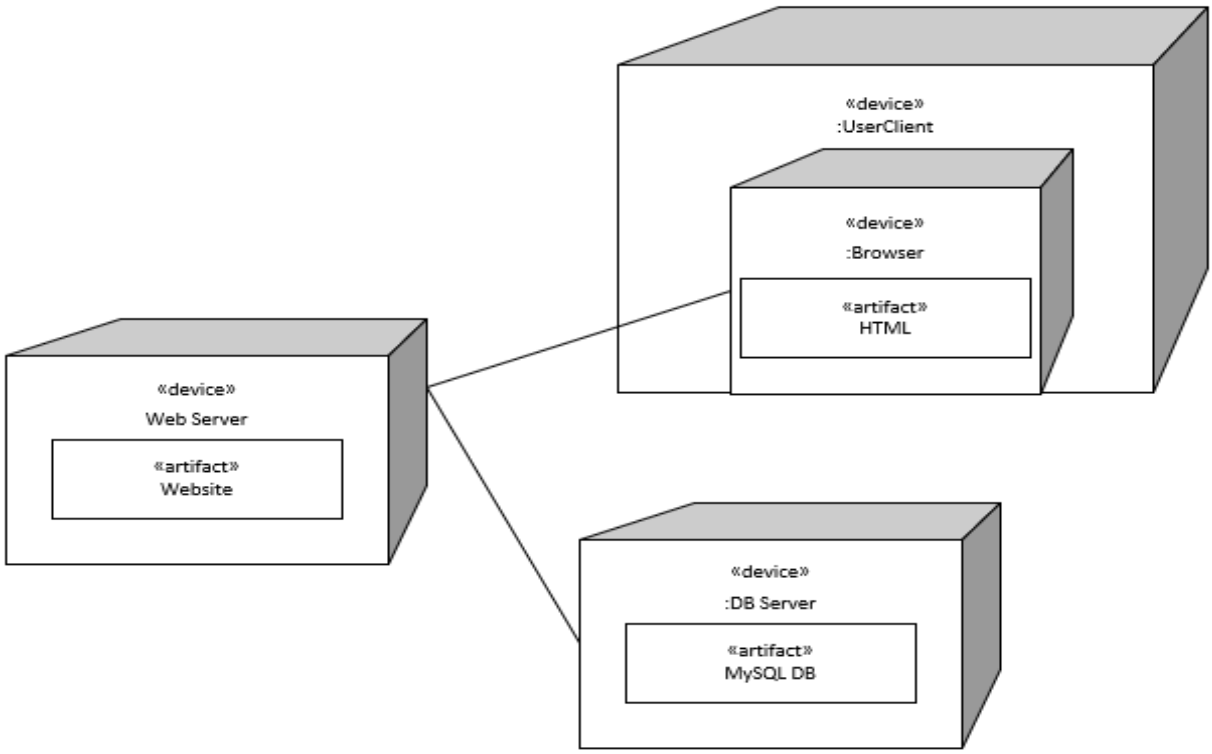


***Figure 13.*** *Block diagram of the information subsystem for recording environmental protection measures*

The diagram includes components such as web servers, databases, additional services and integration modules. It illustrates the principles of interaction between these components, communication protocols and data processing logic.

**6. Design of the database for the information subsystem for monitoring environmental protection measures.** The database of the information subsystem for recording environmental protection measures is compiled on the basis of input documents and reference guides [14]. The list of documents and reference guides is given in Table2.

**Table 2.** Information entities

| № | Name of the information object | Document type |
|---|---|---|
| 1 | 2 | 3 |
| 1 | Form for providing information on demolition waste | Register of information on waste resulting from demolition |
| 2 | Information on damaged properties | Recording details of damaged properties |
| 3 | Management of hazardous waste | Registration of hazardous waste management |
| 4 | Information regarding existing equipment or the need for such equipment | Registration of details regarding existing equipment or the need for such equipment |
| 5 | Information on waste management operations relating to demolition waste | Registration of details regarding operations involving the management of demolition waste |
| 6 | Operational Action Plan | Registration of operational action plans |
| 7 | Information on environmental protection measures that have been implemented | Registration of information on environmental protection measures that have been implemented |
| 8 | Information on environmental protection measures that were planned but not implemented | Registration of information regarding environmental protection measures that were planned but not implemented |

| | | |
|---|---|---|
| 9 | Information on environmental protection measures, taking into account the changes planned for implementation | Registration of information on environmental protection measures, taking into account planned changes |
| 10 | Local authorities | Guide |
| 11 | Data types for damaged objects | Guide |
| 12 | Names of operations for the management of demolition waste | Guide |
| 13 | Names of waste components resulting from demolition | Guide |
| 14 | Areas of environmental conservation | Guide |
| 15 | Environmental benefits | Guide |
| 16 | Environmental protection measures | Guide |
| 17 | Reasons for the failure to implement environmental protection measures | Guide |
| 18 | Names of events | Guide |
| 19 | Task titles | Guide |

Describing the structural relationships between information objects in a database allows relationships to be established between information objects, i.e. between tables. These relationships are established using a key. The established relationships allow simultaneous access to information across multiple tables. A description of the structural relationships between information objects relating to environmental protection measures is provided in Table 3. This description provides a clear understanding of how different information objects interact within the database and which key fields are used to establish these relationships.

**Table 3.** Description of the structural relationships between information objects relating to environmental protection measures.

| № | Information objects | | Type of relationship | Communication key |
|---|---|---|---|---|
| 1 | 2 | | 3 | 4 |
| 1 | Local authorities | Information on environmental protection measures that were planned but not implemented | 1:B | Territorial_communityCode |
| 2 | Environmental protection measures | Information on environmental protection measures that were planned but not implemented | 1:B | Event_Code |
| 3 | Areas of environmental conservation | Information on environmental protection measures that were planned but not implemented | 1:B | Direct_Code |
| 4 | Reasons for the failure to implement environmental protection measures | Information on environmental protection measures that were planned but not implemented | 1:B | Reason_code |
| 5 | Guide to Environmental Effects | Information on environmental protection measures that have been implemented | 1:B | Effect_code |
| 6 | Areas of environmental conservation | Information on environmental protection measures that have been implemented | 1:B | Direct_Code |
| 7 | Environmental protection measures | Information on environmental protection measures that have been implemented | 1:B | Event_Code |
| 8 | Local authorities | Information on environmental protection measures that have been implemented | 1:B | Territorial_communityCode |
| 9 | Areas of environmental conservation | Information on environmental protection measures, taking into account the changes planned for implementation | 1:B | Direct_Code |
| 10 | Environmental protection measures | Information on environmental protection measures, taking into account the changes planned for implementation | 1:B | Event_Code |
| 11 | Local authorities | Information on environmental protection measures, taking into account the changes planned for implementation | 1:B | Territorial_communityCode |
| 12 | Guide to Environmental Effects | Information on environmental protection measures, taking into account the changes planned for implementation | 1:B | Effect_code |

Table 4 provides a description of the structural relationships between information objects relating to demolition waste, comprising the information object's serial number (primary or subordinate), the relationship type and the relationship key.

**Table 4.** Description of the structural relationships between information objects relating to demolition waste

| № | Information objects | | Type of relationship | Communication key |
|---|---|---|---|---|
| | Primary | Subordinate | | |
| 1 | Data types for damaged objects | Information on damaged properties | 1:B | Damaged_object_data_code |
| 2 | Local authorities | Information on damaged properties | 1:B | Territorial_communityCode |
| 3 | Types of data on damaged objects | Form for providing information on demolition waste | 1:B | Code_components |
| 4 | Local authorities | Form for providing information on demolition waste | 1:B | Territorial_communityCode |
| 5 | Local authorities | Management of hazardous waste | 1:B | Territorial_communityCode |
| 6 | Local authorities | Information regarding existing equipment or the need for such equipment | 1:B | Territorial_communityCode |
| 7 | Names of operations for the management of demolition waste | Information on waste management operations relating to demolition waste | 1:B | Operation_Code |
| 8 | Local authorities | Information on waste management operations relating to demolition waste | 1:B | Territorial_communityCode |

Table 5 provides a description of the structural relationships between information objects in operational event plans. It includes: item number, information object (parent, child), relationship type and foreign key. These relationships form the foundation of the logical database model. They ensure the integrity and consistency of information stored in different tables. It is these relationships that define the interactions between the entities: 'Operational Action Plan', 'Event Names', 'Task Names' and 'Local Authorities'. This approach enables database queries to be executed taking into account related parameters. The foreign key acts as an intermediary between tables, allowing data to be joined based on specified attributes.

**Table 5.** Description of the structural relationships between information objects in operational action plans.

| № | Information objects | | Type of relationship | Communication key |
|---|---|---|---|---|
| 1 | Local authorities | Operational Action Plan | 1:B | Territorial_communityCode |
| 2 | Event title | Operational Action Plan | 1:B | Meas_Code |
| 3 | Task titles | Operational Action Plan | 1:B | Task_Code |

The names of the relationships between information objects relating to environmental protection measures are listed in Table 6.

**Table 6.** Names of relationships between information objects

| № | First information item | Second information object | Connection name |
|---|---|---|---|
| 1 | Local authorities | Information on environmental protection measures that were planned but not implemented | Create Create |
| 2 | Local authorities | Information on the environmental protection measures that have been implemented | Create |
| 3 | Local authorities | Information on environmental protection measures, taking into account the changes planned for implementation | Create |
| 4 | Information on environmental protection measures that were planned but not implemented | Reasons for the failure to implement environmental protection measures | They explain |
| 5 | Information on environmental protection measures that were planned but not implemented | Environmental protection measures | Includes |
| 6 | Information on environmental protection measures that have been implemented | Environmental protection measures | Includes |
| 7 | Information on environmental protection measures, taking into account changes that are planned to be implemented | Environmental protection measures | Includes |
| 8 | Environmental protection measures | Areas of environmental conservation | Belongs to |
| 9 | Environmental protection measures | Guide to Environmental Effects | Have |
| 10 | Information on environmental protection measures that were planned but not implemented | Guide to Environmental Effects | Describe |
| 11 | Information on environmental protection measures that were planned but not implemented | Guide to Environmental Effects | Describe |
| 12 | Information on the environmental protection measures that have been implemented | Guide to Environmental Effects | Describe |

The structure of relational tables is based on keys: primary and foreign keys, which form the basis of data integrity.

Primary keys uniquely identify each record in a table, enabling the precise identification of every piece of information stored in the system. This is critically important when working with large data sets, where rapid searching, updating or deleting of records is required. Typically, a primary key is assigned to one or more table attributes, the values of which cannot be duplicated and must not be missing.

Foreign keys establish relationships between different tables, which helps maintain referential integrity – the consistency of data between related objects. They ensure a logical combination of tables, where one contains a reference to the primary key of the other, creating a structured system of interdependencies. For example, a table of action plans may have a foreign key that references a table of local government bodies, allowing specific tasks to be matched with the relevant administrative units.

**Table 7.** Names of relationships between information objects

| № | First information item | Second information object | Connection name |
|---|---|---|---|
| 1 | Local authorities | Information on damaged properties | Data is being entered |
| 2 | Information on damaged properties | Type of data on damaged objects | have |
| 3 | Information on damaged properties | Form for providing information on demolition waste | Provide |
| 4 | Information on damaged properties | Management of hazardous waste | Related to |
| 5 | Management of hazardous waste | Information on waste management operations relating to demolition waste | Includes |
| 6 | Information on waste management operations relating to demolition waste | Names of disaster response operations | Used |
| 7 | Information on waste management operations relating to demolition waste | Names of components damaged | Include |
| 8 | Information on waste management operations relating to demolition waste | Information regarding existing equipment or the need for such equipment | Provided via |

Keys enable the efficient generation of reports, the execution of aggregate queries, and the tracking of changes, whilst also preventing the entry of inconsistent or duplicate data. Furthermore, this structure promotes system scalability, allowing new tables and functions to be added without compromising the consistency and stability of the database. The use of primary and foreign keys results in a coherent, flexible and error-resistant data architecture, which forms the basis of a productive information system. The names of the relationships between information objects in operational action plans are shown in Table8.

**Table 8.** Names of relationships between information objects

| № | First information item | Second information object | Connection name |
|---|---|---|---|
| 1 | Local authorities | Operational Action Plan | Data is being entered |
| 2 | Operational Action Plan | Names of events | Contains |
| 3 | Operational Action Plan | Task titles | Includes |

Each table has its own set of attributes, comprising both mandatory fields—necessary to ensure the system's basic functionality—and additional fields that can be used to enhance analysis and reporting capabilities. The logical structure relating to environmental protection measures is presented as a schematic diagram in Figure 14. This diagram shows tables structured according to the composition and sequence of fields. It illustrates the organisation of data and the relationships between them within the system. Key fields are marked with an asterisk '*'. This is necessary for the quick identification of key attributes that ensure the uniqueness of records and form the basis for establishing structural relationships between tables. Thanks to this visual representation, users and developers can quickly navigate the data structure, track dependencies between objects and analyse the interaction of tables at a logical level.

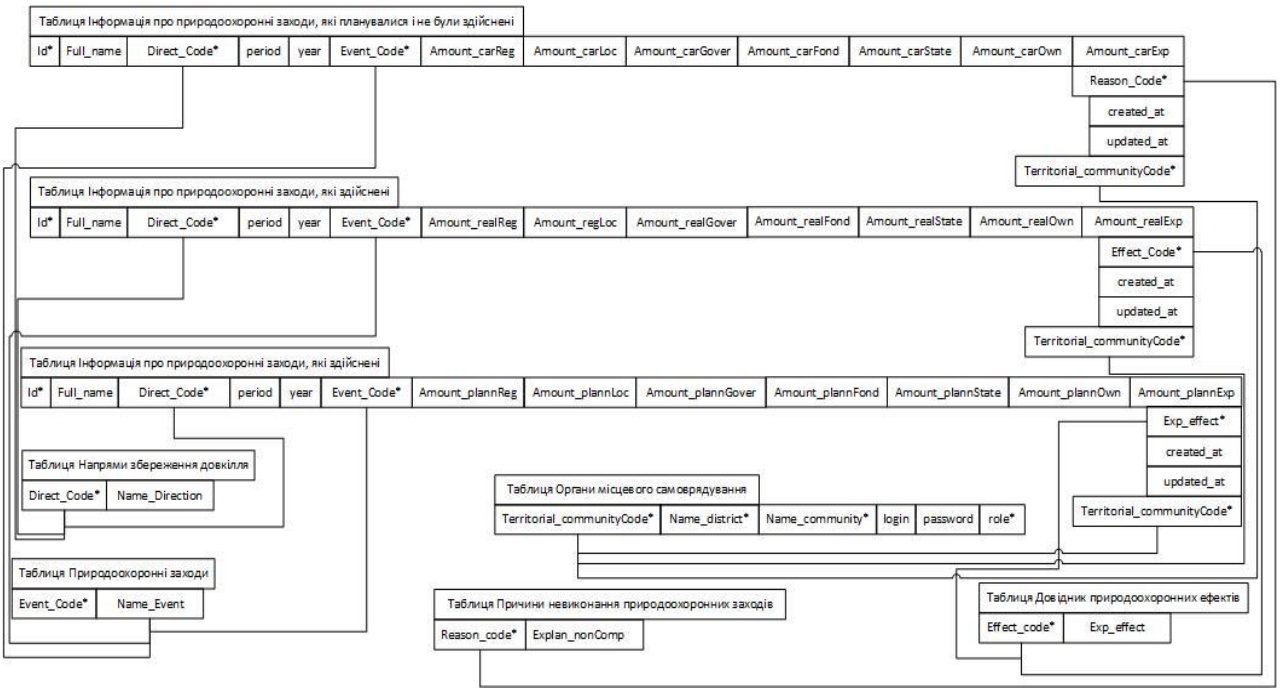


***Figure 14.*** *Logical structure of the database of environmental protection measures*

Logical relationships are represented by lines connecting identical relationship keys. This illustrates the mechanism for establishing 'one-to-many' or 'many-to-one' relationships between information objects. This approach allows for the representation of interdependencies, for example: which measures correlate with specific areas of nature conservation, what caused the failure to implement certain measures, or what role local authorities play in reporting. Furthermore, such a logical schema enables the creation of complex database queries that simultaneously take into account several interrelated objects [17].

The logical structure is illustrated in the form of a flowchart for demolition waste, as shown in Figure 15. In this flowchart, the tables are presented in a structure determined by the composition and sequence of

fields. Key fields are marked with an asterisk (*). Logical relationships are indicated by lines between matching relationship keys.

Логічну структуру зображено у вигляді схеми для операційних планів заходів, представлено на рисунку 16. На цій схемі таблиці подані структурою, обумовленої складом і послідовністю полів. Ключові поля позначені знаком «*». Логічні зв'язки зображені лініями між однаковими ключами зв'язку.

Based on the relationships between information objects, the database structure and the layouts, a functional and technical diagram of the database for environmental protection measures is created. This diagram is a summarising element of the system's technical documentation and allows for a visual demonstration of the logic behind the software suite's operation at the levels of data processing, interaction between components, and load distribution. It illustrates the structure of the entire system architecture, from the user interface to data repositories and analytical tools. Using this diagram, it is possible to trace how information flows through the system – from the moment it is entered by the user to the moment reports are generated or data is archived.

Based on the structural relationships between information objects, the database structure and the layouts, a functional and technical diagram of the database for demolition waste is drawn up. Such a diagram facilitates the smooth organisation of processes, from the information collection stage to the analysis and visualisation of results, ensuring the synchronised interaction of all system components. Creating the diagram allows for all the intricacies of data handling to be taken into account, ensuring maximum system performance and reliability. Each element of the functional and technical diagram is characterised by clearly defined functions, which promotes structured and highly efficient data processing.

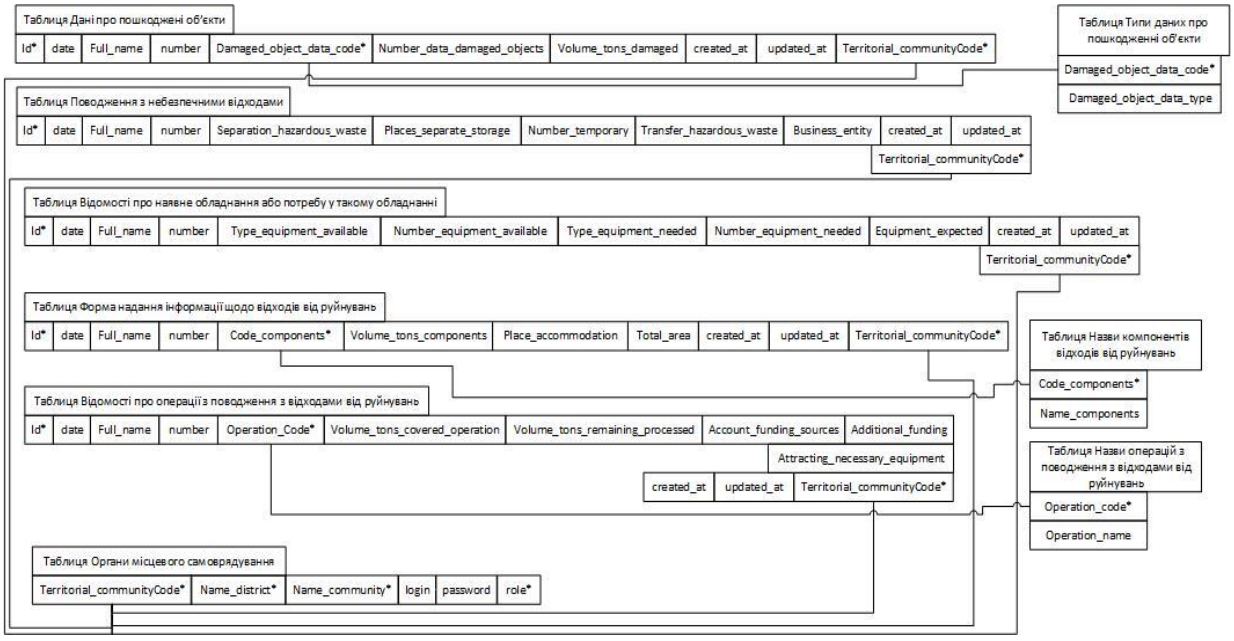


***Figure 15.*** *Logical structure of the demolition waste database*

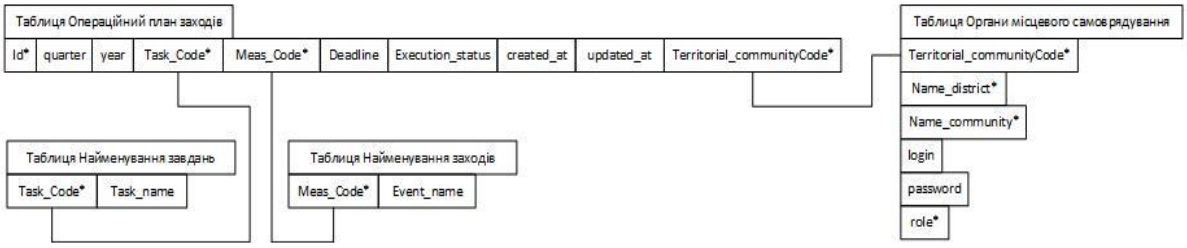


***Figure 16.*** *Logical structure of the operational event plan database*

**7. Physical implementation of the database and the information subsystem for recording environmental protection measures.** Physical implementation of the web application database for the information subsystem for recording environmental protection measures in the MySQL environment [4]. The physical implementation of the database involves the creation of a complete relational structure implemented in the MySQL DBMS environment, selected for its flexibility, performance, scalability and support for complex structured queries. The implementation of the database begins with the formation of its logical model based on the structure of information objects. These objects serve as the basis for creating the corresponding tables, where each information unit is described by details with clearly defined data types, key attributes and relationships.

Based on the logical model, relationships between tables are established, which are implemented through primary and foreign key mechanisms. This structure ensures data integrity and consistency, preventing duplication or incorrect storage. All relationships between tables are described in detail in the structural relationship tables and are also clearly illustrated in the form of a data diagram shown in Figure 17.

In addition to the database structure, the system's visual interfaces—in particular, the on-screen forms—enable users to quickly navigate the data, make changes, and view, filter and export information. All these components form an integral part of the overall information subsystem and are implemented in accordance with the technical specifications.

| | Таблиця | Дія | Рядки | Тип | Зіставлення | Розмір | Фрагментовані |
|---|---|---|---|---|---|---|---|
| ☐ | Dameg_obj | | 5 | InnoDB | utf8_general_ci | 16 КБ | - |
| ☐ | Data_on_damaged_objects | | 1 | InnoDB | utf8_general_ci | 48 КБ | - |
| ☐ | Directions_of_environmental_protection | | 7 | InnoDB | utf8_general_ci | 16 КБ | - |
| ☐ | Directory_of_Environmental_Effects | | 7 | InnoDB | utf8_general_ci | 32 КБ | - |
| ☐ | Environmental_protection_measures | | 21 | InnoDB | utf8_general_ci | 32 КБ | - |
| ☐ | Form_for_providing_information_on_demolition_waste | | 1 | InnoDB | utf8_general_ci | 48 КБ | - |
| ☐ | Hazardous_waste_management | | 0 | InnoDB | utf8_general_ci | 32 КБ | - |
| ☐ | Information_about_available_equipment_or_needed | | 0 | InnoDB | utf8_general_ci | 32 КБ | - |
| ☐ | Information_carred | | 1 | InnoDB | utf8_general_ci | 80 КБ | - |
| ☐ | Information_implemented | | 2 | InnoDB | utf8_general_ci | 80 КБ | - |
| ☐ | Information_on_demolition_waste_management_operations | | 1 | InnoDB | utf8_general_ci | 48 КБ | - |
| ☐ | Information_Planned | | 1 | InnoDB | utf8_general_ci | 80 КБ | - |
| ☐ | Names_of_demolition_waste_components | | 32 | InnoDB | utf8_general_ci | 16 КБ | - |
| ☐ | Names_of_demolition_waste_management_operations | | 7 | InnoDB | utf8_general_ci | 16 КБ | - |
| ☐ | names_op_meas | | 1 | InnoDB | utf8_general_ci | 16 КБ | - |
| ☐ | names_op_task | | 1 | InnoDB | utf8_general_ci | 16 КБ | - |
| ☐ | Operational_action_plan | | 1 | InnoDB | utf8_general_ci | 64 КБ | - |
| ☐ | ReasonsForNon_implementation | | 7 | InnoDB | utf8_general_ci | 32 КБ | - |
| ☐ | Territorial_communities | | 52 | InnoDB | utf8_general_ci | 48 КБ | - |
| | 19 таблиць | Всього | 148 | InnoDB | utf8_general_ci | 752 КБ | 0 Б |

***Figure 17.*** *List of database tables*

Figure 18 shows the database schema. This diagram is a visual representation of the logical structure of the information subsystem for recording environmental protection measures, designed to operate within the MySQL DBMS environment. It shows how data is organised within the system, how tables interact with one another, and what constraints are applied to each field.Схема містить такі основні компоненти:

1. Tables:

- Each table is represented as a rectangle containing a list of fields (attributes) that describe the corresponding information object;

- For ease of organisation, fields are grouped according to data storage logic: identifiers, key parameters, descriptive attributes, timestamps and others;

- Primary Keys (PK), which ensure the uniqueness of records in tables, are marked with an underscore or a separate icon;

- Foreign Keys (FK), which establish links to other tables, are marked with arrows or references to the corresponding keys in external tables.

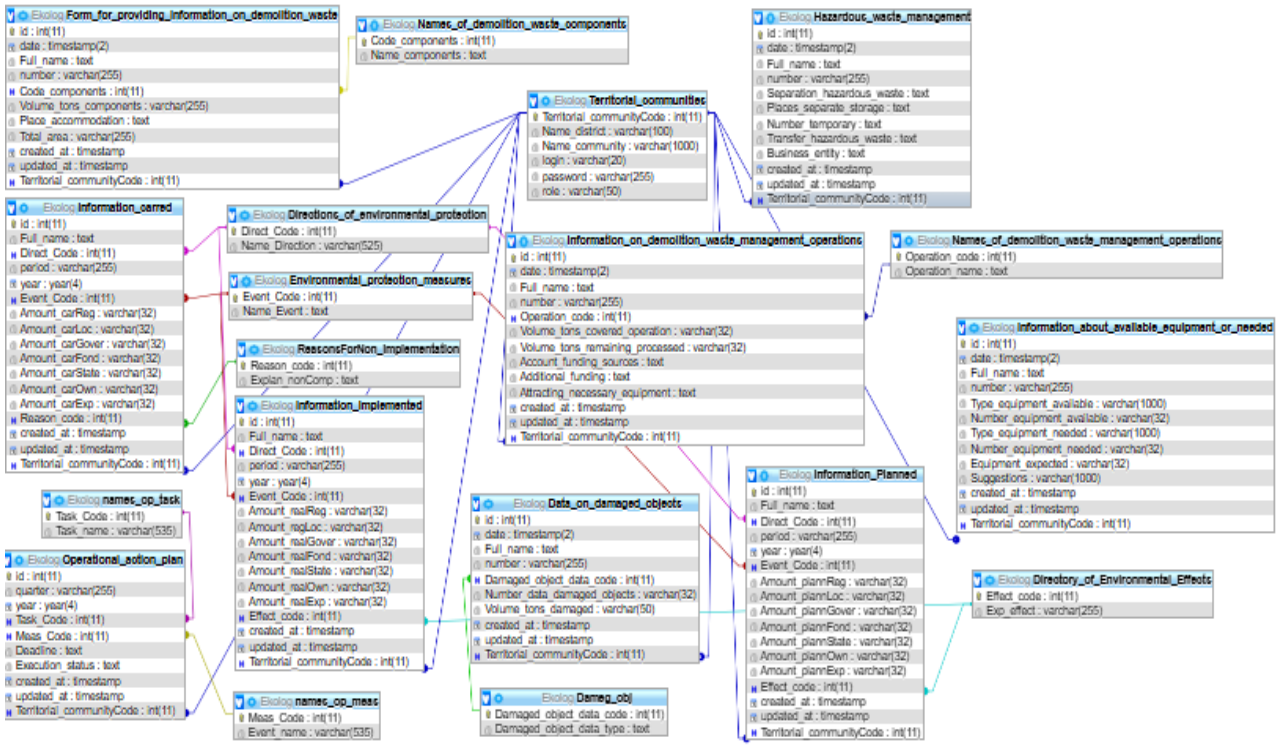


**Figure 18.** Database diagram

2. Relationships between tables:

- Lines are drawn between tables to represent logical relationships. Most relationships are of the 'one-to-many' (1:N) type, meaning that a single record in the primary table can correspond to multiple records in the secondary table;

- The fields used to establish the relationship (the relationship key) are indicated at the ends of the lines.

- The presence of relationships ensures the referential integrity of the database, enabling complex queries to be executed and ensuring the automated processing of related data;

3. Field attributes:

- For each table field, the name, data type (e.g. INT, VARCHAR, DATE, TEXT) and constraints (e.g. NOT NULL, UNIQUE, DEFAULT, AUTO_INCREMENT) are specified;

- These attributes ensure data is entered correctly, enable automated calculations and protect against errors when saving information.

4. Additional elements:

- the diagram may also include indexes, which are used to speed up data retrieval and sorting.

5. Typical relationships are specified for each information object, for example:

- between 'Local authorities' and 'Information on environmental protection measures';

- between 'Environmental protection measures' and 'Areas of environmental conservation';

- between 'Waste management operations' and 'Names of operations', etc.

A database schema is key to understanding how data is organised, the relationships between data, and the methods used to store and manage it within the system. It plays a crucial role during the design, development and maintenance phases of a web application, ensuring ease of interaction with data and enhancing the system's overall performance.

**Software implementation of the user interface.** The key entry point to the information subsystem is the web application's home page. It serves as the main navigation panel and is primarily aimed at regular users — representatives of local authorities who enter or view information on environmental protection measures, demolition waste or operational plans.

The page is optimised for viewing on various devices — computers, tablets and mobile phones. Future plans also include the ability to personalise the interface according to the user's role: administrator, departmental specialist or ordinary user.

The web application has restricted access – only users identified in the database can log in using their username and password. After authorisation, users are redirected to a separate page for selecting reports, where a navigation menu for the web application is displayed. These menus provide quick access to other pages where users can submit their reports.

**Conclusions.** The increasing volume of environmental data received by central and local government bodies necessitates a transition to automated systems for data collection, processing, storage and reporting. The proposed system includes modules for: 1) registering and recording environmental protection measures; 2) reporting on waste from demolition and damaged facilities; 3) processing information on equipment requirements and operational plans for measures; 4) generating standardised reports by period (month, quarter, year), with the ability to filter, edit and export to MS Excel. The system enables a significant increase in the efficiency of local government specialists, facilitates interaction with central executive authorities (in particular, the Ministry of Environmental Protection), and ensures a unified data storage structure and transparency in environmental management matters. Thanks to its flexible architecture, the information system is scalable and can be adapted for use by other communities or institutions, or integrated with state registers via an API.

Future developments for the project may include:

- integration with geographic information systems (GIS) to visualise sites and contaminated areas on a map;
- development of a mobile app to facilitate the work of specialists in the field;
- automation of analytical reporting based on templates and algorithms for assessing environmental impacts;
- provision of multi-level access to data – separately for citizens, specialists and government bodies;
- implementation of additional information security measures, including data encryption and authentication using digital signatures.

This information subsystem ensures the effective monitoring of environmental protection measures, supports environmental safety and promotes transparency in reporting within local authorities.

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