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3. Thematic Geological Information System for Environmental Burdens Monitoring

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Abstract: Specific geological information system for monitoring of environmental burdens (IS EBM) is a basic data platform for monitoring of environmental burdens carried out at SGIDŠ since 2012. The main objectives of the monitoring are to observe the release of pollutants into the environment and to assess trends in the development of contamination. IS EBM is basically divided into two parts: 1) text and general data part used for storing information of various formats, especially for storing various text and graphic files in the directories structure; 2) database and GIS part for managing database and GIS formats in a well-defined structured online form. The development of IS EBM has been necessary for solving tasks requiring effective and fast cooperation of a great number of employees involved in the monitoring process and at the same time when working with a large amount of various data. IS EBM is not publicly available and is part of the SGIDŠ internal network.

Key words: environmental burdens, geological information system, monitoring, database

3.1 Introduction

The basic and official data platform ensuring the collection of data and the provision of general information on environmental burdens is the Information System of Environmental Burdens (abbreviated as IS EB, www.enviroportal.sk) managed by the Slovak Environmental Agency (SEA) authorised by the Ministry of Environment of the Slovak Republic. The basis for its creation was the geological task "Systematic identification of environmental burdens of the Slovak Republic" carried out in 2006 – 2008 (Paluchová et al., 2008) and "Completion of the information system of environmental burdens" (Pacola, 2015).

Since 2012, the State Geological Institute of Dionýz Štúr has been gradually implementing tasks related to monitoring of 309 environmental burdens across Slovakia. The aim of the work is to monitor potential pollution/real pollution of the environment (mainly groundwater and surface waters) and assess trends of contamination development. The purpose of creating a thematic information system for environmental burdens monitoring (**IS EBM**) at SGIDŠ was to solve tasks requiring effective and fast cooperation of employees participating in the monitoring process, as well as processing a large amount of data of various types and quality. The primary basis for the creation of the IS EBM was the geological task "Monitoring of environmental burdens at selected localities in Slovakia", which was carried out in 2012 – 2015 (Kordík & Slaninka et al., 2015). IS EBM is part of the SGIDŠ intranet and it is not publicly accessible.

The use of information technology in the field of research, monitoring and remediation of contaminated sites (environmental burdens) has been dealt with by many authors and institutions around the world (e.g. Tkacs, 1994; Krieger, 1995; Mattikall, 1994; Hiscock et al., 1995; Wilkinson, 1996; Chen et al., 2002). The paper discusses the thematic IS EBM developed at SGIDŠ. The purpose of the themetic information system is to provide information in such a way that it is accessible and easy to use by the team and that the results of the monitoring of environmental burdens are also usable for the needs to address the EBs in general.

3.2 Information system for environmental burdens monitoring

As part of the planning and implementation of the environmental burdens monitoring, data and information from various types of geological work (geology, hydrogeology, geophysics, geochemistry, engineering geology, remote sensing, modeling, etc.) are developed, collected and analysed. Therefore, there has arisen a need in practice for a flexible and efficient evaluation of monitoring data, both temporally and spatially. The best solution was to create a dedicated information system for monitoring environmental burdens. The IS EBM is basically divided into two parts – 1) texts and general data, and 2) structured database and GIS. The text and data part of the system serves for storing general information of various formats obtained in the scope of the solution of the geological task, especially for storing various text and graphics files in the directory structure. The database and GIS part of the information system is used to manage database and GIS formats in a precisely defined structured form. In general, GIS in conjunction with the database tools is a highly effective means of solving a wide range of problems in any discipline (Demers, 1999).

3.2.1 IS EBM – general data and text documents

The general data and text part of the IS EBM is used for central storage and archiving of various (final and temporary) documents/files. Access to this part of the information system is possible via FTP (File Transfer Protocol) connection. Access rights are defined at the

directory level, access is protected by a system that only allows users with appropriate access. Information stored in the general data and text part of the information system can be divided into main groups (directories), which are briefly commented below. The main directories are further subdivided as needed. Different access and editing rights are defined for directories and subdirectories according to the type of data and user needs.

The "*Sites" directory* contains essential files (information) that can be associated with a specific site. Subdirectory names are compiled by site names. For the sake of clarity, a subdirectory structure is proposed for each site to further unify storing the same types of information. For example, a separate location has storage of map layers, text files, primary geological documentation (sampling protocols, audit records of monitoring objects, photo documentation, etc.), annual reports, and others. Such a structure serves for efficient orientation in the amount of stored data and at the same time it is easy to use.

The *"General" directory* serves as a repository of files/information that are not site-specific but important for the operation of EBM projects. The subdirectory structure is relatively flexible and depends on the type of information stored. The examples are, for instance, data files such as various information layers (mining works, geological map, hydrogeological zones, protected areas, buffer zones, groundwater bodies, etc.), legislation, archival reports, sample documents, and others.

The examples of photo documentation, or graphical, data and text information stored in the general data and

	ŠGÚDŠ Geoanalytické laboratórià Spišská Nová Ves	**PROTOKOL O ODBERE VZORKY VODY**	č. dokumentu: 320.25.7.4 dátum vydania: 9/2005 dátum revízie: 16.3.2017

Plán odberu

objednávateľ: ŠGÚDŠ Bratislava				
názov úlohy: Zabezpečenie monitorovania environmentálnych záťaží Slovenska - 1. časť (ZMEZ1)			**číslo úlohy:** 13 16	
názov lokality: Pukanec - skládka kalov Hampoch	**zdroj:** PV254-2	**č. lokality**	**označenie vzorky**	**por. číslo**
	☐ vzorka zlievaná ☐ vzorka bodová	254		
koordinátor lokality: Jozef Kordík		pôvodné označenie zdroja: —		
požadovaný druh rozboru: 17-BTEX; 18-PrChlArom; 19-PrChlAlif				
plánovaný dátum odberu [rrrr-mm-dd]: 2019-03-25				
postup odberu: IP 18.4 Odbery všetkých typov vôd				

Odber vzorky

dátum odberu: **hodina:**	**dátum dodania do laboratória:** **hodina:**	
vzorku odobral: Kordík, Jankulár	**odovzdal:**	**podpis:**
	prevzal:	**podpis:**

Údaje zistené pri odbere

teplota vody [°C]:	**teplota vzduchu** [°C]:
pH:	**konduktivita** [mS/m]:
vzhľad vzorky: **zákal:** 0-bez, 1-nepatrný, 2-slabý, 3-viditeľný, 4-výrazný **farba:** 0-bez, 1-nažltlá, 2-hnedastá, 3-zelenkastá, 4-opalizujúca, 5-belavá, 6-sivastá, 7-hrdzavohnedá **sediment:** 0-bez, 1-nepatrný, 2-slabý, 3-mierny, 4-značný **pach (stupeň):** 0-bez, 1-nepatrný, 2-slabý, 3-znateľný, 4-výrazný **pach (druh):** 0-žiadny, 1-zemitý, 2-hnilobný, 3-chlórový, 4-plesňový, 5-zatuchlý, 6-organický, 7-po H_2S, 8-po amoniaku, 9-TKO, 10-ropný, 11-dechtový, 12-chemický, 13-železitý	
iné údaje: O_2 [mg/l]: O_2 [%]: ORP (SenTix 900) [mV]:	

Vzorka konzervovaná v teréne: (nehodiace sa škrtnite)

konzer. činidlo	**HNO_3**	**H_2SO_4**	**NaOH**	**HNO_3+$K_2Cr_2O_7$**	**$CaCO_3$**	**octan zinočnatý + octan sodný**	**octan sodný + kyselina octová**
stanovenie	stopové prvky	$CHSK_{Mn}$	CN,FNI	Hg	agr.CO_2 p.Heyera	$H_2S + S^{2-}$	Fe^{2-}

Poznámka

laboratórne číslo vzorky:	**číslo zákazky:**

*Fig. 3.1 Water Sampling Protocol automatically generated directly from the IS EBM system. *Note: As the IS is developed only in Slovak, the protocol is presented in its output form.*

Lokalita (MEZ č. a názov): 90 Banská Štiavnica – odkalisko Lintich, Koordinátor: Kordík

Vrt VN90-1

Dátum merania: **Meranie vykonal**: Kordík – Jankulár **Fotodokumentácia**: áno / nie

Kontrola nadzemnej časti vrtu (nepoškodené – poškodené/opis):

(kovová chránička - uzáver, poklop chráničky - výtyčka s označením - zámok)

. . . . . .

Meranie hĺbky vrtu - *Odberný bod (o.b.)= vrchný okraj kovovej chráničky vrtu*

Hĺbka vrtu (m od o.b.) = pôvodná: . . . . . – aktuálna: . . . . . .

Kontrola priechodnosti vrtu: Výška vodného stĺpca: Stav zanesenia vrtu:

TERÉNNE MERANIA

HPV (m od o.b.): Spôsob merania / odberu vzorky: odberák - čerpadlo

pH = ... **EC** = ... **T vody** = ... **T vzduchu** = ...

O_2 (mg/l) = ... **O_2 nasýtenie (%)** = ...

SENZORICKÉ VLASTNOSTI:

Ropné látky = áno / nie, **Zákal** = **0**-bez, **1**-nepatrný, **2**-slabý, **3**-viditeľný, **4**-výrazný

Farba = **0**-bez, **1**-nažltlá, **2**-hnedastá, **3**-zelenkastá, **4**- opalizujúca, **5**-belavá, **6**-sivastá, **7**-hrdzavohnedá

Sediment = **0**-bez, **1**-nepatrný, **2**-slabý, **3**-mierny, **4**-značný

Pach-stupeň = **0**-bez, **1**-nepatrný, **2**-slabý, **3**-znateľný, **4**-výrazný

Pach-druh = **0**-žiadny, **1**-zemitý, **2**-hnilobný, **3**-chlórový, **4**-plesňový, **5**-zatuchlý, **6**-organický, **7**-po sírovodíku, **8**-po amoniaku, **9**-TKO, **10**-ropný, **11**-dechtový, **12**-chemický, **13**-železitý

*Fig. 3.2 Monitoring Object (well) Revision Record form. *Note: As the IS is developed only in Slovak, the protocol is presented in its output form.*

Fig. 3.3 Field measurements (pH, conductivity, temperature, etc.) of surface water properties – (locality Istebné, slug heap)

text part of the IS EBM are shown in Figs. 3.1 to 3.4 (Water Sampling Protocol, Monitoring Object Review Record, Photo Documentation of Surface Sampling, Photo Documentation of Field Measurements).

3.2.2 IS EBM – structured database and GIS

Structured database of environmental burdens monitoring is built centrally on the SGIDŠ database server in Bratislava. The technical platform of the database is the object-relational database system PostgreSQL/PostGIS. Access to the database is possible from different user interfaces, e.g. via web application, ODBC driver (e.g. from MS Access, MS Excel and MapInfo Professional), QGIS or pgAdmin. This flexibility of access and use is very important because of the wide diversity of users' needs of IS EB, while technical skills, conditions of use and users' demands are often significantly different.

Internet interface and access to the database part of the IS EBM

The web application was created in the open-source PHP scripting language in combination with HTML, JavaScript and CSS. The application runs on the Apache web server (Linux) and is accessible online at the appropriate Internet address (Fig. 3.5). Internet communication between the browser and the server is encrypted using HTTPS, which enables secure communication between the client and the web server. Access to the application is protected by security features. For security reasons, the level of user access to information also varies depending on user rights. The database system in the web interface is divided according to the type of data into **general information** (e.g. list of monitored sites and objects, information about wells, information sources), **field characteristics** of monitored media (water, sediments, soils, rocks, soils), monitoring

Fig. 3.4 Photo documentation of field measurement and groundwater sampling from well in the shaft (locality Bratislava – Vrakuňa)

deleting, searching, and exporting records. In addition, it is possible to select individual records according to user requirements. Web interfaces for individual data areas have various functionalities that help with data processing. One of the most frequently used data areas are, for example, the results of chemical and isotopic analyses of water. In the web interface of this data area one can use specially created functions, e.g. function enabling automatic evaluation of analysed results of chemical composition of water compared to selected limit values (e.g. limit values of the Directive of the Ministry of Environment of the Slovak Republic No. 1 / 2015-7 on the analysis of risk analysis of contaminated area) highlighted

*Fig. 3.5 IS EBM, database part – demonstration of access through the IS EBM web application. *Note: As the IS is developed only in Slovak, the protocol is presented in its output form.*

results, especially analytical (engineering-geological and laboratory soil tests, chemical analyses of water and solid samples, isotope analyses, pumping test results, data logger records) and **monitoring** (planning, management and archiving of the monitoring programme). Other user interfaces, such as MS Access or pgAdmin, can be used to access specific data areas of the IS EBM that are not available through a web application.

After log in to the web application and selecting the appropriate data area, the desired form will appear, along with the controls for inserting, editing, displaying, in colour (black, green, orange, red) to distinguish the exceedance of the indication and intervention criteria within the meaning of the Directive (Fig. 3.6).

From the point of view of planning of field measurements and groundwater and surface water sampling, the data area "*monitoring design on objects*" is important, in which the respective site coordinator plans the date of field measurements and sampling for each year. In case of a change in the field work term, it is necessary to update the information in this table (Fig. 3.7). In the case of planning and implementation of such an extensive monitoring

MEZ / ZMEZ1 / MEZ3 - výsledky chemických analýz vôd (ukončené analýzy) - Smernica MŽP SR č.1/2015-7 - Indikačné a intervenčné kritériá podzemnej

objekt	dátum odberu	Li [mg.l-1] (lítium)	Mn [mg.l-1] (mangán)	Sr [mg.l-1] (stroncium)	Fe2+ [mg.l-1] (železo dvojm.)	Fe3+ [mg.l-1] (železo trojm.)	Fe [mg.l-1] (železo celk.)	ID 1.2 IT 2.4 NH4 [mg.l-1] (amoniakálne ióny)	ID 0.4 IT 0.5 NO2 [mg.l-1] (dusitany)
VN49-7	2018-10-01							0.68	
VN49-7	2019-04-15		0.012	0.478			0.022	0.3	
VN49-7	2019-09-25							0.16	
VN49-8a	2015-02-25	0.044	3.38	2.92			24.4	2.47	
VN49-8a	2015-04-27	0.022	1.423	1.013			17.1	3.23	
VN49-8a	2015-07-23	0.034	2.166	1.758			10.522	14.2	
VN49-8a	2016-09-30							32.6	0.59
VN49-8a	2017-04-11		2.95	3.27			25.3	1.9	
VN49-8a	2017-10-09							1.39	
VN49-8a	2018-04-05		3.07	2.77			27.4	1.49	
VN49-8a	2018-10-01							1.2	
VN49-8a	2019-04-30		2.99	2.99			25.3	2.7	
VN49-8a	2019-09-25							2.15	
VN49-8b	2015-02-25	0.013	0.888	0.527			0.435	20.9	
VN49-8b	2015-04-27	0.011	0.956	0.532			0.079	25.9	
VN49-8b	2015-07-23	0.014	1.073	0.592			0.617	34	
VN49-8b	2017-04-11		1.14	0.614			0.072	6.46	
VN49-8b	2018-04-05		1.12	0.591			0.396	9.81	
VN49-8b	2019-04-30		1.39	0.649			1.65	10.4	
VO49-11	2013-12-03	0.019	1.16	1.7			0.145	44.32	0.28
VO49-11	2017-04-12		1.57	1.96			9.31	3.35	
VO49-11	2018-04-04		1.5	1.85			14.8	35.9	
VO49-11	2019-04-15		1.45	1.68			6.85	102	
VO49-12	2013-12-03	0.021	1.13	0.709			0.565	98.14	-0.01

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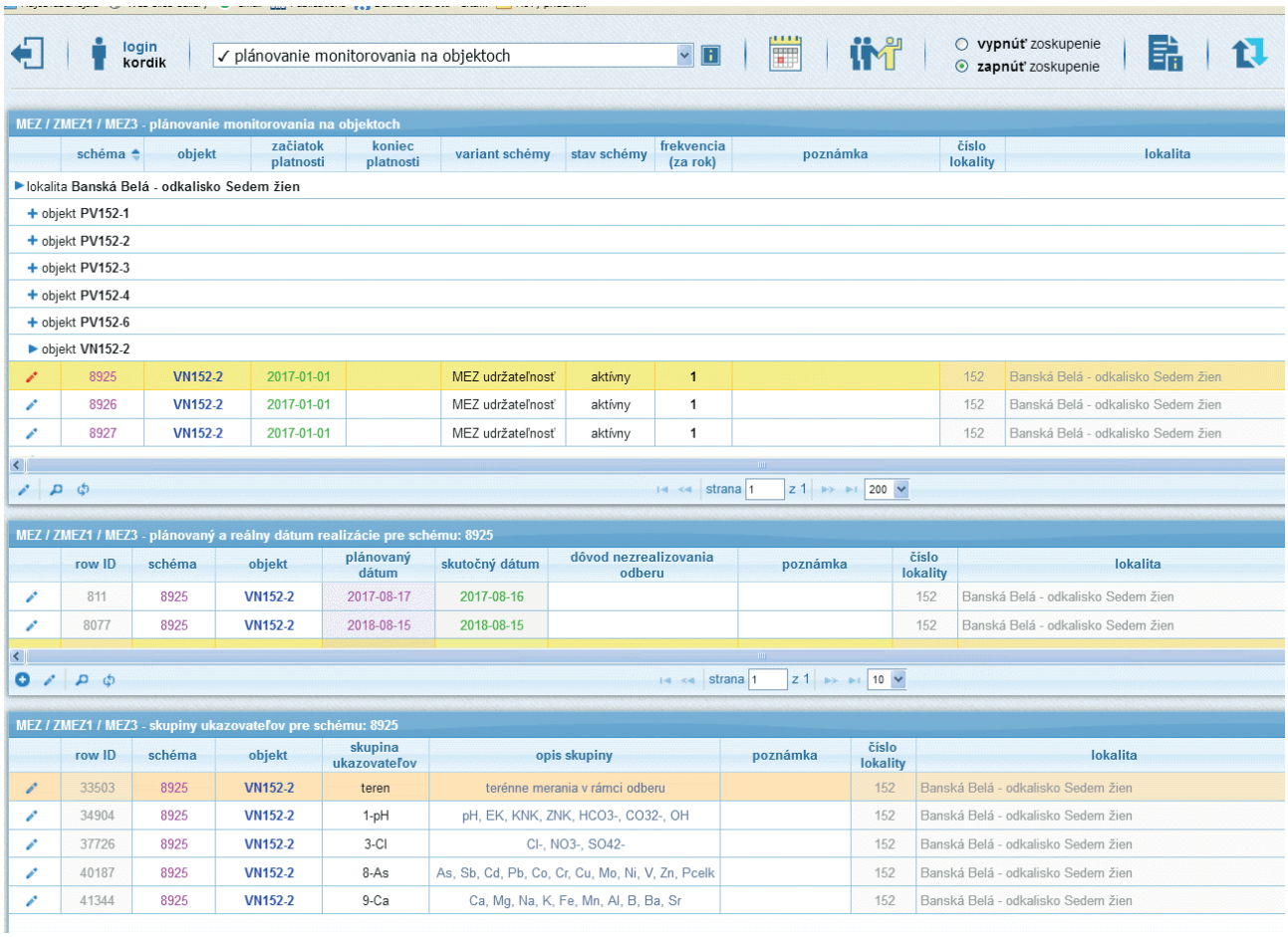
*Fig. 3.6 Data area "Results of chemical and isotopic analyses of water" – access via web application. *Note: As the IS is developed only in Slovak, the protocol is presented in its output form.*



login kordik

✓ plánovanie monitorovania na objektoch

vypnúť zoskupenie
zapnúť zoskupenie

MEZ / ZMEZ1 / MEZ3 - plánovanie monitorovania na objektoch

	schéma	objekt	začiatok platnosti	koniec platnosti	variant schémy	stav schémy	frekvencia (za rok)	poznámka	číslo lokality	lokalita
▶ lokalita Banská Belá - odkalisko Sedem žien										
+ objekt PV152-1										
+ objekt PV152-2										
+ objekt PV152-3										
+ objekt PV152-4										
+ objekt PV152-6										
▶ objekt VN152-2										
	8925	VN152-2	2017-01-01		MEZ udržateľnosť	aktívny	1		152	Banská Belá - odkalisko Sedem žien
	8926	VN152-2	2017-01-01		MEZ udržateľnosť	aktívny	1		152	Banská Belá - odkalisko Sedem žien
	8927	VN152-2	2017-01-01		MEZ udržateľnosť	aktívny	1		152	Banská Belá - odkalisko Sedem žien

strana 1 z 1 200

MEZ / ZMEZ1 / MEZ3 - plánovaný a reálny dátum realizácie pre schému: 8925

	row ID	schéma	objekt	plánovaný dátum	skutočný dátum	dôvod nezrealizovania odberu	poznámka	číslo lokality	lokalita
	811	8925	VN152-2	2017-08-17	2017-08-16			152	Banská Belá - odkalisko Sedem žien
	8077	8925	VN152-2	2018-08-15	2018-08-15			152	Banská Belá - odkalisko Sedem žien

strana 1 z 1 10

MEZ / ZMEZ1 / MEZ3 - skupiny ukazovateľov pre schému: 8925

	row ID	schéma	objekt	skupina ukazovateľov	opis skupiny	poznámka	číslo lokality	lokalita
	33503	8925	VN152-2	teren	terénne merania v rámci odberu		152	Banská Belá - odkalisko Sedem žien
	34904	8925	VN152-2	1-pH	pH, EK, KNK, ZNK, HCO3-, CO32-, OH		152	Banská Belá - odkalisko Sedem žien
	37726	8925	VN152-2	3-Cl	Cl-, NO3-, SO42-		152	Banská Belá - odkalisko Sedem žien
	40187	8925	VN152-2	8-As	As, Sb, Cd, Pb, Co, Cr, Cu, Mo, Ni, V, Zn, Pcelk		152	Banská Belá - odkalisko Sedem žien
	41344	8925	VN152-2	9-Ca	Ca, Mg, Na, K, Fe, Mn, Al, B, Ba, Sr		152	Banská Belá - odkalisko Sedem žien

*Fig. 3.7 Table "Object monitoring plan" – access via web application. *Note: As the IS is developed only in Slovak, the protocol is presented in its output form.*

programme, such as monitoring of environmental burdens at 309 sites, it was also necessary to create a control and alert system. The principle is to create functions (directly above the database), which signalise the deadlines of tasks, check the completeness of information, or implementation of planned tasks. For upcoming dates (especially field work), or to indicate delay in fulfilment of planned tasks (e.g. implementation and insertion of field measurements), they send an e-mail alert message.

Other specific results used by the investigators of the geological task of environmental burdens monitoring are stored, for example, in the data area of continuous measurements of groundwater heads in selected objects (table "*processed data from dataloggers*"). There is a function in the web application that allows graphical visualization of results (Fig. 3.8). The created graphic object can be transferred and used for interpretation in reports.

Access to the IS EBM via ODBC driver

The *ODBC* (*Open Database Connectivity*) driver is used to access and modify remote databases (insert, update and delete data) directly. It allows to load external data from the IS EBM database into selected user interface, e.g. to MS Office programmes (MS Access, MS Excel) or MapInfo Professional and work with them directly in this environment.

In MS Access programme environment, one can import source data into a new table in the current database via the ODBC driver or create a link to a data source by creating a linked table (changes to MS Access data are immediately applied to the source database and vice versa). In the MS Access it is possible to create local user forms, functional elements or other support systems for work with data stored in the IS EBM. For example, in the IS EBM, a user interface is created in MS Access for online entry and modification of chemical analyses results of the EBM samples and other related data directly in the SGIDŠ GAL laboratory, which increases the reliability and efficiency of work.

In MS Excel it is possible to read data and work with them locally, but it is not possible to write directly back to the database, which is a disadvantage for work. MS Excel, on the other hand, offers wide possibilities for data processing, analysis and interpretation (creation of graphs, statistics, tables, etc.).

Editing database data stored in IS EBM via ODBC driver is also possible **in the MapInfo programme**, which is a GIS programme, but it also enables quite effective work with the structured IS EBM data.

Direct access to the IS EBM database on the intranet

Access from QGIS

The QGIS software is primarily a freeware GIS programme, but it also allows to work with structured spreadsheet data from connectable databases. The advantage is the ability to connect directly to the PostgreSQL database system, which forms the basis of the IS EBM and results in high reliability and link speed.

Management and editing data areas in pgAdmin

The pgAdmin graphical environment is accepted as the official graphical user interface of PostgreSQL.

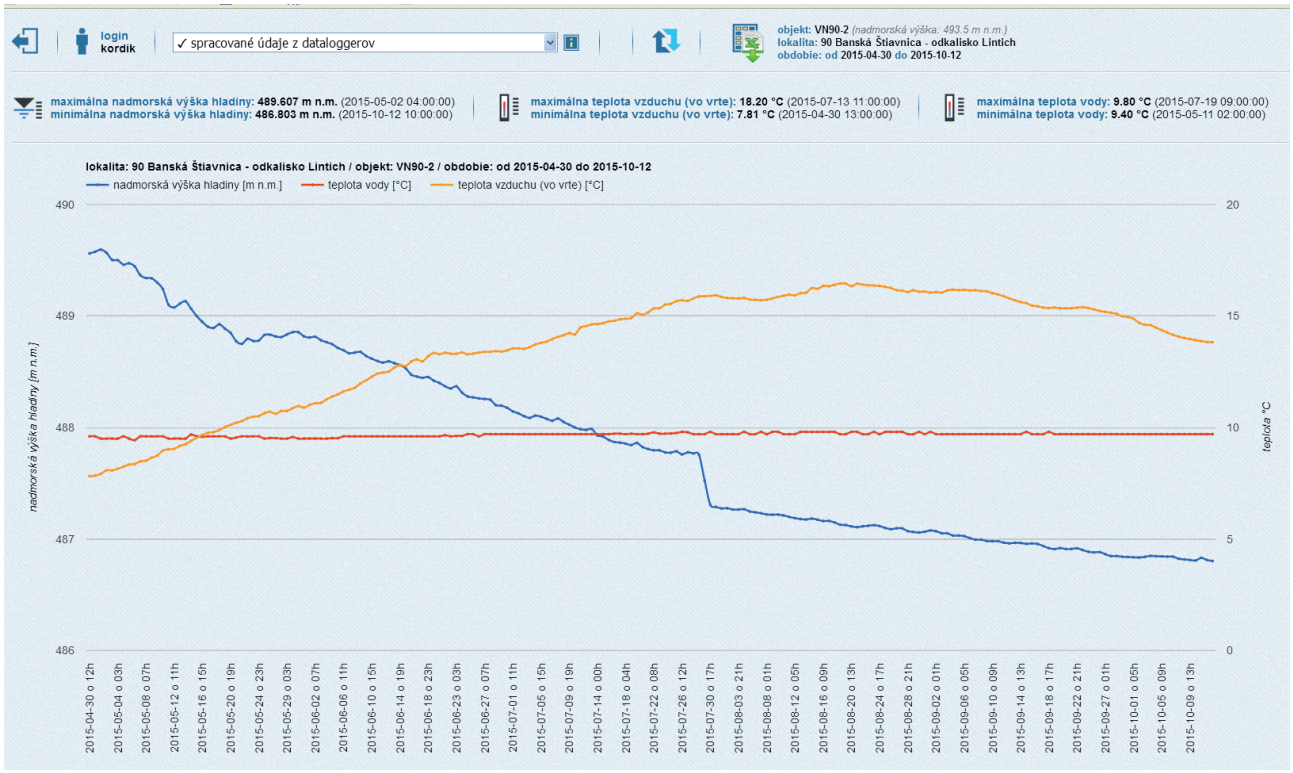


*Fig. 3.8 Graphic object with groundwater levels, automatically processed on the basis of the table "processed data from dataloggers" – purpose functionality of the IS EBM web application. *Note: As the IS is developed only in Slovak, the protocol is presented in its output form.*

The pgAdmin programme is primarily used for Postgres database administrators. It is part of the open-source PostgreSQL project and the installation files can be freely downloaded from http://www.pgadmin.org/download/. It provides a set of tools not only for database administration (at the programming level), but also allows working with database tables – e.g. inserting data, updating data as well as deleting records and batch deleting (truncate). Very effective is a powerful SQL interpreter, which also incorporates the geographical functions associated with the spatial extension of Postgres (PostGIS).

3.2.3 Principle of compilation of database of environmental burdens monitoring

Structured relational database of results of environmental burdens monitoring is one of the key components of the IS EBM. Given the complex nature of the information provided, the database is divided into a number of data areas (tables) that create relations with each other. It is possible to combine the records listed in each database table through these relations in the database operations. An example of a relational link scheme of selected important data areas is shown in Fig. 3.9. An illustration is the interconnection of the data area that manages the data of monitored objects (table "*mez_objekty*") with the data about field measurements results (table "*mez_teren_vody*") through the key system defined by the "*objekt_oznacenie*" column, and/or consequently a field data field ("*mez_teren_vody*") with a data area of chemical analyses results (table "*mez_analyz_vody_chem*") via the field "*id-teren*". A similar system of relational links (system of primary or foreign keys) is created for the whole structure of the IS EBM.

3.2.4 Systematization of data areas – structure of database tables

Systematization of collected data from environmental burdens monitoring enables better storage, processing and analysis of data. One possibility is to define precisely structured database tables. Each database table consists of rows (records) and columns (fields). The names, number, and data types of each field determine the structure of each table. Some of the tables contain so-called spatial geometry (the 'geom' field), which allows spatial localization of stored information, in particular, that the information stored in a table is "mapable"; viewable and analysable

Table 3.1 Structure of the table "lokality_centroidy"

Field	Data type	Metadata
row_id	Serial	Database record identifier, primary key
cislo_lokality	Integer	The sequence number of the site to which the object belongs
lokalita	Integer	Official site name
centroid_x_jtsk	Float	Centroid X coordinate in the S-JTSK03 coordinate system
centroid_y_jtsk	Float	Centroid Y coordinate in the S-JTSK03 coordinate system
folder	Text	The name of the appropriate directory on the FTP file server
okres	Text	District abbreviation
kraj	Text	Region Name
riesitel_meno	Text	Name and surname of the principal investigator
riesitel_id	Integer	ID of the principal investigator
poznamka	Text	Miscellaneous remarks
geom	Geometry	PostGIS geometry (point topology) in binary WKB format
kraj_mez	Text	Integration to administrative units (counties)
barologger	Logical data type	Barologger location at the site – yes / no
kto	Text	The last user (login role) who edited the entry. It is automatically added based on the current_user() database function
kedy	Timestamp	The date and time the record was last edited. Added automatically based on now() database function
kde	Inet	The IP address from which the entry was last edited. Adds automatically based on the inet_client_addr() database function
co	Text	Insert / Update statement. It is automatically added based on the current_query() database function
bolo	Text	Old statement (query) – before the last change. It is automatically added based on a combination of database functions and co field
editor	Text	Name of current operator, or responsible solver of the authorized worker for entering data into the database for the given site

Table 3.2 Structure of table “mez.objekty”

Field	Data type	Metadata
row_id	Serial	Database record identifier, primary key
cislo_lokality	Integer	The sequence number of the site to which the object belongs. It is generated automatically based on the object‘s designation
objekt_oznacenie	Text	Object designation
kod_objekt_druh	Integer	Basic object type (category), generated automatically: adds one of the 10 options given by the code table
kod_objekt_typ	Integer	Basic type (category) of the object, one of the 33 options given by the coding table is selected
objekt_nazov	Text	Existing, or the name of the object, if any
objekt_opis	Text	Brief description of the object
x_jtsk	Float	Coordinate X in the S-JTSK03 coordinate system
y_jtsk	Float	Coordinate Y in the S-JTSK03 coordinate system
z_bpv	Float	Altitude – e.g. in the case of borehole its collar, for soil probes terrain surface, etc.
funkcia_monit_bodu	Text	Monitoring point function, choose from: “indication” – location in the indication area, “reference” – location in the reference area, “source” – location in the source area
pristup_monit_bodu	Text	Indication of whether the proposed site is freely accessible or what the access conditions/on-site sampling options are
lokalita	Text	The official name of the site. To be populated automatically based on the site number and link to the mez.lokality_centroidy table
riesitel	Text	Name of the responsible investigator for the site. To be filled-in automatically based on the site number and link to the mez.lokality_centroidy table
ku_nazov	Text	The name of the cadastral territory within which the object is located. To be filled in automatically based on the geographical position and link to the table mapove_podklady.svm50_katastralne_uzemia
cislo_lv	Text	The property sheet number of the relevant parcel
cislo_parcely_knc	Text	Registry number C (KNC)
cislo_parcely_kne	Text	Registry number E (KNE/UO)
vlastnik_pozemku	Text	Name of the owner of the property concerned
najomca_uzivatel	Text	Name of the lessee / user or manager, if not the same as the owner and address
poznamka	Text	Miscellaneous remarks
geom	Geometry	PostGIS geometry (point topology). It is added automatically according to the entered object coordinates or by a direct click in the GIS programme
editor	Tex	Name of current operator, or authorized worker to enter data into the database for the site. The name of the logged-in person is filled in automatically
Kto	Text	The last user (login role) who edited the entry. It is automatically added based on the database function current_user()
Kedy	Timestamp	The date and time the record was last edited. It is automatically added based on the now() database function
kde	Inet	The IP address from which the entry was last edited. Adds automatically based on the inet_client_addr() database function
Co	Text	Insert / Update statement. It is automatically added based on the current_query() database function
Bolo	Text	Old statement (query) – before the last change. It is automatically added based on a combination of database functions and field co
mi_style	Text	How to display an entity in MapInfo. It is written automatically using the colour code in MapInfo

Table 3.3 Structure of table “teren_vody”

Field	Data type	Metadata
row_id	Serial	Database record identifier, primary key
cislo_lokality	Integer	The sequence number of the site to which the object belongs. It is generated automatically based on the object‘s designation
objekt_oznacenie	Text	Indication of the object to which the record relates or from which the sample was taken
id_teren	Integer	Field documentation or sampling number (generated automatically and must be unique)
vzorka_chem	Logical data type	Indication of whether a sample for chemical analysis (yes/no) has been taken from a given horizon
vzorka_izotop	Logical data type	Indication of whether a sample for isotopic analysis (yes/no) was taken from the given horizon
oznacenie_vzorky	Text	Field designation of the sample. To be completed only if a sample has been taken (for chemical or isotopic analysis). An example of a typical designation: 14-VN66-4-20150422, i.e. fourteenth sample in the consignment taken from borehole VN66-4, on 22.4.2015
datum_cas_merania	Datum form: 2014-10-10 00:00:00	Date and time of field measurement/sampling
odobral	Text	Name of the person taking the measurement/sampling
ph_ter	Float	Water reaction in situ
t_vody	Float	In-situ water temperature (°C)
t_vzduchu	Float	In-situ sampling air temperature (°C)
vodivost_25	Float	Specific electrical conductivity at 25 °C (mS/m), in situ
o2_mgl	Float	Dissolved oxygen content (mg/l), in situ
o2_perc	Float	Dissolved oxygen content (%), in situ
knk45_ter	Float	Acid neutralization capacity 4.5 (mmol)
znk83_ter	Float	Alkaline neutralization capacity 8.3 (mmol)
knk83_ter	Float	Acid neutralization capacity 8.3 (mmol)
znk45_ter	Float	Acid neutralization capacity 4.5 (mmol)
farba_senz	Integer	Sensory determination of the colour of the water sample (list code)
zakal_senz	Integer	Sensory determination of turbidity in a water sample (list code)
pach_stupen	Integer	Sensory determination of the degree of odour strength of a water sample (list code)
pach_druh	Integer	Sensory determination of the type of odour of a water sample (list code)
eh_ter	Float	The redox potential value (mV) converted to a hydrogen electrode
ropne_latky_senz	Logical data type	Presence of petroleum substances assessed visually (“free phase”): yes/no
vzhlad_vzorky	Text	Sample appearance descriptively
hlb_hlad_pv	Float	Groundwater depth from casing/OB (m)
prietok	Float	Surface flow rate (l/s)
vydat_vyver	Float	Groundwater output rate (l/s)
poznamka	Text	Miscellaneous remarks
editor	Text	Name of current operator, resp. responsible solver of the authorized worker for entering data into the database for the given site
kto	Text	The last user (login role) who edited the entry. It is automatically added based on the current_user() database function
kedy	Timestamp	The date and time the record was last edited. Added automatically based on now() database function
kde	Inet	The IP address from which the entry was last edited. Adds automatically based on the inet_client_addr() database function
co	Text	Insert/Update statement. It is automatically added based on the current_query() database function
bolo	Text	Old statement (query) – before the last change. It is automatically added based on a combination of database functions and field co
riesitel	Text	Name of the responsible investigator for the site. To be populated automatically based on the site number and link to the mez.lokality_centroidy table
lokalita	Text	The official name of the site. To be populated automatically based on the site number and link to the mez.lokality_centroidy table

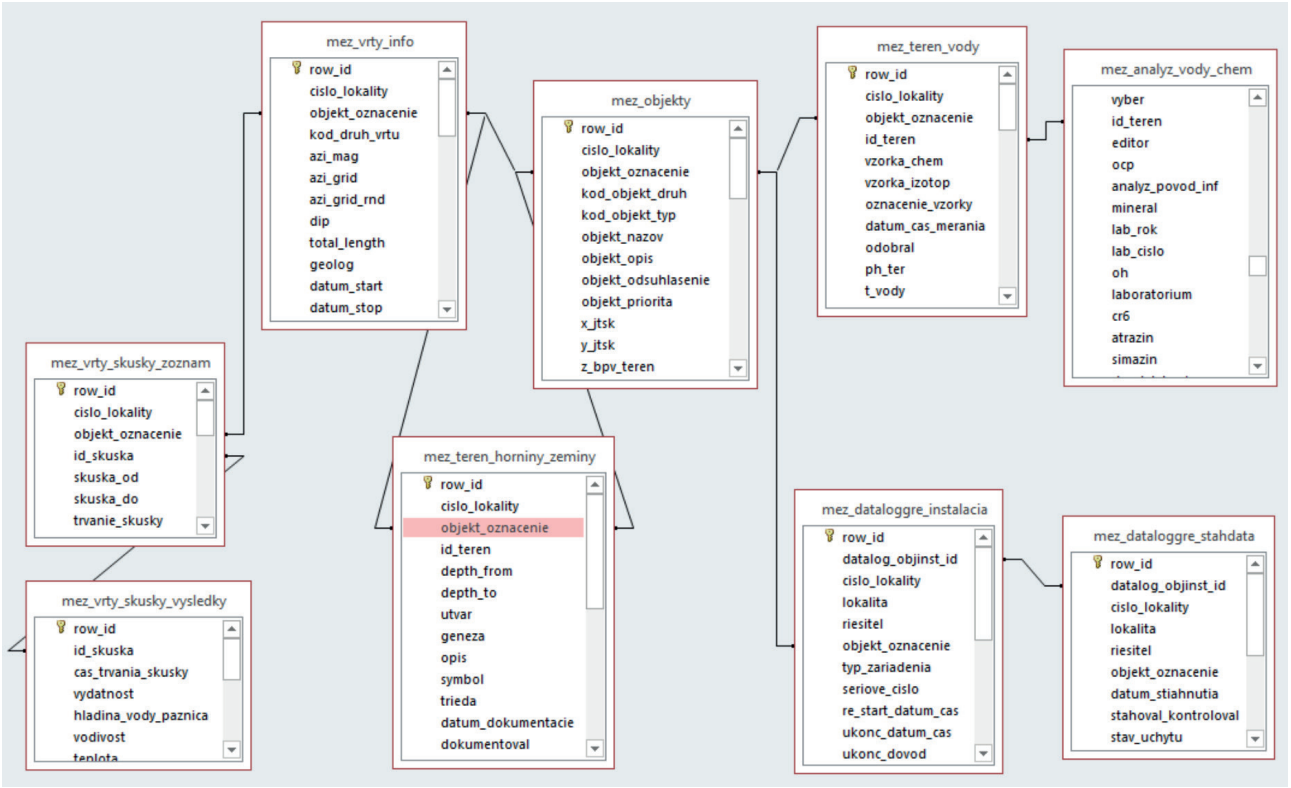


Fig. 3.9 Example of relation of selected tables

in any of the used GIS programmes/applications (e.g. MapInfo Professional, QGIS, thematic web application MEZonátor). Some of the table fields are filled in automatically based on defined criteria and requirements; while other fields must be filled in by the user (otherwise an error message will appear). The remaining fields are optional and may be left blank. At the same time, it is possible to introduce rules defining the required form, or the content of the data to be inserted. Several methods can be used for this purpose, e.g. defining the type of data for a given field when creating a database structure, using triggers (the trigger defines the action that takes place in the case of a certain event occurring above the database table, for example when data is entered), or the possibility of programming purpose-built functions linked to the database. The following text offers a brief description of selected relevant tables of the EBM database, whose simplified structures are shown in Tabs. 3.1 to 3.4.

Monitored data area – "lokality_centroidy" table

The table contains general information on environmental burdens sites, such as: name of the principal investigator, district, region, cadastral territory, launch and end of the monitoring network development, etc. (Tab. 3.1). The table is mapable, containing geometry with point topology – the point represents the geometric centroid of the polygon bounding the site.

Data area of monitored objects – table "mez. objekty"

It contains a list of all EBM objects (boreholes, wells, springs, drainages, surface streams, soil probes, heaps, etc.). Each object is given its own designation (field objekt_oznacenie), which must be unique and unrepeatable. The table contains geometry (i.e., it is mapable) with point topology, i.e. each object in the map is represented by a point determined by its coordinates in S-JTSK03 (Tab. 3.2).

Data area including storage of results of field measurements of natural waters – table "teren_vody"

This data area represents an important part of the results of natural water monitoring obtained directly during fieldwork. It contains the field characteristics of the waters at the time of documentation and/or sampling (Tab. 3.3). The table is not mapable and does not contain geometry. When entering a field measurement record, it shall be stated, inter alia, whether a sample has been taken for chemical and/or isotopic analysis. In the case of sampling, a record is automatically created in the appropriate analysis results table with all identification elements, which subsequently enables reliable insertion of the analysis results by laboratory staff.

Data area of chemical water analysis results – table "analyz_vody_chem"

It contains basic information about the results of chemical analyses of water samples or leakage liquids. The basic division of the structure of this table is shown in Tab. 3.4. There are many columns in this table due to the high number of indicators to be determined. The number of indicators varies depending on the addition of newly determined substances. Currently Currently there are about 300 substances in the database. Similarly-structured are

Table 3.4 Structure of table "teren_vody"

Field	*Data type*	*Metadata*
id_teren	Integer	Field documentation or sampling number (generated automatically and must be unique)
objekt_oznacenie	Text	Indication of the object to which the record relates or from which the sample was taken
datum_odberu	Datum form: 2014-10-10	Date of sampling
row_id	Serial	Database record identifier, primary key
cislo_lokality	Integer	Sequence number of the EBM site to which the object belongs. It is generated automatically based on the object's designation
lokalita	Text	The official name of the site. To be populated automatically based on the site number and link to the mez.lokality_centroidy table
oznacenie_vzorky	Text	Field designation of the sample. To be completed only if a sample has been taken (for chemical or isotopic analysis). An example of a typical designation: 14-VN66-4-20150422, i.e. fourteenth sample in the consignment taken from borehole VN66-4, on 22.4.2015
labor_cislo	Text	Laboratory sample number
ph_lab	Float	Water reaction in laboratory
ek25_lab	Float	Specific electrical conductivity at 25 °C (mS/m) in the laboratory
knk45_lab	Float	Alkaline neutralization capacity 4.5 in mmol, in the laboratory
znk83_lab	Float	Alkaline neutralization capacity 8.3, in mmol, in the laboratory
knk83_lab	Float	Acid neutralization capacity 8.3 in mmol, in the laboratory
znk45_lab	Float	Alkaline neutralization capacity 4.5 in mmol, in the laboratory
poznamka	Text	Miscellaneous remarks
Jednotlivé stanovované ukazovatele: (napr. nh4, ca, ...) [*1]	Float	*Values of each set of indicators** [1]
editor	Text	Name of current operator, or responsible solver of the authorized worker for entering data into the database for the given site
kto	Text	The last user (login role) who edited the entry. Adds automatically based on the current_user() database function
kedy	Timestamp	The date and time the record was last edited. Added automatically based on now() database function
kde	Inet	The IP address from which the entry was last edited. Adds automatically based on the inet_client_addr() database function
co	Text	Insert/Update statement. It is automatically added based on the current_query() database function
bolo	Text	Old statement (query) – before the last change. It is automatically added based on a combination of database functions and field co
riesitel	Text	Name of the responsible investigator for the site. To be filled in automatically based on the site number and link to the mez.lokality_centroidy table

*Note. * 1 – the row is only a symbolic representation of a large number, about 300 columns (indicators) in the respective database table representing the results of the chemical analysis*

the tables of results of chemical analyses of solid materials (sediments, soils, rocks, earths) and isotope analyses of water. Data are entered in the IS EBM system directly in the laboratory, while the laboratory user interface in the MS Access environment has been developed for input. This environment also provides the initial check of completeness and correctness of analyses.

3.2.5 GIS applications in the IS EBM

An important feature of the IS EBM is the possibility of interconnection to standard and special-purpose GIS applications. This is important for efficient and flexible use of stored data for analysis, interpretation and presentation. Multiple platforms and software applications are supported within the system. The purpose-built online web interface with GIS elements can include an application with an internal name MEZonátor (up to now publicly not accessible). It is possible to use several GIS applications that can be connected directly (e.g. QGIS) or via ODBC driver (e.g. MapInfo). Under certain conditions it is possible to use the currently used ESRI products (ArcGIS).

Special purpose web presentation GIS interface – MEZonátor

An interesting, particularly visualization and presentation platform is the web interface with the internal name

"MEZonátor" (Fig. 3.10), which enables GIS presentation of data from the IS EBM. The application was created in R, using the Shiny web framework. The main menu (Fig. 3.11) consists of sections: site selection, site list, info, meteo, map, Piper diagram, water quality, tables.

After selecting the site(s) it is possible to obtain basic information about the site (number of samples, records from continuous measurements, etc.) in the "Info" section (Fig. 3.12), contamination data (frequency of exceedance of the standard, contamination intensity compared to the standard), site objects data.

The "Meteo" section (Fig. 3.13) shows the long-term average monthly precipitation amounts and the long-term average monthly air temperatures. The data are retrieved from WorldClim.org and represent the long-term averages for 1960 – 1990. For individual sites they are interpolated

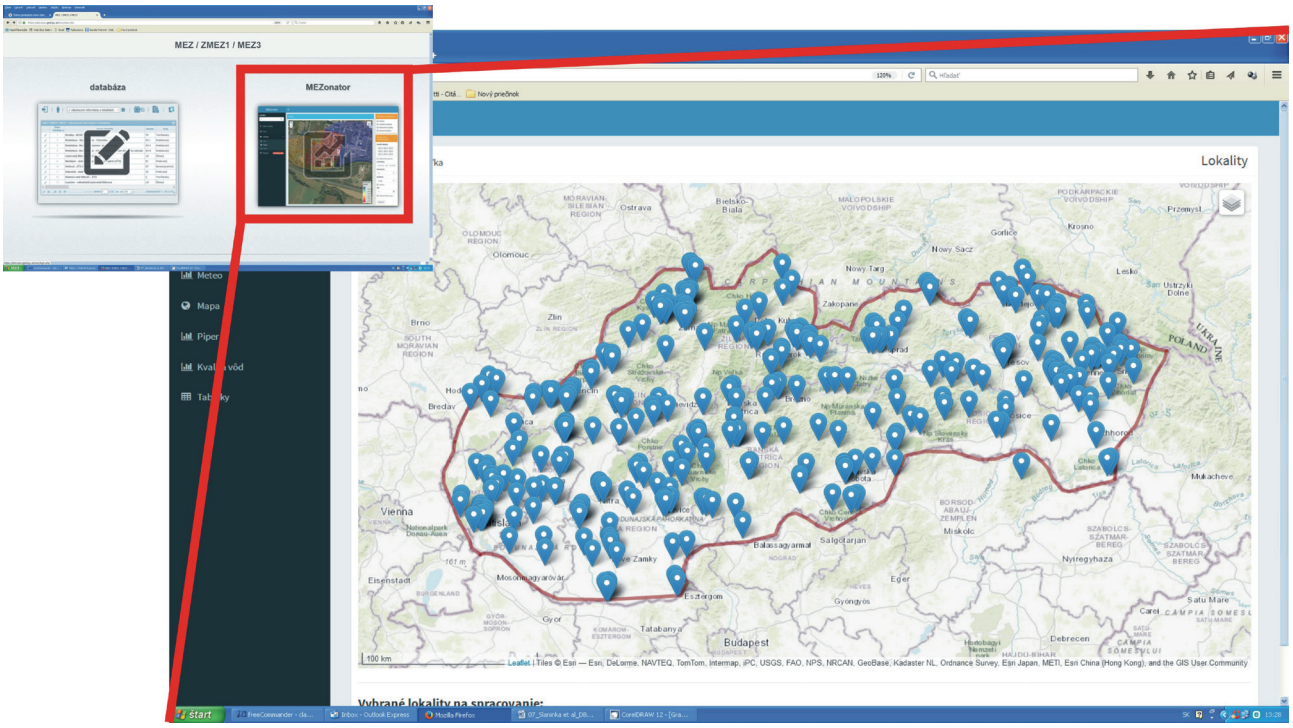


Fig. 3.10 Web application "MEZonator"

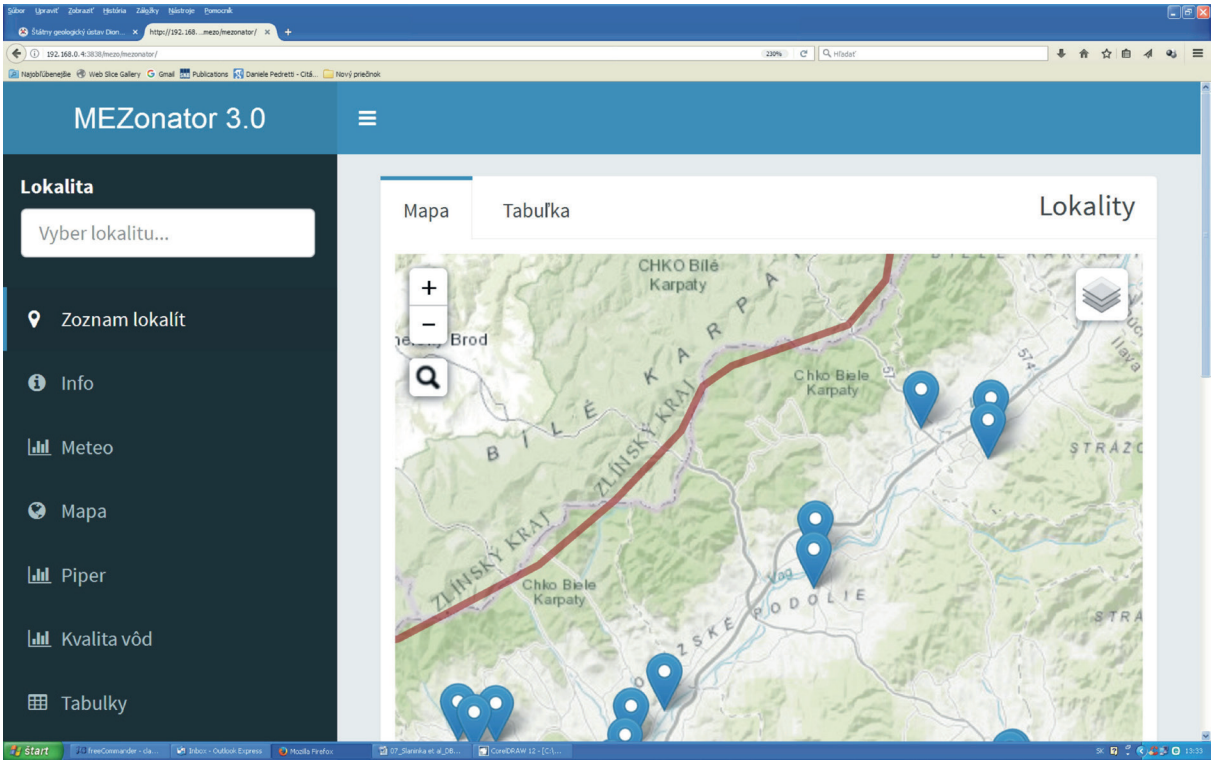


Fig. 3.11 Basic application menu "MEZonator"

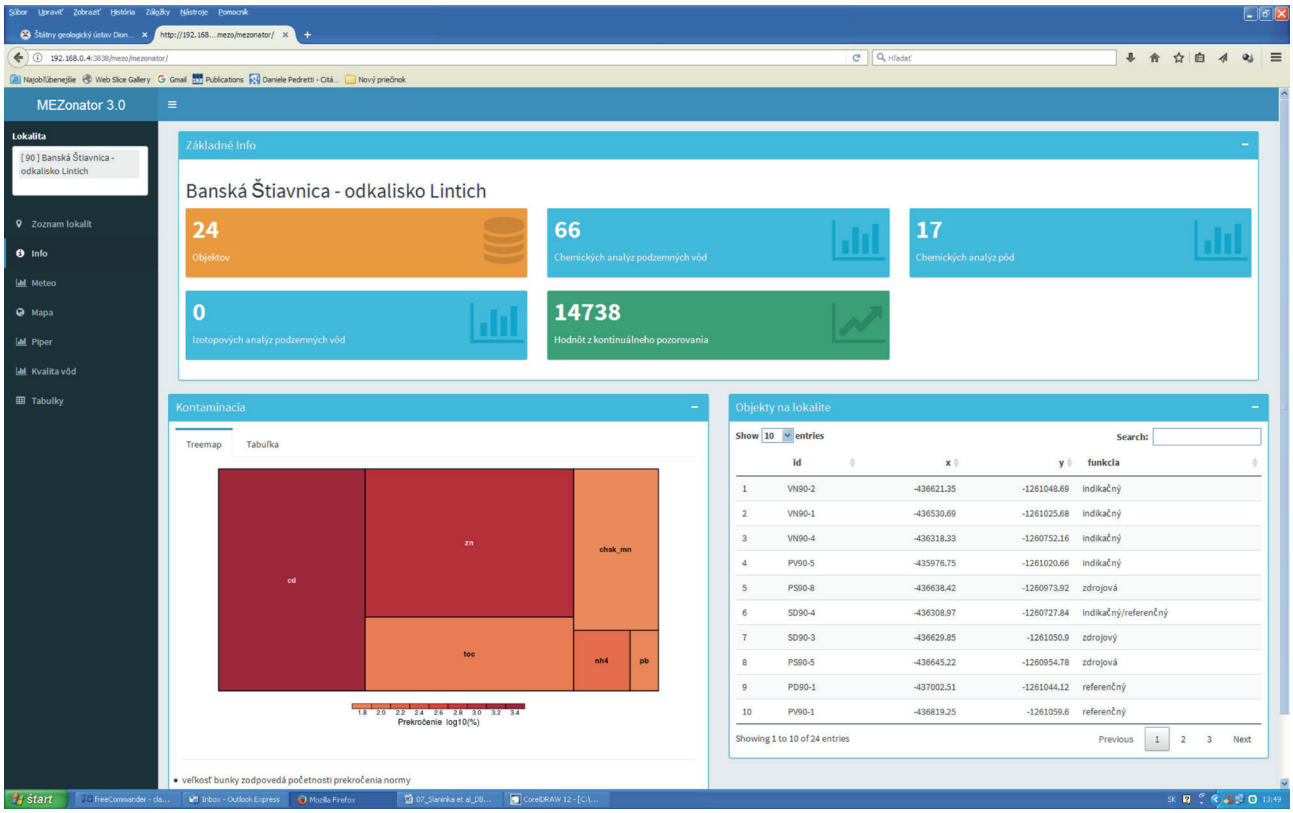


Fig. 3.12 Information under section "Info"

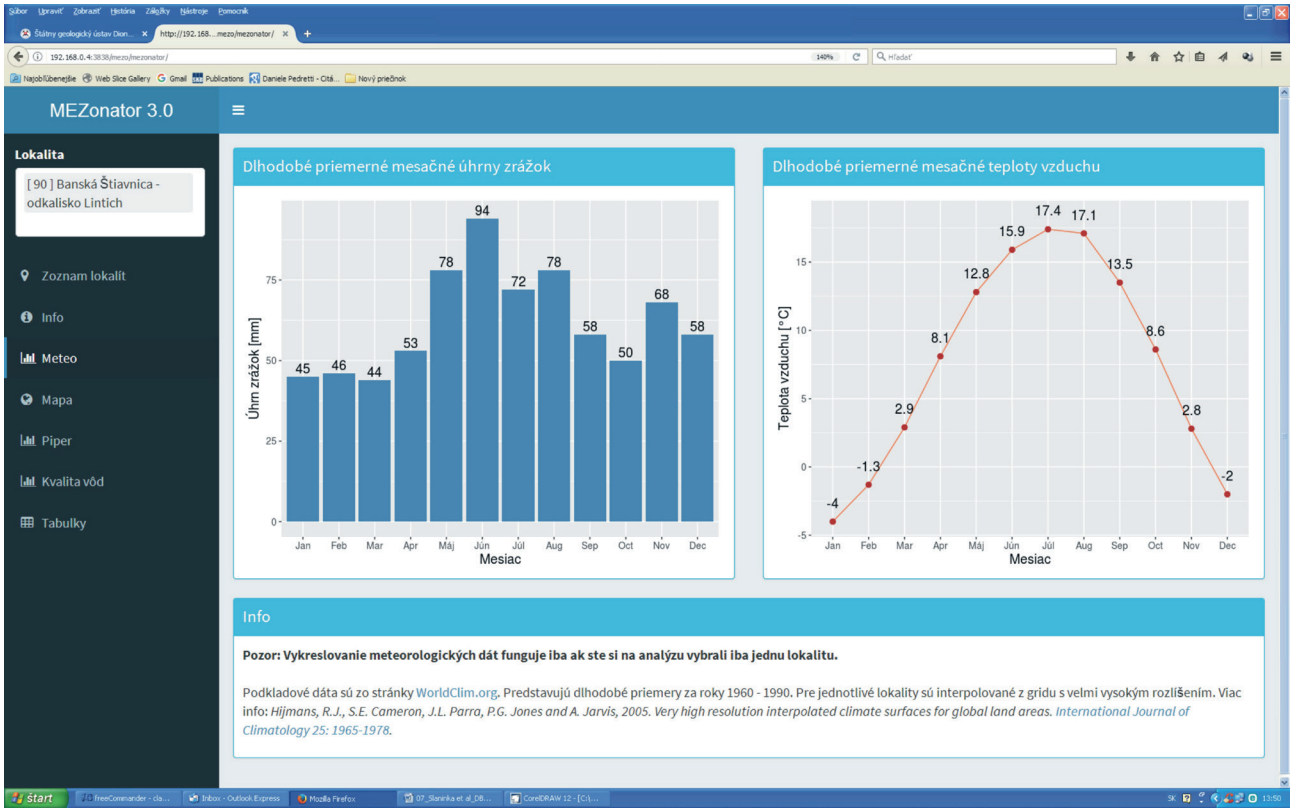


Fig. 3.13 Information provided in section "Meteo"

from a very high resolution grid (more info: Hijmans et al., 2005).

In the "Piper" section (Fig. 3.14) it is possible to plot the Piper systemization diagram for selected objects in the given locality. Piper diagrams represent one of the basic ways of presenting the chemical composition of groundwater.

In the section "Water quality" it is possible to obtain information from basic statistical processing, distribution, course of contents over time for selected objects and selected indicators (Fig. 3.15).

In the "Map" section (Fig. 3.16) it is possible to plot distribution maps of selected indicators for selected objects. The mapping of element concentrations can serve

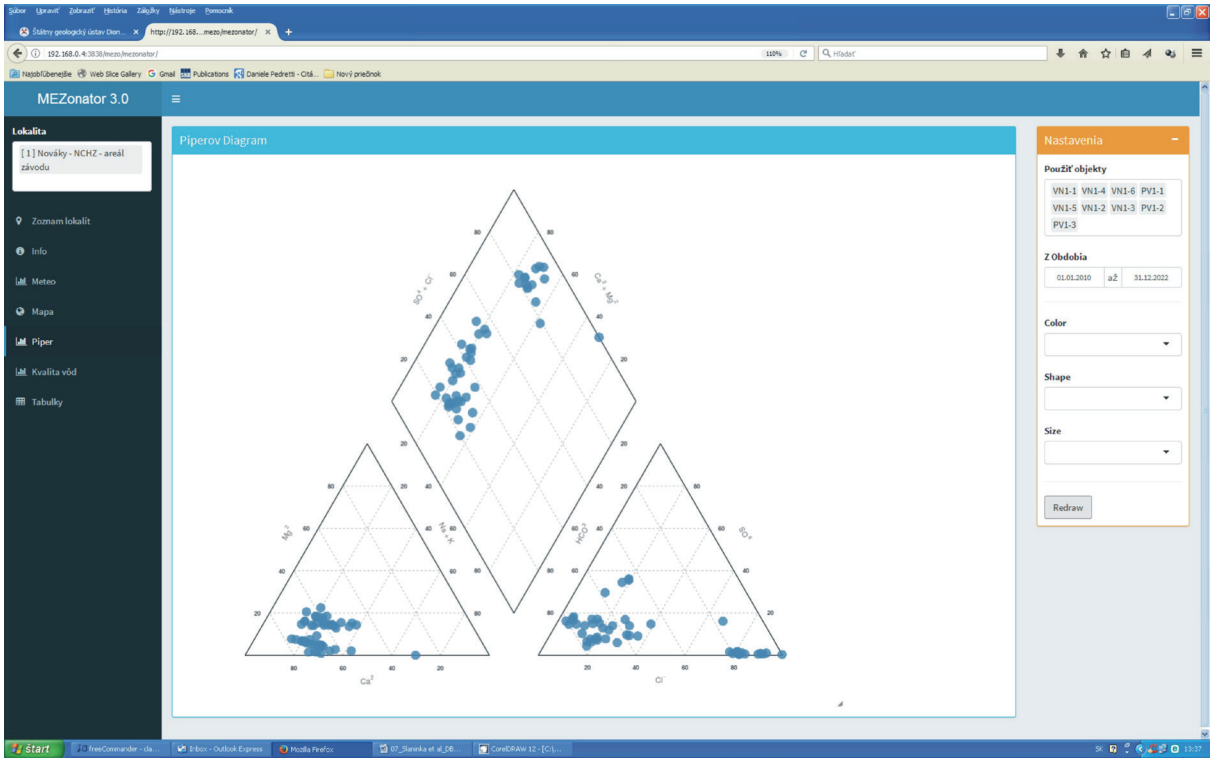


Fig. 3.14 Information provided in section "Piper"

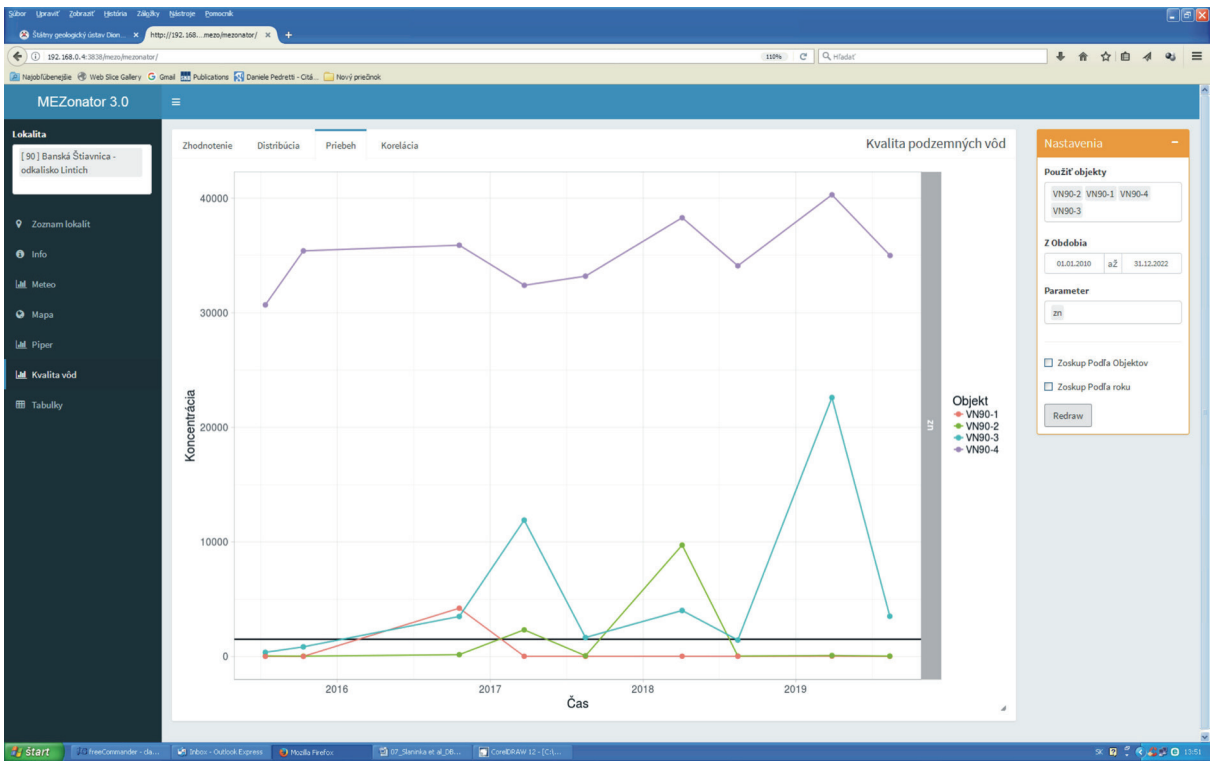


Fig. 3.15 Information provided in section "Water quality"

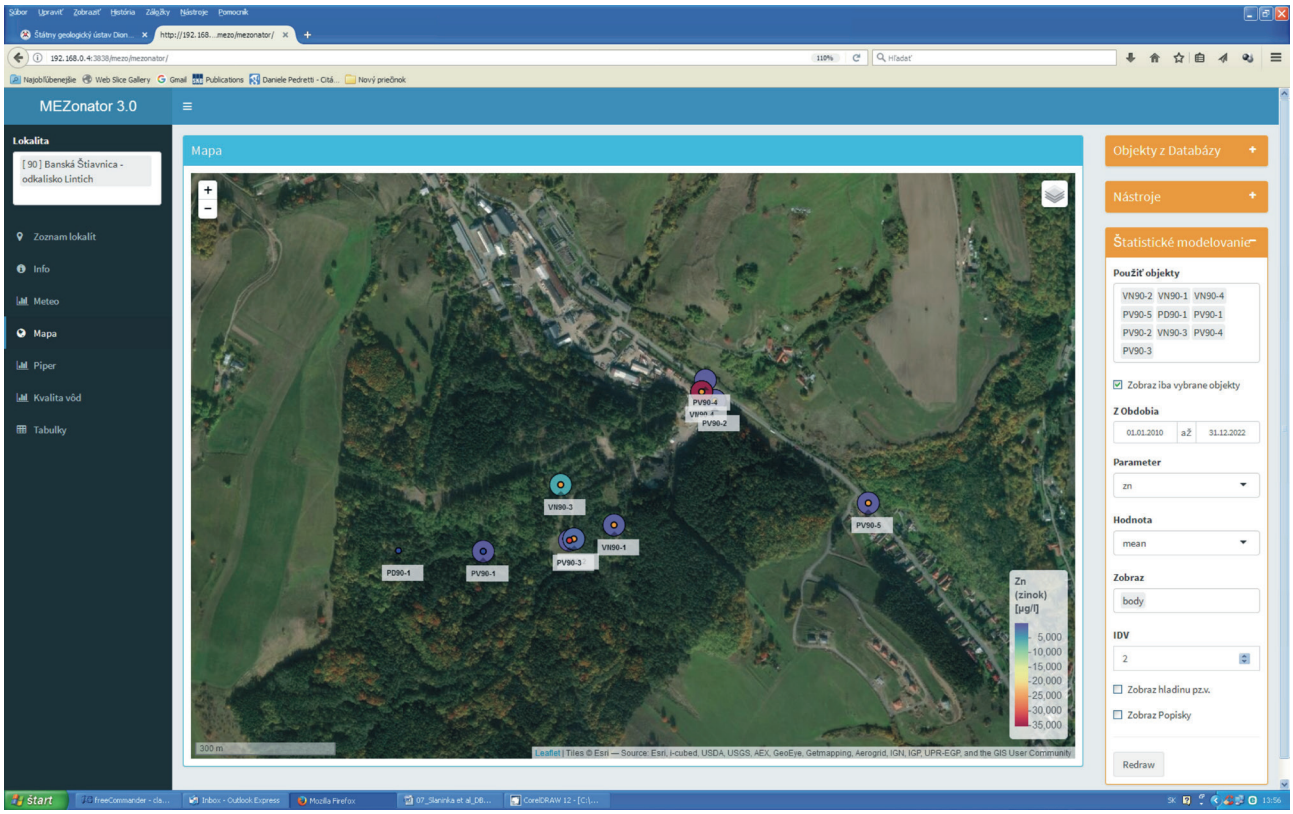


Fig. 3.16 Information provided in section "Map"

to quickly guide the user in the area-wide distribution of the values of the presented indicator. Created distribution maps can be transferred to another software environment, such as interim evaluation reports for sites.

Standard GIS products usable for work with the IS EBM data

The **QGIS programme** is an open source (GPL) GIS programme distributed through the Internet (http://www.qgis.org/). Under the GPL License, the programme can be freely used, modified, and distributed, including for commercial purposes. The benefits of QGIS are also full support for multiple spatial databases (including PostGIS), full integration of GRASS GIS, SAGA GIS, R statistical software, and almost unlimited configurability (full programme source code available), as well as a number of optional external tools, so-called "plugins". QGIS also allows to directly open files from other programmes (ESRI ArcGIS, MapInfo, Microstation, Autocad, etc.) and combine them in a map window.

3.3 Conclusions

The thematic information system for environmental burdens monitoring (IS EBM), created and developed in the SGIDŠ, is an essential tool for planning, storing and presenting the results of the environmental burdens monitoring in the Slovak Republic. Currently, it includes data on monitoring of selected 309 environmental burdens sites across Slovakia. The selection of sites was based on the requirements of the Operational Programmes "Environment" and "Quality of Environment", as well as the requirements of the MoE SR.

The IS EBM is used for the implementation of projects aimed at the environmental burdens monitoring carried out by SGIDŠ. The system is interconnectable with the IS EB managed by the SEA for the needs of the MoE SR. In terms of content, the IS EBM stores various information resulting from the implementation of several types of geological work (in particular environmental monitoring, geochemistry, hydrogeology, geophysics, engineering geology, etc.). In terms of form, the IS EBM is divided into: 1) general data and text part and 2) structured database and GIS applications.

The information stored in the general data and text part of the IS is divided into a system of directories by type. The structured database of the EBs monitoring is built centrally; the technical platform of the database is the object-relational database system PostgreSQL/PostGIS. Access to the database is possible from various user interfaces, allowing great flexibility in data usage. This is very important because of the wide variety of users demands, whereas the technical skills, conditions of use and user demands are often significantly different.

Access to the IS EBM is possible under intranet and Internet conditions (including remote access via VPN – virtual private network) and through online web applications.

The IS EBM represents a significant help in ensuring the functioning of the monitoring of environmental burdens, and it is also highly economical due to the use of cost-effective "open-source" codes. At the same time, it is very flexible and allows flexible access to stored data, with the possibility of applying different levels of use as well as data security.

Despite the difficulty of creating a thematic IS EBM (the first such tool in the field of the EBs monitoring at SGIDŠ), the geological task of monitoring of 309 EBs with the involvement of nearly 100 experts from various specializations (hydrogeology, geochemistry, engineering geology, environmental geology, laboratory analyses, trend modeling, statistics, etc.) in a relatively short time it would not even be possible to realize it in the required professional level.

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