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Methodology and results of geological survey of the environmental burden of the former Slovenský hodváb plants – Senica (Slovakia)

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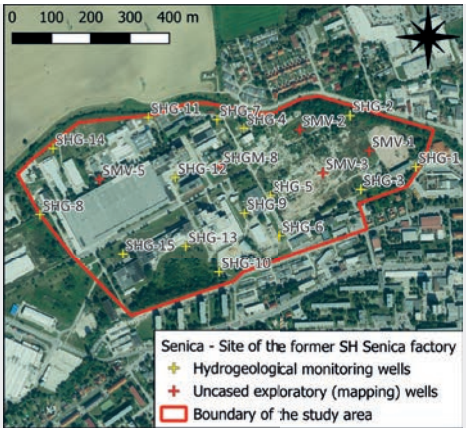
Abstract: In the years 2021–2023, the State Geological Institute of Dionýz Štúr, Slovakia, carried out a detailed geological survey of the environmental burden on the Senica site, identified as a probable environmental burden with a high priority within the project Geological survey of selected environmental burdens ŠGÚDŠ-3. The task was carried out in accordance with the strategic planning document for a systematic survey and removal of environmental burdens entitled *State Program for Remediation of Environmental Burdens of the Slovak Republic (2016–2021)* within the Operational Program of Environmental Quality. The goal of the survey was a detailed verification of all components of the environment at locations that, based on a preliminary risk assessment in the information system of environmental burdens, represented a potential risk for human health and the environment. The survey verified in detail an area of approximately 37 ha, on which 210 chemical indicators were analytically determined from a wide range of indicators according to the type of activity of the former Slovenský hodváb plants, which were evaluated in accordance with the current applicable legislation in the field of environmental burdens. The results of the survey did not confirm serious pollution of the underground water and rock environment, which would be in a causal or spatial context. An environmental and health risk was not detected by the risk analysis, it is not necessary to carry out remediation of the investigated area.

Key words: probable environmental burden, information system of environmental loads, geological survey of the environment, risk analysis

Graphical abstract



Highlights

- Detailed geological survey of the environment has not confirmed the expected pollution in the area of the former Slovenský hodváb plants in Senica, Slovakia.
- The environmental and health risks have not been confirmed by the elaborated risk analysis.
- Two-year groundwater quality monitoring is proposed before burden removing from the Register of Information system of environmental loads of the Slovak Republic.

1 Introduction

Environmental burdens are defined as polluted areas caused by human activity that pose a serious risk to human health or the rock environment, groundwater and soil. The problem of solving environmental burdens in Slovakia began in 2006 as part of the project Systematic identification of environmental burdens (Paluchová et al., 2008) with the aim to identify probable environmental burdens from the entire territory of the Slovak Republic. That resulted in the compilation of the Register of Environmental Burdens, in which registered burdens are sorted according to their relative risk to the life and health of residents as well as damage to ecosystems, and which is part of the Information System of Environmental Loads (IS EZ). The information system is continuously updated primarily on the basis of geological surveys and series of

remedial measures in accordance with the currently valid legislation: Act No. 569/2007 Coll., Act No. 409/2011 Coll. Act No. 364/2004 Coll., Act SNR No. 372/1990 Coll., Regulation of the Ministry of the Interior of the Slovak Republic dated January 28, 2015 No. 1/2015-7 to develop a risk analysis of the polluted area.

Currently, 1,782 loads are registered in Slovakia, divided into registers according to the status of their examination and the implementation of corrective measures with the aim of minimizing their negative impact on human health and the environment. This work presents the results of the geological task entitled *Geological survey of selected probable environmental loads 3 – which ŠGÚDŠ* solved within the Operational Program Environmental Quality – priority axis 1. The task was developed in accordance with the strategic planning document for the systematic survey and removal of environmental burdens entitled *State Program for Remediation of Environmental Burdens of the Slovak Republic (2016–2021)*, in which the relevant environmental burden of the Trnava Region is recorded in section 7.1.1. *The most risky locations in terms of the need to carry out a survey of probable environmental burdens and the need to develop a risk analysis*.

The environmental burden (EB) in the area of the former Slovenský hodváb (SH) plants is registered in the information system in category A as a probable environmental burden with a high priority denoted as SK/EZ/SE/2004 under the name SE/2004/Senica – the area of the former SH Senica. The area of the former plants is located in the built-up area of the inner city of Senica, in the industrial zone, in the area of the former manufacturing company Slovenský hodváb Senica. The territory is bordered on the eastern side by the Lidl store and the bus station, and on the northern side by the Teplica stream. The investigated area is roughly in a shape of rectangle of area approximately 37 ha (Fig. 1).

High priority of the environmental burden was assigned in the system of environmental loads primarily on the basis of a visual inspection of the site at the time of registration in 2014, which corresponded to the state of the finished industrial activity of the former plants (Fig. 2). The SH Senica plants were built in the 20st of the last century with the aim of producing synthetic fibers. The plants were liquidated in 2005. The activity connected with the creation of EB, has not been carried out since 1989. During their activity (production of synthetic fibers), an extensive fuel oil farm was built consisting of 7 fuel oil tanks, a boiler room, and a pumping station. The tanks have already been demolished. There was also a neutralization station, chemical warehouses (HCl, etc.). The activity that influenced the creation of EB is no longer carried out on the site, the operation is used for other purposes. In the western part of the area, there is currently a variety of industrial activity unrelated to the activity causing the load. The data on the holder / holders of the burden listed in the IS EZ system were out of date at the time of the survey, the former holder has changed since 2014 and, as a result of the sale, there is still a change of owners of various parcels of the environmental burden.

At the time of the geological survey in 2022–2023, the current visual condition did not correspond to the condition of the site at the time of its registration in 2014.

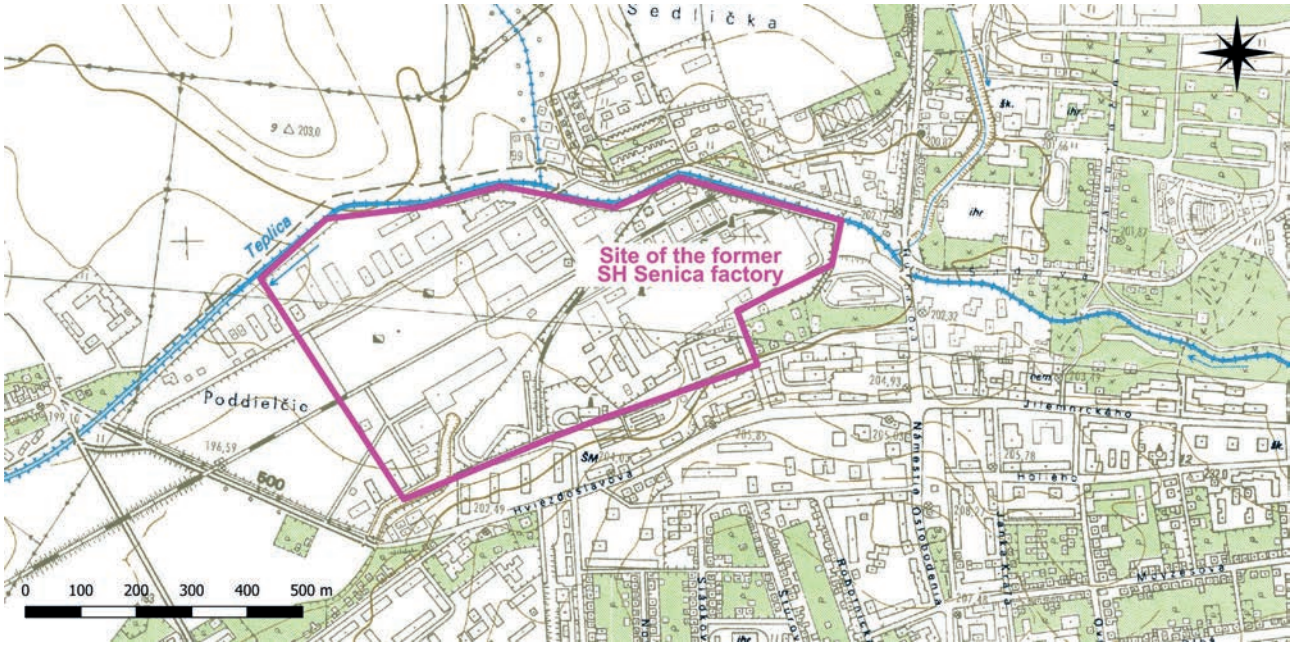


Fig. 1. Localization of the investigated site (IS EZ, 2014).

Fig. 2. A view of the site where tanks of the former fuel oil industry and chemicals were located (IS EZ, 2014).

In the eastern part of the territory, in the places of the most probable source of pollution, extensive construction and remediation activities were taking place, with land modification intended for further development activities of civil and housing construction. Decontamination and subsequent improvement of the land was carried out based on the recommendations of the environmental audit in the area of Slovenský hodváb PLUS, s.r.o. (Žitňan, 2011), consisting in the partial demolition and reconstruction of old decaying buildings, the removal of the existing fuel oil plant and demolition of the factory chimney (Fig. 3).

Directly in the area of the former Slovenský hodváb factories, groundwater quality monitoring was carried out in 2000 (Žitňan et al., 2000). The aim was to specify the direction of groundwater flow in the plants, to verify the quality of groundwater in the range of nonpolar solvents [NEL (IR)], SO_4 and Zn and measuring of physico-chemical parameters of existing wells in the SH area and three wells in the waste water treatment plant (WWTP) area. The results of the monitoring confirmed the south-west to west direction of groundwater flow in the SH area. From the analysed values, no exceeding values of STN 75 711 for Drinking water were proven in any sample, except for the conductivity in one water sample. Concentration of sulfate also did not exceed the respective limit values of STN valid at that time in any of the monitored objects, except for the values in the WWTP area, where they were on the border of the limit concentrations of the respective STN valid at that time. The contents of NEL (IR) in all monitored objects and in objects in the WWTP area did not exceed STN limit values. In 2011, an environmental audit was carried out in the plant area with the aim of an indicative verification of the pollution of the rock environment in the unsaturated zone and in the groundwater in existing objects and wells (reservoirs) in the eastern part of the area of the former SH plant (Žitňan, 2011). The scope of the monitored indicators was based on the nature of the activities and production processes (viscose production, fuel oil management) and on stored chemicals in the plant area, and thus formed an indicator of potential environmental contamination. A total of 16 soil samples with a sampling depth of up to 60 cm and 9 groundwater samples were taken. In addition, liquids were taken in various tanks and concrete tubs, the presence of which was confirmed at the time of the survey. The soil samples were analysed for the total NEL (IR) content and the content of selected indicators in the aqueous leachate. In the groundwater from existing wells, water samples were analysed in the range of $CHSK_{Cr}$, sulfates, sulfides, sodium and NEL (IR) indicators. The results were analysed according to the Instruction of the Ministry for the Administration and Privatization of the National Property of the Slovak Republic and the Ministry of the Environment of the Slovak Republic No. 1617/97-min. on the procedure for evaluating the company's obligations from the point of view of environmental protection in the privatization project submitted by the company as part of the privatization. Journal of the MŽP SR 1/98. Part VI. Indicators and standards for remediation of soil, soil and groundwater pollution. The results of the audit confirmed and located the contamination of the territory in the area of the track inside the area to a depth of 0.60 m. In the case of fuel oil farming, significantly high contents of petroleum substances NEL (IR) were confirmed, in some samples the values were high in the order of hundreds to thousands of $mg.kg^{-1}$. Most of the soil samples reached higher values than background values of category A (around 50 $mg.kg^{-1}$) and some of them already exceeded the limit value of category "B" and even the limit values for remediation category "C". Removal of contaminated soil by mechanical excavation was proposed. The result of the environmental audit was the finding that the groundwater is not critically contaminated and does not indicate the

Fig. 3. Views on the reclaimed eastern and western industrial part of the area after sanitation and reclamation as well as its surrounding (taken from Grexová et al., 2023).

need for remedial interventions. For a more detailed assessment of the extent of soil pollution in the basement of the halls and other buildings, it was recommended, after the renovation of the buildings and cleaning of the area, the implementation of a regular network of shallow boreholes up to approx. 1.0 m below the ground for soil sampling in the scope of the NEL (IR) and four complete analyses according to the instructions of the MSPNM SR and the Ministry of the Environment SR No. 1617/97-min. (Žitňan, 2011).

A complex geological survey ensuring detailed identification of surface and spatial pollution was not carried out in the area of the former plants.

2 Geological and hydrogeological characterization of the investigated site

According to the regional geological division of the Western Carpathians (Vass et al., 1988), the territory belongs to the area of intermountain basins and basins, the sub-region of the Vienna basin, the Senica part. The Vienna basin is of Baden origin, it is filled with Neogene (mainly marine) sediments several thousand meters thick. In the studied area, the entire layer sequence of the Neogene is developed, with the exception of the Aquitan with numerous hiatuses. The geological structure is complex, laterally and vertically variable. The basin itself is divided by a number of faults, which mostly

follow the Carpathian direction NE–SW. At the base, the Neogene is lithologically represented by a formation of sandstones, sands and sandy clays, in the upper positions (lower Pannonian) fine-sandy marly clays and fine-sandy clays predominantly greenish-gray with positions of marls were sedimented. The uppermost positions are built by pelitic sediments of the Helvetian. These are greenish-gray, mostly slightly gray to slightly sandy, loamy, semi-solid calcareous clays or loams in layered positions. The top positions of these rocks are intensively weathered to decomposed, of the nature of clays of low to high plasticity, firm consistency. In the Quaternary, tectonic differentiation according to faults and erosive-denudative modeling of the relief with accumulation of sediments continued in the territory. The Quaternary is built by Pleistocene fluvial sediments, which mainly build the terraces of Morava. Holocene alluvial sediments deposited in the floodplain of Teplice and its tributaries are lithologically represented by covering cohesive clays, sandy clays to clays, which form an overburden of clay-sandy to sandy gravels, sands with gravels, or clayey sands. Gravel can be characterized as monomictic, formed by well-worked sandstone clasts up to 5 cm in diameter, occasionally 7–10 cm. The cohesive soils of the alluvial floodplain facies are sometimes overlain by aeolian sediments. The geological structure of the studied area is influenced by the sediments of the Neogene fill and its Quaternary cover (Baňacký et al., 1973). The Quaternary is mainly represented by lithologically unorganized fluvial sediments of the Holocene – floodplain clays or sandy to gravelly clays of valley floodplains and mountain tributary floodplains (fhh). They are the youngest and most widespread fluvial sediments, emerging in the form of valley floodplains (floodplain terraces) of rivers and streams. Postglacial alluvial floodplain sediments form a substantial part of the fine-grained sedimentary surface cover of the sand-gravel assemblage of bottom accumulation of rivers, or just a separate filling of valleys in the cross profile of all streams. Alluvial sediments of larger rivers form the lithofacies of the most varied laterally and horizontally changing assemblage, manifested by the rapidly changing microrelief of the floodplains and the complicated structure and lithofacies composition of the sediments.

The upper parts of the floodplain of the Teplica stream consist of dusty sandy deposits 1.5–5.4 m thick. In some places, they contain thin layers and lenses of putrefaction (Baňacký et al., 1973). In the north and northwest, fluvial sediments of the older Pleistocene emerge – gravels and sandy gravels of higher middle terraces covered with loess, deluvial clays and washes. In the wider vicinity of the site, there are also eolian sediments of the younger Pleistocene (loess and fine sandy loess, calcareous and loess clays in general), proluvial sediments of the Holocene (mainly clays and sandy loams with rock fragments and muddy gravels in alluvial alluvial cones) and younger Pleistocene (clay and sandy gravels with rock fragments in low alluvial cones with a cover of loess and deluvial washes). The thickness of the Quaternary is variable, mostly from 2 m to 8 m (Žitňan, 2011).

Hydrogeological monitoring and temporarily equipped (mapping) boreholes (Grexová et al., 2023) verified quaternary (Holocene – anthropogenic sediments) to Neogene (Miocene – claystones, siltstones, sandstones) lithotypes in the investigated area. The Quaternary of the studied area is represented in the near-surface layer by fluvial sediments of the nature of clays and sandy gravels at a depth with an irregular thickness from 5.0 m to 9.0 m above sea level. (189.63–193.57 m above sea level). The Neogene bedrock is represented by Miocene clay-type sediments and clayey clays of a stiff to firm consistency. In the eastern part of the former SH plants, the thickness of Quaternary sediments ranges from 6.50 m to 9.0 m, in the western part of the former plants, the thickness of Quaternary sediments varied between 5.0 and 8.5 m. In summary, it can be concluded that the interface between the Quaternary and the Neogene varies at the level from 189.63 to 193.57 m above sea level, depending on the location of the wells near the main recipient of the Teplica River. Geological sections A–A', B–B', C–C' and D–D' in the area of the investigated area documenting the geological structure of the site of the former SH plants verified by survey in 2022–2023 are shown in Fig. 4. Based on the hydrogeological regionalization of Slovakia (Šuba et al., 1984), the territory belongs to the hydrogeological region N 002 Neogene Chvojnická pahorkatina. The region is bounded in the south by the Myjava plain, in the west by the Morava plain, in the northeast by the White Carpathians and in the east by the Myjava highlands. The region is built in the Neogene and Paleogene with a thin cover of Quaternary loess, loess clay, deluvium and, in the western part, also white sands. The investigated area itself is located in the extravillage of the cadastral territory of the city of Senica, in the right-hand valley floodplain of the Teplica stream.

The geological environment creates favorable conditions for the creation and accumulation of groundwater with the ceiling of the water collector at the level of 193.41–196.30 m above sea level. The depth of the groundwater level of a free nature is in the range of 1.80–5.50 m p.t. and the general flow direction is westward. The fairly strong permeability of fluvial gravels was documented by hydrodynamic tests with a filtration coefficient in the range of $6.65.10^{-4}$–$9.92.10^{-4}$ $m^2.s^{-1}$ (Grexová et al., 2023). The underground water of the investigated area has the character of a predominantly distinct basic type with a predominance of the calcium-hydrogen carbonate component. The chemical composition of groundwater of fluvial gravels in the substrate of

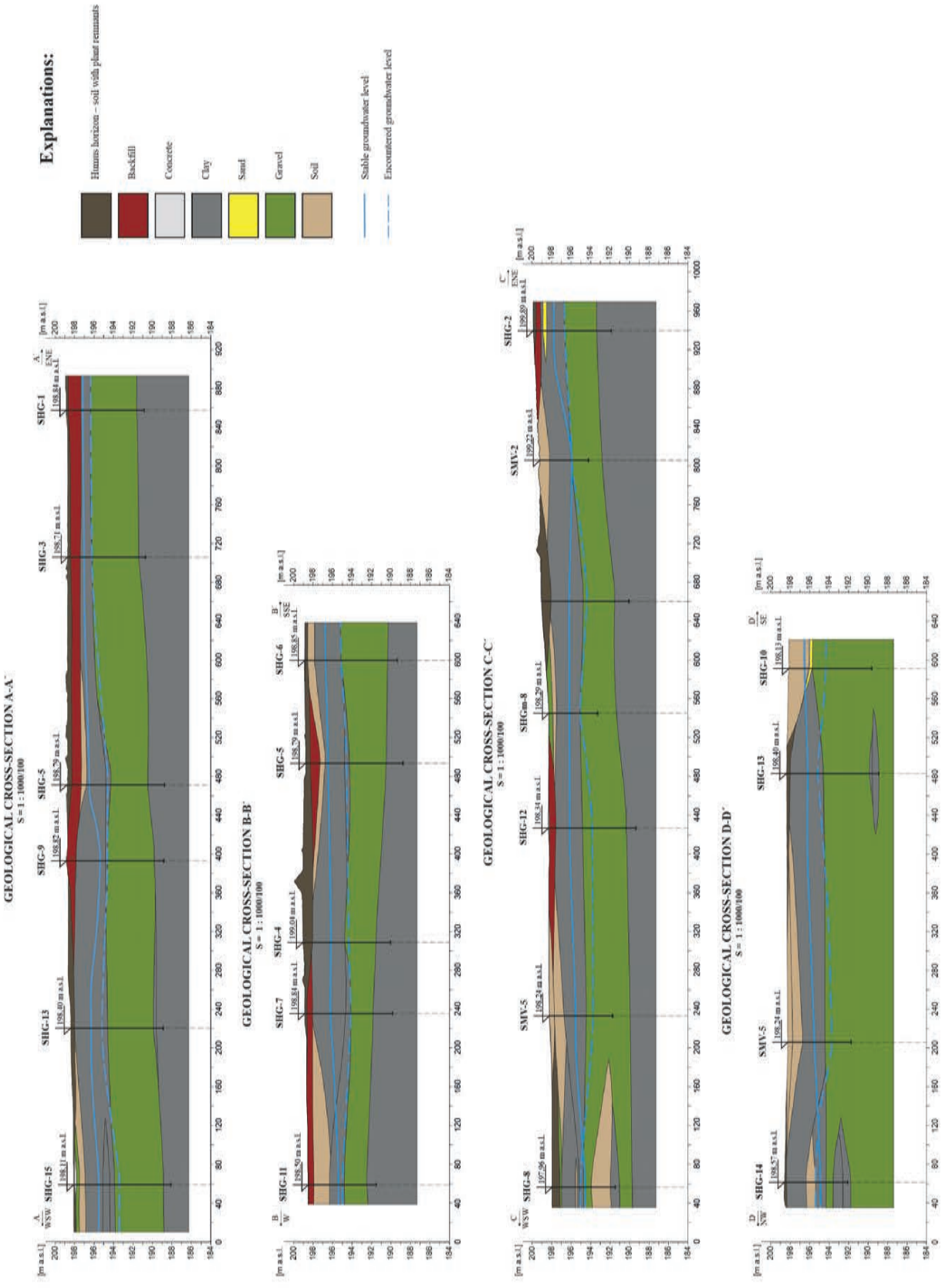


Fig. 4. A view of the reclaimed eastern and western industrial part of the area after sanitation and reclamation (taken from Grexová et al., 2023).

Holocene alluvial sediments is stable, predominantly bicarbonate component (HCO_3 > Ca + Mg), with the most common type of groundwater of carbonate class, calcium group, first to third class [CCaIa to CCaIIIa (Alekin)]. Overall picture the chemical composition of groundwater is documented by the graphic interpretation of the semi-logarithmic diagram according to Schoeller, which documents the stable chemical composition of groundwater in the investigated area of probable environmental stress, Fig. 5.

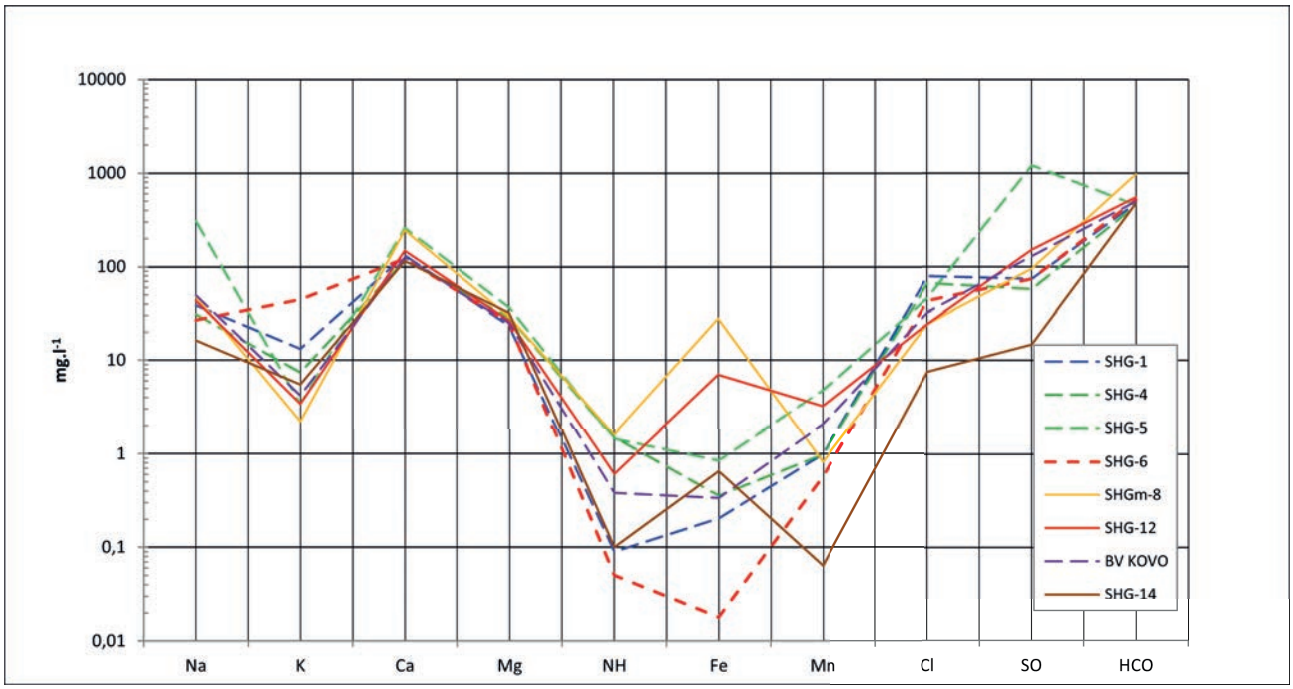


Fig. 5. Schoeller's graph of the ions concentration in groundwater in the area of the former SH plants (Grexová et al., 2023).

3 Methods

The methodology of the realized detailed geological survey based on the currently valid legislation of the Slovak Republic, namely the Methodological Guide for the Geological Survey of the Environment in a Polluted Area (SAŽP, 2020) and Directive of the Ministry of the Environment No. 1/2015-7 for the analysis of the risk of the polluted area.

A set of geological works was carried out on the site, aimed at a comprehensive survey and characterization of the pollution of all components of the environment, including the evaluation of the potential health and environmental risk resulting from any detected pollution. Realized works in the area of probable environmental burden included technical works (drilling works) for the purpose of specifying the geological structure of the site and the extent of contamination of the rock environment and underground and surface waters, measurements and sampling of the rock environment in the aeration zone and the saturation zone, sampling of underground, surface and wastewater from newly built and existing wells, atmospheric geochemical measurements, soil air sampling, chemical analyses of groundwater samples, chemical and granular analyses of rock samples. The methodology of the survey works is described in detail in the work of Grexová et al. (2023).

As a part of the technical works, 15 hydrogeological monitoring wells, 5 unequipped exploratory mapping wells and 15 manual diagnostic gasometric probes were drilled, Fig. 6. The depth of the built-in hydrogeological wells varied between 9 and 12 m, the depth of the mapping wells was 5 m. Manual probes were carried out to a maximum depth of 1 m. The basic parameters of the wells are listed in Tab. 1.

Atmogeochemical measurements

Atmogeochemical in-situ measurements of soil air were carried out using hammered tube probes with a total length of approx. 1 m in the locations of manual gasometric probes, hydrogeological and mapping wells, this means that the measurements correspond to the composition of soil air approx. 80 cm – 90 cm from the reclaimed surface of the investigated area with the aim of identifying volatile pollutants in the soil air, indicating contamination of the soil / rock environment with petroleum substances. The measurements were carried out using a portable field device

Tab. 1

Basic parameters of realized hydrogeological and mapping wells

Object	Depth [m]		Drilling			Equipment	
	Projected	Realized	Date of realization	Drilling diameter / ensuring [mm]	Range of depth [m]	Instalation diameter [mm]	Perforation [m]
Hydrogeological monitoring wells (129 m)							
SHG-1	10.0	8.0	15/5/2023	196/175	0/2/2–7/7–8	125	2.0–7.0
SHG-2	10.0	8.0	15/5/2023	196/175	0–3/3–5.5/5.5–8	125	3.0–6.5
SHG-3	10.0	8.0	15/5/2023	196/175	0–2.5/2.5–7/7–8	125	2.5–7.5
SHG-4	10.0	9.0	16/5/2023	196/175	0–4.5/4.5–7.5/7.5–9	125	4.5–8.5
SHG-5	10.0	10.0	15/5/2023	196/175	0–5.3/5.3–8.3/8.3–10	125	5.5–8.5
SHG-6	10.0	9.5	17/5/2023	196/175	0–3.5/3.5–8.5/8.5–9	125	3.5–8.5
SHG-7	10.0	9.0	16/5/2023	196/175	0–4/4–7/7–9	125	4.0–7.0
SHG-8	10.0	6.5	18/5/2023	196/175	0/3/3–5/5–6.5	125	3.0–4.5
SHG-9	10.0	10.0	17/5/2023	196/175	0–4/4.0–7.0/7–9	125	4.0–9.0
SHG-10	10.0	9.0	19/5/2023	196/175	0–4/4–8.5/8.5–9.5	125	4.0–8.5
SHG-11	10.0	7.0	18/5/2023	196/175	0–3/3–6/6–7	125	3.0–6.0
SHG-12	10.0	9.0	18/5/2023	196/175	0–3.5/3.5–8/8–9	125	3.0–8.0
SHG-13	10.0	9.5	17/5/2023	196/175	0–3/3–8.5/8.5–9.5	125	3.0–8.5
SHG-14	10.0	6.5	18/5/2023	196/175	0–3.5/3.5–5/5–6.5	125	3.5–5.0
SHG-15	10.0	10.0	17/5/2023	196/175	0/4.5/4.5–9/9–10	125	4.5–9.0
Exploration unequipped mapping wells (26.5 m)							
SMV-1	10.0	5.0	18/5/2023	156	0–3/3–5	110	3.0–5.0
SMV-2	10.0	5.0	18/5/2023	156	0–3/3–5	110	3.5–5.0
SMV-5	10.0	5.0	19/5/2023	156	0–3/3–5	110	4.5–6.5
SMV-3	10.0	5.0	19/5/2023	156	0–3/3–5	110	3.0–5.0
SHG_M-8	10.0	6.5	19/5/2023	156	0–3/3–5	110	3.0–5.0
Manual gasometric probes (13.45 m)							
SPS-1–SPS-15	1 m	0.0	XII/2022	–	0.5–1	0.50	–

ECOPROBE 5 from RS Dynamics, which enables, among other things, online measurements of methane, oxygen and carbon dioxide concentrations. The field instrument also determined the content of other relevant gases (O_2, CH_4, CO_2, PID) and total petroleum hydrocarbons (T.P) from the soil air. The measurement consisted in suctioning and subsequent analysis of soil air with a device from unequipped mapping wells, newly built hydrogeological wells and hand probes. The instrument used verified the overall spectrum of soil gas and vapor concentrations. A total of 35 atmogeochemical measurements were carried out.

Sampling works

Sampling works consisted of taking samples of soil, underground and surface water and river/bottom sediments,

taking soil air and taking waste water from the WWTP, Fig. 6. Groundwater and surface water samples were taken in two cycles, soil air and soil samples were taken once during drilling operations. The density, method and amount of samples taken was specified by the responsible researcher and was stated in the Sampling Plan of the rock environment, underground and surface water, developed according to Annex No. 17 of the Methodological Guide for the Geological Survey of the Environment in a Polluted Area, (SAŽP, 2020). A complex map of documentation points and environmental sampling is interpreted in Fig. 7.

Soil sampling was carried out with the aim to determine the area and spatial distribution of the rock environment pollution at different depth levels to map the centres of pollution and delineate the contamination clouds of the aeration zone and the saturation zone. Samples were taken using a shovel into PE bags or glass bottles in a total amount of 0.5–1 kg, depending on the purpose. During sampling, the pollution was evaluated sensory – smell and visual assessment of the signs of pollution. A total of 90 soil samples were taken, of which 83 soil samples were used to determine selected indicators, including control samples, 5 soil samples were used to determine the physico-mechanical properties of soils, 2 samples were used to determine leachability, including ecotoxicity on selected soil samples.

Soil air sampling was carried out using a soil probe at a depth of approximately 1.5 m located at the location of the drilling/probes. The wellhead was insulated. The pumping of soil air itself was performed by a peristaltic pump as a part of the ECOPROBE 5 device. The flow rate was set to 0.5 l/min for a pumping time of 5 min, which represents 2.5 l of extracted air. The soil air was adsorbed onto an SKC tube, which was sealed with plastic plugs immediately after sorption and placed in the cold. A total of 40 soil air samples were taken to determine selected indicators.

Sampling of groundwater and surface water and bottom sediments as part of the survey was carried out in accordance with the applicable STN EN ISO 5667 standards as well as the instructions of the accredited laboratory and technical possibilities in the field and was carried out in two rounds. A Gigant type pump was used for sampling. The following were determined directly in the field: temperature, pH, conductivity, ORP and O_2. A total of 53 groundwater samples and 9 surface water and sediment samples were taken for the analysis of selected indicators.

Part of the sampling work was also the determination of the organoleptic properties of the samples, i.e. temperature, colour, turbidity, transparency, or taste. These sensory evaluations were performed for each sample collected and documented in each sample collection protocol / record. A total of 153 organoleptic determinations were carried out. The comprehensive range of analyses is documented in Tab.2.

Fig. 6. Realization of geological works during the geological survey.

Tab. 2

Sampled objects and scope of analyses

Rock environment – soil	**Scope of analyses**
Wells: SHG-1, SHG-2, SHG-3, SHG-4, SHG-5, SHG-6, SHG-7, SHG-8, SHG-9, SHG-10, SHG-11, SHG-12, SHG,13, SHG-14, SHG-15, SMV-1, SMV-2, SMV-3, SMV-5, SHGm-8 Manual probes: SPS-1 to SPS-15	NEL-GC, ClU, BTEX, TOC, PAU, sulfur total, sulfur sulphide, trace elements (As, Cr, Cd, Cu, Pb, Zn, Hg, B), leachate, native sample + ecotoxicity in accordance with Decree No. 382/2018 Coll., physical and mechanical properties of soils
Rock environment – soil air	**Scope of analyses**
Sampling sites in the Teplica area: DS-1, DS-2, DS-3	NEL-GC, TOC, PAU, BTEX, CIU, trace metals: (As, Cr, Cd, Cu, Pb, Zn, Hg)
Underground water	**Scope of analyses**
Wells: SHG-1, SHG-2, SHG-3, SHG-4, SHG-5, SHG-6, SHG-7, SHG-8, SHG-9, SHG-10, SHG-11, SHG-12, SHG,13, SHG-14, SHG-15, SMV-1, SMV-2, SMV-3, SMV-5, SHGm-8, S-1, well BV-kovo	NEL-GC, PAU, BTEX, CIU, sulfur sulphide, B, TOC, As, Cr, Cd, Cu, Pb, Hg, Zn, basic physico-chemical analysis + Palmer–Gazda, microbiology (minimal),
Surface water	**Scope of analyses**
Sampling sites on the Teplica area: PV-1, PV-2, PV-3	Annex No. 1 GR No. 269/2010 part A, Annex No. 1 GR No. 269/2010, part B
Waste water	**Scope of analyses**
WWTP	Annex No. 6 GR No. 269/2010, tab. 6.8: water reaction-pH, insoluble substances (NL), CHSKCr, BSK_5

To evaluate the soil and groundwater pollution, chemical analyses were performed in the accredited Geoanalytical Laboratories of the ŠGÚDŠ in Spišská Nová Ves according to standard procedures. The samples were, depending on their nature, analysed by different analysers: atomic absorption spectrometry – mercury analyser, atomic emission spectrometry with inductively coupled plasma, coulometry, photometry, gas chromatography with electron capture detector, gas chromatography – mass spectrometric detector and – flame ionization detector, ion chromatography, mass spectrometry with inductively coupled plasma.

As a priority, samples of the rock environment of the aeration zone and saturation zone and groundwater were taken and evaluated with regard to the indication and intervention criteria specified in the directive of the Ministry of the Interior of the Slovak Republic no. 1/2015-7 to develop a risk analysis of the polluted area.

The indicator criterion (ID) is the limit value of the concentration of the pollutant determined in the rock environment and groundwater, exceeding which can endanger human health and the environment, which implies the need to start monitoring of the polluted area.

The intervention criterion (IT) is the critical value of the concentration of the pollutant determined in the rock environment and groundwater, the exceeding of which presupposes, already with the given method of land use, a high probability of endangering human health and the environment, which implies the necessity of developing a risk analysis of the polluted area. As it is planned in the future in the eastern part of the former SH Senica plants to change the use of the territory to a residential zone, and thus from an environmental point of view, a more sensitive territory, as a precaution, we proceeded to evaluate the intervention criteria (IT) in this part of the territory according to stricter criteria, and therefore ratings for residential zones.

Qualitative parameters of the groundwater taken from existing wells were compared in accordance with the requirements of decree No. 91/2023 of the Ministry of Health of the Slovak Republic, establishing indicators and limit values of drinking water quality and hot water quality, the procedure for monitoring drinking water, risk management of the drinking water supply system and risk management of domestic distribution systems.

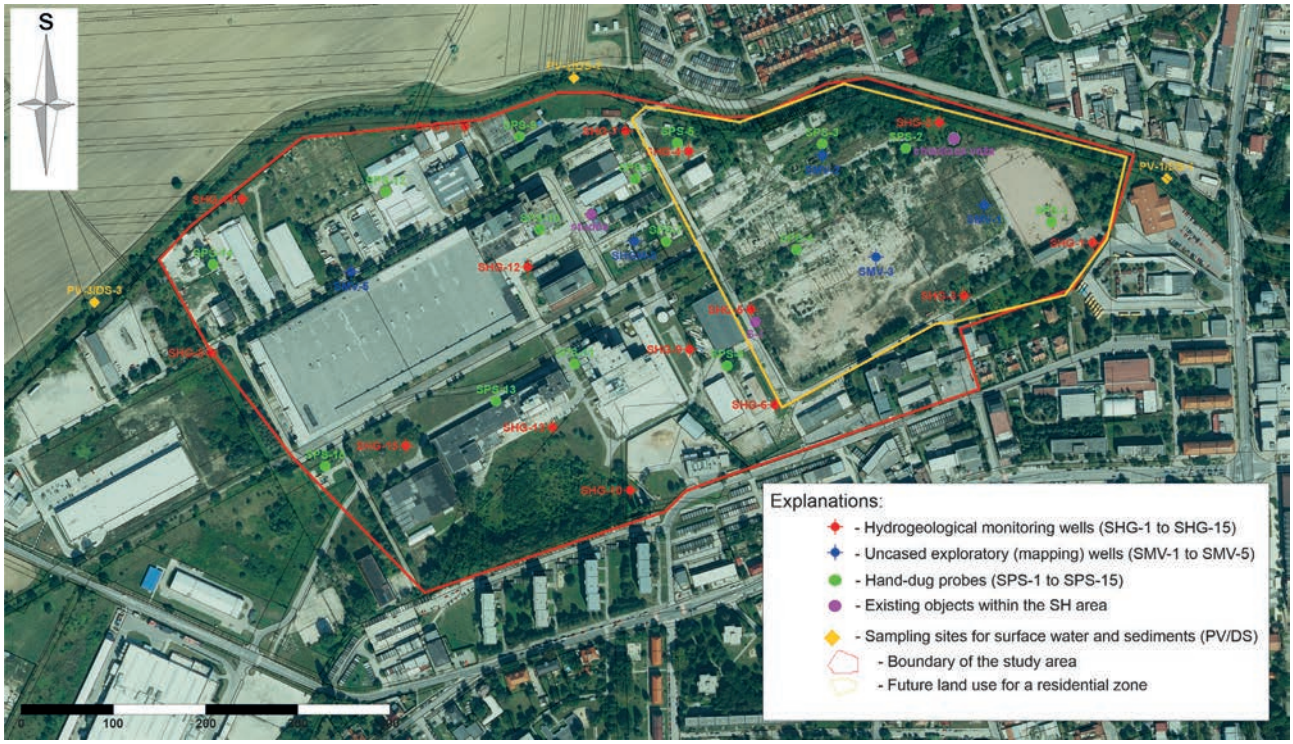


Fig. 7. Map of documentation points and sampling (taken from Grexová et al., 2023).

The evaluation of the soil air samples taken was carried out in accordance with the instruction of the Ministry for the Administration and Privatization of National Property of the Slovak Republic and the Ministry of the Environment of the Slovak Republic on dated December 15, 1997 No. 1617/97-min.

Qualitative parameters of sampled surface water and wastewater were compared in accordance with the requirements of SR Government Regulation No. 269/2010 Coll., which establishes requirements for achieving good water status.

The leachate and native sample, including ecotoxicity for soil classification in terms of waste management, were evaluated in accordance with the requirements of the Decree of the Ministry of the Interior of the Slovak Republic No. 382/2018 Coll. on waste dumping and storage of waste mercury.

In more detail, the methodology of the geological works carried out is given in the final report of Grexová et al. (2023).

4 Results

The aim of the detailed survey was to verify and identify the detected potential pollution of all components of the environment.

Pollution of the rock environment, of the soil and soil air

Before drilling, soil air samples were taken at the locations of manual probes and planned wells, in which, due to the nature of the site, the presence of petroleum hydrocarbons determined as benzene and toluene were detected. Higher concentrations of indicators exceeding

Tab. 3

Concentration of potential carcinogens in soil air samples (taken from Grexová et al., 2023)

Parameter	Unit	B	C	Planned residential zone				Reclaimed industrial zone			
				SPS-3	SPS-3_k	SPS-5	SPS-5_k	SPS-10	SPS-10_k	SPS-13	SPS-13_k
Benzene	mg/m^3	1	5	28	< 0.4	48	< 0.4	10	< 0.4	5	< 0.4
Toluene	mg/m^3	5	10	7	< 0 .4	19	< 0.4	< 1	< 0.4	5	< 0.4

B – to determine the origin of the pollution source
C – to start remediaton or other survey

concentrations B and C of MSPN instruction No. 1617/97-min., were confirmed only in manual probes of the SPS type. By repeated control sampling in which were not confirmed higher concentrations, we evaluated as pollution of a point nature, with the probability of affecting ongoing construction works and the possibility of free access for the public in the eastern part of the former plants, which is not related to the activity that conditions the inclusion of the investigated area into the system of environmental burdens (ISEZ), Tab. 3.

Results of soil air analyses from soil samples taken from the aeration zone and the saturation zone from wells (SHG, SMV) and probes (SPS) confirmed low concentrations in all analysed parameters not exceeding the indication and intervention criteria of the *Guidelines of the Ministry of the Environment SR No. 1/2015-7* to develop a risk analysis of the polluted area. Exceeding the indication and intervention criterion of the directive for residential zones was confirmed by higher concentrations of mercury (SPS-1: 3.76 mg.kg^{-1} of dry matter), copper (SPS-3: 593 mg.kg^{-1} of dry matter) and lead (SPS-3: 1 860 mg.kg^{-1} of dry matter). The detected higher concentrations were not confirmed by control samples (Cu – SPS_K-3: 32 mg.kg^{-1} of dry matter), (Pb – SPS_K-3: 24 mg.kg^{-1} of dry matter) located in the eastern part of the investigated site, Tab. 4.

From the hydrogeological monitoring wells of the SHG, elevated concentrations of trace metals exceeding the indication criterion of the directive were detected in the indicators of copper (548 mg.kg^{-1} of dry weight) and the intervention criterion for lead (593 mg.kg^{-1} of dry weight) only in the well SHG-10, located in the new of the industrial part of the area of the former Slovenský hodváb plants, whose current activity is not related to the activities of the factories causing environmental burden. Elevated concentrations of trace metals were also confirmed by control sampling, when according to more stringent criteria, and thus the assessment for residential zones, the concentrations of the monitored indicators slightly exceeded the intervention criterion, Tab. 4.

In this well, a high concentration of NEL-GC (nonpolar solvents analysed by gas chromatography) exceeding the indication criterion (774 mg.kg^{-1}of dry matter) was also detected, which was also confirmed by a control sample, which proved that the concentration was exceeded within the intervention criteria of the directive of the Ministry of the Interior of the Slovak Republic No. 1/2015-7 min. (774 and 3 179 mg.kg^{-1} of dry matter). Identification of

Tab. 4

Overview of indicators exceeding ID or IT criteria in accordance with the directive of the Ministry of the Environment of the Slovak Republic No. 1 / 2015-7 in a rock environment (taken from Grexová et al., 2023)

Indicator	Indication criteria	Intervetion criteria		Planned residential zone				Reclaimed industrial zone			
	(ID)	*Residential zones ITr*	**Industry ITi**	SPS-1	SPS-3	SPS_k-3	SMV-3	SPS-9	SPS_k-9	SHG-10	SHG_k-10
	[mg.kg^{-1} dry matter]			0–1,0 m u.t.			0,2–0,5 m u.t.	0–1,0 m u.t.		2 m u.t.	
I. METALS											
As	65	*70*	**140**	12	5	11	9	3	–	5	8
Cd	10	*20*	**30**	< 0.001	< 0.001	< 0.001	< 1	< 0.001	–	< 1	< 1
Cr_{total}	450	*500*	**1 000**	64	90	80	170	73	–	85	106
Cu	500	*600*	**1 500**	19	593	32	73	12	–	548	*713*
Hg	2.5	*10*	**20**	3.76	0.22	0.98	0.42	0.03	–	2.33	3.39
Pb	250	*300*	**800**	69	**1 860**	24	77	46	–	*593*	*460*
Zn	1 500	*2 500*	**5 000**	103	1 485	532	392	165	–	346	462
VIII. POLYCYCLIC AROMATIC HYDROCARBONS (HALOGENATED)											
NEL-GC (C_{10}–C_{40})	200	*250*	**500**	28	46	–	*346*	**1 001**	35	*774*	**3 179**

hydrocarbons in the rock environment in the investigated location, when the concentration of NEL-GC exceeded the IT criterion of the Ministry of the Interior of the Slovak Republic No. 1/2015-7 pointed out in the case of the hydrogeological monitoring borehole SHG-10 (1.5–2.0 m above sea level) and SHGK-10 (control sampling) and in the mapping borehole SMV-3 (0.2–0.5 m above sea level) for the dominant percentage representation of hydrocarbons of the C16–C24 series (heating oils; Fig. 8).

Local pollution by aliphatic petroleum hydrocarbons of the rock environment of the biological contact zone is illustrated in Fig. 9. The pollution is characterized by residual hydrocarbons that have the character of low-volatile hydrocarbons, with low solubility and a high degree of retardation (limitation of migration) in the rock matrix. The confirmation of the local presence of this hydrocarbon in part of the investigated area is, according to the oral information of the current owner, a consequence of the remediation of the hot water boiler for burning fuel oil in 2000, which in the past ensured the central heating of the city of Senica, and therefore with a high probability it is a residual pollution. In summary, it can be concluded that the slightly increased concentrations confirmed only in manual probes are with a high probability point pollution of a residual nature as a result of the implemented partial rehabilitation of objects in the planned residential

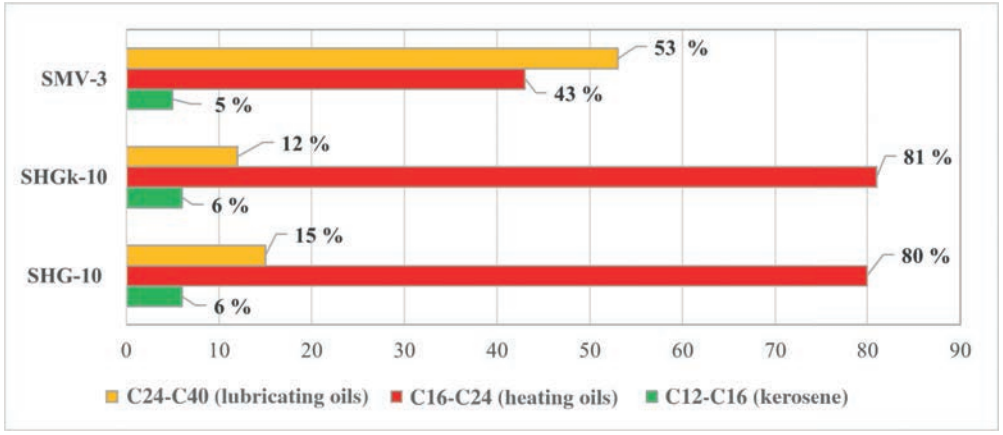


Fig. 8. Concentration of individual hydrocarbon fractions in the rock environment of the biological contact zone in the soil samples taken from the hydrogeological monitoring well and the unequipped mapping well with high C10–C40 (taken from Grexová et al., 2023).

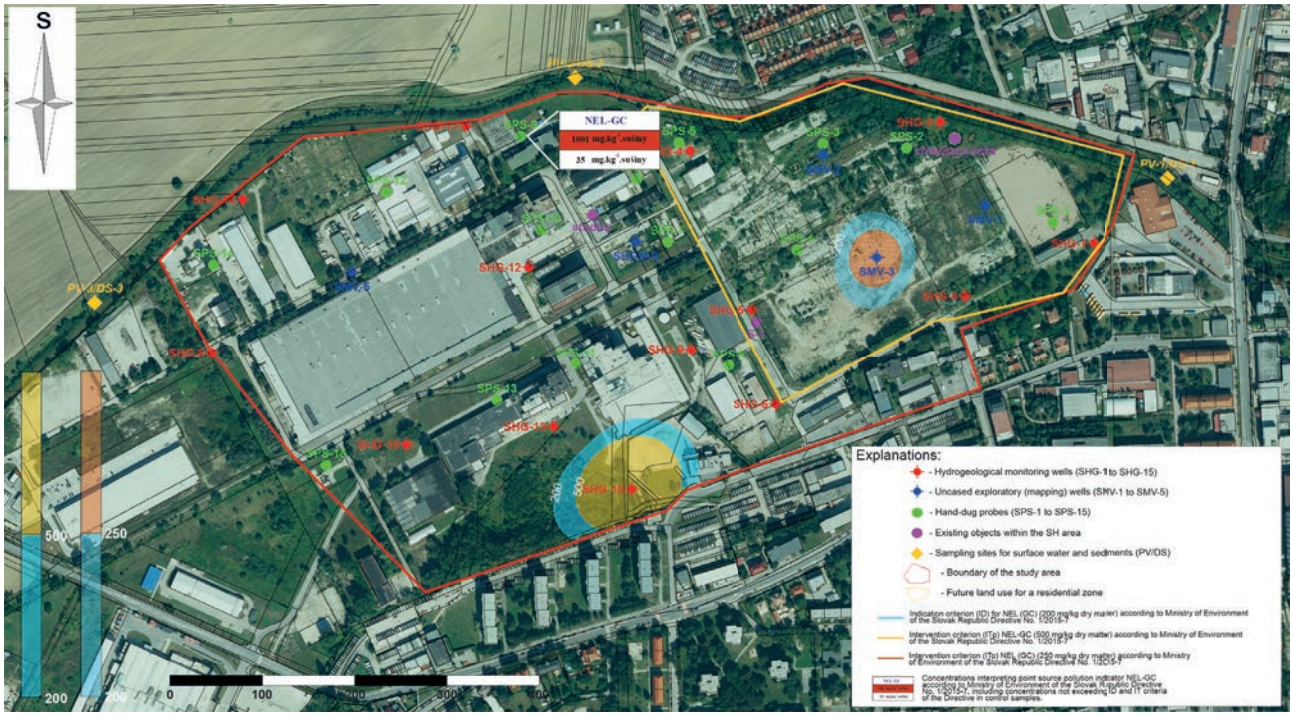


Fig. 9. Areal distribution of petroleum hydrocarbons in the studied site (taken from Grexová et al., 2023).

zone, which, according to the recommendations of the environmental audit (Žitňan, 2011), resulted in the removal of a potential source of contamination.

Groundwater pollution

Groundwater sampling carried out in two rounds with an interval of 30 days did not confirm water contamination, even in places where local residual pollution was confirmed. From all groundwater samples from hydrogeological – SHG wells, as well as unequipped SMV mapping wells and existing objects, the values of the monitored indicators were below the limit of detection, or at low values not exceeding the indication and intervention criterion of the Ministry of the Interior of the Slovak Republic No. 1/2015-7 to develop a risk analysis of the polluted area. An interesting fact was the slightly increased values of sulphide sulfur in the eastern part of the territory in only two of the five unequipped exploratory (mapping) wells located according to the historical map from 1958 in the places of the former old arm with maximum average concentrations not exceeding the indication criterion of the directive, Tab. 5. Sulphide sulfur occurs in waters as undissociated sulfane, simple HS^- and S^{2-} ions. Sulfane and its ionic forms are unstable in water. They can be chemically or biochemically oxidized to sulphates, it can be permanently present in water only in an anaerobic environment, therefore it is evidence for reduction processes in water. Since the exceeding of ID and IT limits was recorded only in samplings from unequipped mapping wells in the eastern part of the territory and in regime measurements in hydrogeological and mapping wells did not record negative values of oxidation-reduction potential (ORP) in this part of the investigated site, with a high probability this is the natural origin of occurrence in this environment, Tab. 6. Also, taking surface water samples from the stream of Teplica in two cycles in the direction of presumed pollution from the former plants did not confirm exceeding values of concentrations in any of the monitored indicators, as well as in groundwater samples.

Risk analysis of the investigated site

Risk analysis of the polluted area was also a part of the survey work. Its elaboration resulted from the legislative requirements of Directive No. 1/2015-7. Thus from the reason of the presence of pollutants exceeding the intervention and indication criteria in the rock environment of the biological contact zone in the aeration zone with the NEL indicator GC and trace metals Cu, Pb and Hg, an environmental and health risk assessment was required. An interpretation of the detected polluting substances in

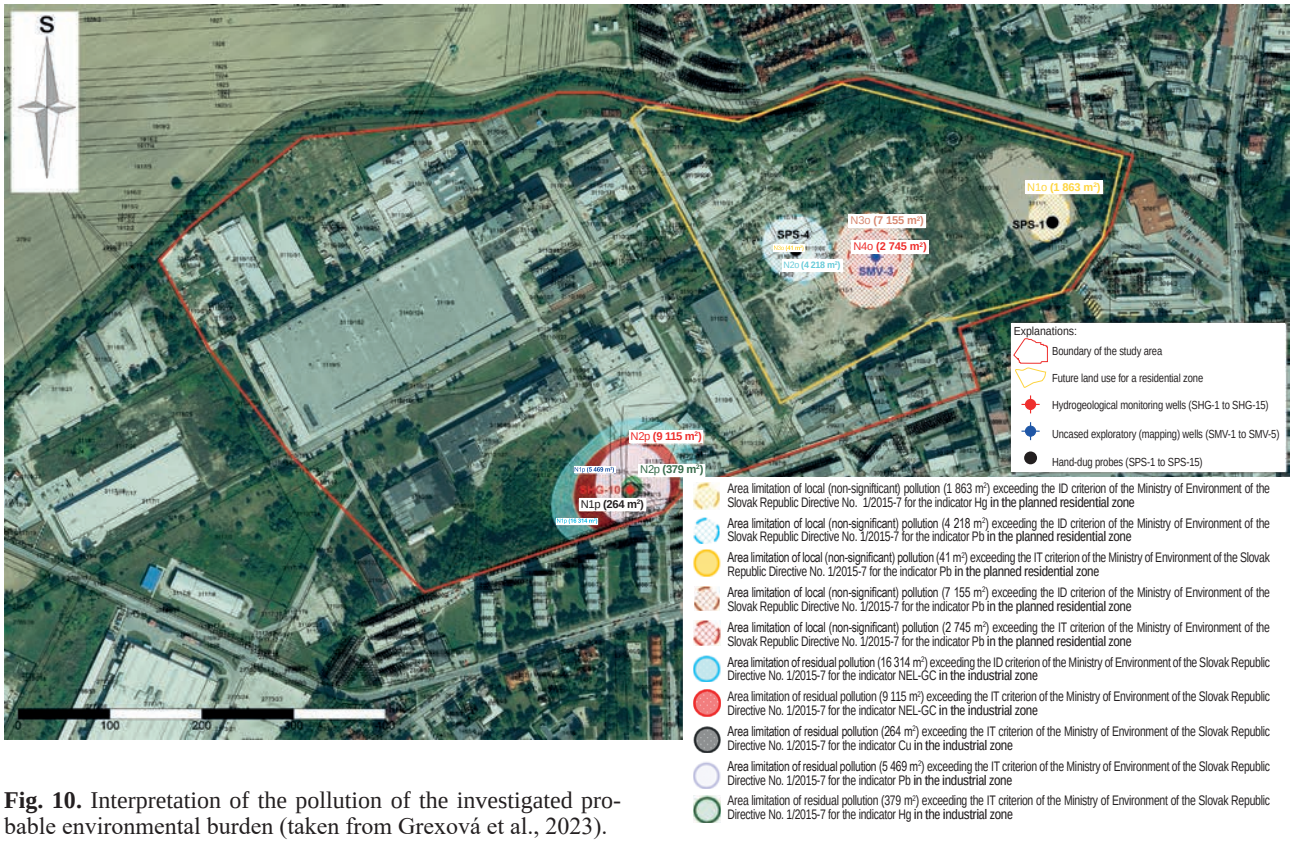


Fig. 10. Interpretation of the pollution of the investigated probable environmental burden (taken from Grexová et al., 2023).

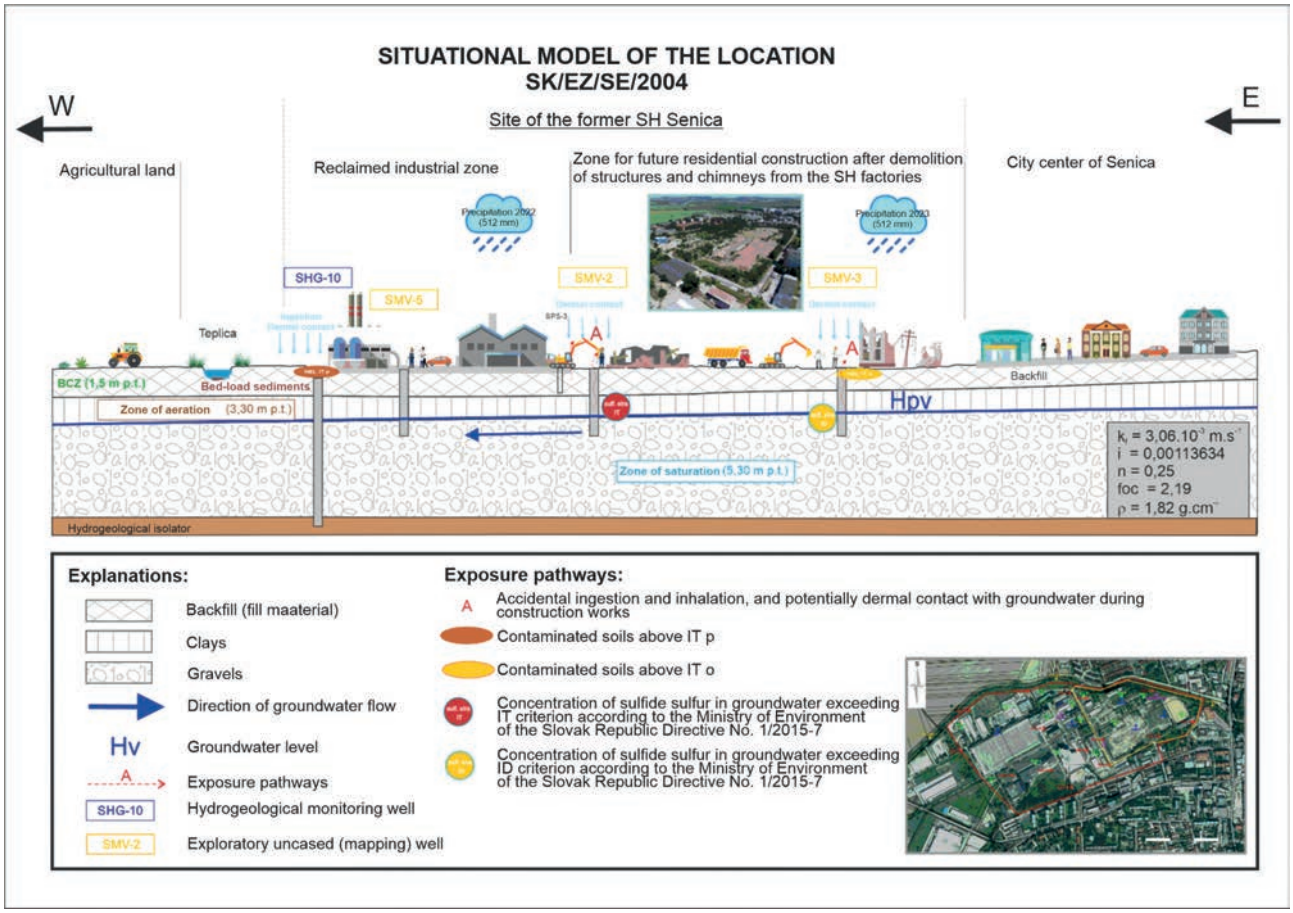


Fig. 11. Situation model of the site (taken from Grexová et al., 2023).

Tab. 5

Overview of indicators exceeding the ID or IT criteria in accordance with the directive of the Ministry of the Interior of the Slovak Republic No. 1/2015-7 in the groundwater of the investigated area (taken from Grexová et al., 2023)

Parameter	Directive No. 1/2015-7		SMV-1		SMV-3	
	ID [µg.l^{-1}]	IT [µg.l^{-1}]	1. sampling round	2. sampling round	1. sampling round	2. sampling round
IX. other						
Inorganic substances						
Sulfur sulphide (S sulp.)	*150*	300	330	370	< 10	*220*

the area of the former plants is shown in Fig. 10. Fig. 11 shows the situational model of the site, which is based on the results obtained from the geological survey according to Annex 4 to the directive of the Ministry of the Interior of the Slovak Republic No. 1/2015-7, which characterizes sources and centers of pollution, migration possibilities and possible transport routes of pollutants in the subject area. It also shows sources of environmental pollution as well as exposure scenarios in connection with the receptors present. The elaborated risk analysis did not identify an environmental or health risk, there was no need to propose costly remediation of the site.

Tab. 6

Results of field measurements of groundwater during the survey (source: Grexová et al., 2023)

Object	Date of sampling	Water temperature [° C]	Air temperature [° C]	pH	Electrolytic conductivity [mS.m^{-1}]	ORP [mV]	Dissolved O_2 [mg.l^{-1}]	At the temperature [° C]	Water saturation O_2 [%]	At the temperature [° C]
SHG-1	21.6.2023 10:42	13.5	23	7.02	109.0	198.9	1.720	13.5	16.80	13.5
SHG-2	21.6.2023 11:50	11.6	26	7.00	164.5	274.7	0.322	11.6	3.00	11.6
SHG-3	21.6.2023 9:54	12.6	22	7.00	121.6	249.2	0.268	12.6	2.60	12.6
SHG-4	27.6.2023 12:00	11.6	20	7,22	97.50	188.2	0.198	11.6	1.90	11.6
SHG-5	20.6.2023 15:52	12.7	30	7.20	279.0	57.6	1.300	12.7	12.50	12.7
SHG-6	21.6.2023 8:44	23.2	21	7.02	110.6	310.3	0.645	23.2	6.30	23.2
SHG-7	27.6.2023 12:30	12.3	20	7,29	85.9	59.8	0.470	12.3	4.40	12.3
SHG-8	21.6.2023 16:04	13.1	31	6.96	94.8	364.5	5.890	13.1	56.80	13.1
SHG-9	20.6.2023 12:08	13.6	28	6.85	166.3	104.1	0.267	13.6	2.60	13.6
SHG-10	20.6.2023 10:56	13.5	26	7.04	128.4	299.6	0.570	13.5	5.60	13.5
SHG-11	27.6.2023 11:25	11.8	20	7.07	180.1	178.5	0.240	11.8	2.40	11.8
SHG-12	20.6.2023 13:55	13.1	29	7.13	114.8	76.4	0.274	13.1	2.60	13.1
SHG-13	20.6.2023 11:40	13.4	27	7.05	115.7	184.0	0.525	13.4	5.20	13.4
SHG-14	21.6.2023 15:38	12.2	31	7.15	91.1	348.5	3.150	12.2	29.80	12.2
SHG-15	20.6.2023 12:35	13.4	28	7.13	114.5	165.8	0.516	13.4	4.90	13.4
SMV-1*	21.6.2023 11:16	13.1	24	7.02	137.2	8.4	0.552	13.1	5.30	13.1
SMV-2	21.6.2023 12:22	13.7	26	6.93	148,1	429.9	0.621	13.7	6.10	13.7
SMV-3*	21.6.2023 9:26	12.5	22	7.17	281.0	50.7	0.198	12.5	1.80	12.5
SMV-5	21.6.2023 15:00	12.3	28	6.99	129.3	143.1	0.273	12.3	2.60	12.3
SHGM-8	20.6.2023 15:18	12.8	30	6.85	159.7	0.9	0.195	12.8	1.80	12.8

* Objects with a higher concentration of sulphide sulfur content

5 Conclusion

In the years 2021 to 2023, ŠGÚDŠ carried out a detailed geological survey of the environment at a site of probable environmental burden with a high priority, where pollution of the rock environment and groundwater was assumed due to the industrial activity of the former Slovenský hodváb plants and the potential leakage of pollution from 7 fuel oil tanks and cooling towers. The quality of all the samples taken with the analytical evaluation of 210 indicators from an area of approximately 37 ha did not confirm the expected pollution resulting from the nature of the industrial activity of the environmental burden. From the obtained results in accordance with the currently valid legislative regulations, it can be concluded that no serious pollution of the underground water and rock environment was detected, either in the zone of aeration or in the zone of saturation with priority pollutants [NEL-GC, trace elements (As, Cr total, Cu , Hg, Pb, Zn), BTEX, CIU and PAU], which would be in a causal or spatial context.

Local pollution detected in the biological contact zone by the NEL-GC indicator, which was the only one of the wide range of indicators examined that exceeded the IT criterion of the Ministry of the Interior of the Slovak Republic No. 1/2015-7 is of a residual nature unrelated to the activities of the former SH plants. Pollution of groundwater with sulphide sulfur with increased concentrations exceeding the ID criterion of the Ministry of the Interior of the Slovak Republic No. 1/2015-7 in the planned residential zone, was sporadically and locally detected only in the eastern part of the investigated area, and only in exploratory unequipped mapping wells in the upper part of the incomplete watered collector. The presence of sulphide sulfur in the eastern part of the investigated area is of natural origin unrelated to reduction processes in water, which would be confirmed in this part of the environment.

Whereas the environmental and health risks have not been confirmed by the prepared risk analysis of the polluted area, it is not necessary to carry out remediation of the polluted area with the current use of the area. Due to the confirmed residual soil pollution in the western part of the newly built industrial part and the sporadic occurrence of sulphide sulfur in the groundwater, we recommend, as a precaution, two-year groundwater quality monitoring in this part of the site, after which, in the event of a favorable development of the groundwater quality, to remove the location from the Register of Information of the system of environmental loads of the Slovak Republic.

It can be concluded that the implementation of this survey is another positive step in the systematic solution of the problem of environmental burdens on the territory of the Slovak Republic, the results of which are the basis for the gradual improvement of the environment, including sustainability for future generations.

Acknowledgement

The contribution was made thanks to the financial support of the geological task *Geological survey of selected probable environmental burdens 3 – SGUDS* within the Operational Program Environmental Quality – priority axis 1: Sustainable use of natural resources through the development of environmental infrastructure, specific objective 1.4.2: Ensuring the remediation of environmental burdens in urban environment, as well as in abandoned industrial sites (including areas undergoing change), call code PKZP-PO1-SC142-2015-3, guideline No. 4, dated 18.10.2021.

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Laws and other legislative standards

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Regulation of the Government of the Slovak Republic No. 269/2010 Coll., which establishes the requirements for achieving good water status as amended. Instruction of the Ministry for the Administration and Privatization of National Property of the Slovak Republic and the Ministry of the Environment of the Slovak Republic dated December 15, 1997 No. 1617/97-min. on the procedure for evaluating the company's obligations from the point of view of environmental protection in the privatization project submitted by the company as part of the privatization.

Journal of the MŽP SR 1/98. Part VI. Indicators and standards for remediation of soil, soil and groundwater pollution, p. 47–51.

Použitá metodika a výsledky geologického prieskumu environmentálnej záťaže bývalých závodov Slovenský hodváb Senica

Environmentálne záťaže sú definované ako znečistené územia spôsobené činnosťou človeka, ktoré predstavujú závažné riziko pre ľudské zdravie alebo horninové prostredie, podzemnú vodu a pôdu. Problematika environmentálnych zaťaží na Slovensku sa začala riešiť v roku 2006 v rámci projektu *Systematická identifikácia environmentálnych záťaží* (Paluchová et al., 2008) s cieľom identifikácie pravdepodobných environmentálnych záťaží z celého územia Slovenskej republiky. Výsledkom bolo zostavenie *Registra environmentálnych záťaží*. Registrované záťaže sú v ňom zoradené podľa ich relatívnej rizikovosti ohrozenia života a zdravia obyvateľov, ako aj poškodenia ekosystémov. Register je súčasťou *Informačného systému environmentálnych záťaží* (IS EZ). Aktuálne je na Slovensku evidovaných 1 782 záťaží, rozdelených do registrov podľa stavu ich preskúmanosti a realizácie nápravných opatrení s cieľom minimalizácie ich negatívneho dosahu na zdravie človeka a životné prostredie.

Práce prezentované v tomto článku vychádzajú z výsledkov geologickej úlohy pod názvom *Geologický prieskum vybraných pravdepodobných environmentálnych záťaží 3 – ŠGÚDŠ*. Úloha sa riešila v rámci operačného programu *Kvalita životného prostredia – prioritná os 1*. Bola vypracovaná v súlade so strategickým plánovacím dokumentom v rámci systematického prieskumu a odstraňovania environmentálnych záťaží s názvom *Štátny program sanácie environmentálnych záťaží SR (2016 – 2021)*. Environmentálna záťaž v Trnavskom kraji, ktorá je predmetom nášho článku, je v ňom evidovaná v časti *7.1.1. Najrizikovejšie lokality z hľadiska potreby realizácie prieskumu pravdepodobných environmentálnych záťaží a potreby vypracovania rizikovej analýzy*. Environmentálna záťaž (ďalej EZ) v areáli bývalých závodov Slovenský hodváb je v informačnom systéme zaregistrovaná v kategórii A ako pravdepodobná environmentálna záťaž s vysokou prioritou s označením SK/EZ/SE/2004 pod názvom SE/2004/Senica – areál bývalého SH Senica.

Areál bývalých závodov je lokalizovaný v zastavanom území intravilánu mesta Senica, v priemyselnej zóne, v areáli bývalého výrobného podniku Slovenský hodváb Senica. Územie je z východnej strany ohraničené obchodnou prevádzkou Lidl a autobusovou stanicou, zo severnej strany tokom Teplica. Plocha skúmaného areálu predstavuje zhruba obdĺžnik s rozlohou približne 37 ha.

Vysoká priorita environmentálnej záťaže bola v systéme environmentálnych záťaží priradená predovšetkým na základe vizuálnej obhliadky lokality v čase registrácie v roku 2014, ktorá zodpovedala stavu ukončenej priemyselnej činnosti bývalých závodov. Závody SH Senica boli vybudované v 20. rokoch minulého storočia s cieľom výroby syntetických vlákien. Závody zanikli v roku 2005. Samotná činnosť podmieňujúca vznik EZ sa od roku 1989 už nevykonáva. V areáli podniku (výroba syntetických vlákien) bolo v čase aktívnej činnosti vybudované rozsiahle mazutové hospodárstvo (nádrže sú už zbúrané) pozostávajúce zo 7 nádrží na mazut, kotolne a stáčacieho miesta. Nachádzala sa tam aj neutralizačná stanica a sklady chemikálií (HCl a pod.). Činnosť podmieňujúca vznik EZ sa na lokalite už nevykonáva, prevádzka sa využíva na iné účely. V západnej časti areálu v súčasnosti prebieha rôznorodá priemyselná činnosť. Údaje o držiteľovi/držiteľoch záťaže uvedené v systéme ISEZ boli v čase realizovaného prieskumu neaktuálne. Od roku 2014 sa zmenil pôvodný držiteľ a v dôsledku odpredaja sa stále menia vlastníci na rôznych parcelách environmentálnej záťaže.

V čase prieskumu v rokoch 2022 – 2023 aktuálny vizuálny stav nezodpovedal stavu lokality v čase jej registrácie z roku 2014. Vo východnej časti územia v miestach najpravdepodobnejšieho zdroja znečistenia prebiehala rozsiahla stavebná a asanačná činnosť s úpravou pozemku určeného na ďalšie rozvojové aktivity občianskej a bytovej výstavby. Asanácia a následná úprava pozemku sa realizovala na základe odporúčaní environmentálneho auditu v objektoch areálu Slovenský hodváb PLUS, s. r. o. (Žitňan, 2011).

Metodika realizovaného podrobného prieskumu sa odvíja od aktuálne platnej legislatívy Slovenskej republiky, a to predovšetkým *Metodickej príručky geologického prieskumu životného prostredia v znečistenom území* (SAŽP, 2020) a smernice Ministerstva životného prostredia č. 1/2015-7 na analýzu rizika znečisteného územia.

Na lokalite sa uskutočnil súbor geologických prác zameraný na komplexný prieskum a charakterizáciu znečistenia všetkých zložiek životného prostredia vrátane zhodnotenia potenciálneho zdravotného a environmentálneho rizika vyplývajúceho z prípadného zisteného znečistenia. Realizované práce v oblasti výskytu pravdepodobnej environmentálnej záťaže zahŕňali technické práce (vrtné práce). Ich cieľom bolo spresnenie geologickej

stavby lokality a rozsahu znečistenia horninového prostredia a podzemnej aj povrchovej vody, meranie a odbery vzoriek horninového prostredia v pásme prevzdušnenia a pásme nasýtenia, odbery vzoriek podzemnej, povrchovej a odpadovej vody z novovybudovaných aj existujúcich vrtov, atmogeochemické merania, odbery pôdneho vzduchu, chemické analýzy odobratých vzoriek podzemnej vody a chemické a zrnitostné analýzy odobratých vzoriek horninového prostredia. Metodika prieskumných prác je detailne opísaná v práci Grexovej et al. (2023).

V rámci technických prác sa uskutočnilo 15 hydrogeologických monitorovacích vrtov, 5 nevystrojených prieskumných mapovacích vrtov a 15 ručných diagnostických plynometrických sond. Hĺbka zabudovaných hydrogeologických vrtov varírovala v rozsahu 9 až 12 m, hĺbka mapovacích vrtov bola 5 m. Ručné sondy sa robili do maximálnej hĺbky 1 m.

Pred realizáciou vrtných prác sa v miestach ručných sond a plánovaných vrtov odobrali vzorky pôdneho vzduchu. Vzhľadom na charakter lokality v nich bola zaznamenaná prítomnosť ropných uhľovodíkov stanovených ako benzén a toluén. Vyššie hodnoty koncentrácie ukazovateľov prekračujúce koncentráciu B a C pokynu *MSPN č. 1617/97-min*. boli potvrdené iba v ručne realizovaných sondách typu SPS. Hodnoty, ktoré neboli potvrdené opakovanými kontrolnými odbermi, sme vyhodnotili ako znečistenia bodového charakteru s pravdepodobnosťou ovplyvnenia prebiehajúcich prác stavebného charakteru a možnosťou voľného prístupu pre verejnosť vo východnej časti bývalých závodov, ktorá nemá súvis s činnosťou podmieňujúcou zaradenie skúmanej lokality do systému environmentálnych záťaží (ISEZ).

Na základe výsledkov analýz pôdneho vzduchu sa počas realizácie vrtných prác odobrali vzorky zemín z pásma prevzdušnenia a pásma nasýtenia z vrtov (SHG, SMV) a sond (SPS). Výsledky z nich potvrdili nízku koncentráciu vo všetkých analyzovaných ukazovateľoch neprekračujúcu indikačné a intervenčné kritériá stanovené smernicou MŽP SR č. 1/2015-7 na vypracovanie analýzy rizika znečisteného územia. Výnimkou bola len vyššia koncentrácia *ortuti* (SPS-1 – 3,76 mg . kg^{-1} . sušiny), *medi* (SPS-3 – 593 mg . kg^{-1} . sušiny) a *olova* (SPS-3 – 1 860 mg . kg^{-1} . sušiny) prekračujúca indikačné a intervenčné kritérium smernice pre obytné zóny. Z hydrogeologických monitorovacích vrtov SHG sa zistila zvýšená koncentrácia stopových kovov prekračujúca indikačné kritérium smernice v ukazovateli *meď* (548 mg . kg^{-1} . sušiny) a intervenčné kritérium v ukazovateli *olovo* (593 mg . kg^{-1} . sušiny) iba vo vrte SHG-10, situovanom v novej priemyselnej časti areálu bývalých závodov Slovenský hodváb. Jeho aktuálna činnosť ale nemá súvis s činnosťou závodov podmieňujúcou vznik environmentálnej záťaže. V tomto vrte sa zistila aj vysoká koncentrácia *NEL-GC* prekračujúca indikačné kritérium (774 mg . kg^{-1} . sušiny). To sa potvrdilo aj kontrolnou vzorkou, ktorá preukázala prekročenie koncentrácie v rámci intervenčného kritéria smernice MŽP SR č. 1/2015-7-min. (774 a 3 179 mg . kg^{-1} . sušiny). Identifikácia uhľovodíkov poukázala na dominantné percentuálne zastúpenie uhľovodíkov radu $C_{16} – C_{24}$ (vykurovacie oleje).

Lokálne znečistenie horninového prostredia biologickej kontaktnej zóny alifatickými ropnými uhľovodíkmi je charakterizované reziduálnymi uhľovodíkmi, ktoré majú charakter málo prchavých uhľovodíkov s nízkou rozpustnosťou a vysokým stupňom retardácie (obmedzenia migrácie) v horninovej matrici. S vysokou pravdepodobnosťou ide o bodové znečistenia reziduálneho charakteru v dôsledku realizovanej čiastočnej sanácie objektov v plánovanej obytnej zóne.

Odbery vzoriek podzemnej vody realizované v dvoch kolách s odstupom 30 dní nepotvrdili kontamináciu vody, a to ani v miestach, kde sa potvrdilo lokálne znečistenie reziduálneho charakteru.

Zaujímavou skutočnosťou boli mierne zvýšené hodnoty *sulfidickej síry* vo východnej časti územia iba v dvoch z piatich nevystrojených prieskumných (mapovacích) vrtov, podľa historickej mapy z roku 1958 lokalizovaných v miestach bývalého starého ramena. Maximálna priemerná koncentrácia neprekročila indikačné kritérium smernice. Keďže prekročenie limitov ID a IT bolo zaznamenané iba pri odberoch z nevystrojených mapovacích vrtov vo východnej časti územia a pri režimových meraniach v hydrogeologických a mapovacích vrtoch v tejto časti územia sa nezistili záporné hodnoty oxidačno-redukčného potenciálu, s vysokou pravdepodobnosťou ide o prirodzený pôvod výskytu v tomto prostredí.

Zvýšená koncentrácia v žiadnom zo sledovaných ukazovateľov, rovnako ako vo vzorkách podzemnej vody, sa nepotvrdila ani odbermi vzoriek z povrchového toku Teplica v dvoch cykloch v smere predpokladaného znečistenia z bývalých závodov.

Súčasťou prieskumných prác bola aj analýza rizika znečisteného územia, ktorej vypracovanie vyplynulo z legislatívnych požiadaviek smernice MŽP SR č.1/2015-7. Týkala sa prítomnosti znečisťujúcich látok prekračujúcich intervenčné a indikačné kritériá v horninovom prostredí biologickej kontaktnej zóny v pásme prevzdušnenia ukazovateľom NEL-GC a stopovými kovmi Cu, Pb a Hg, pri ktorých bolo potrebné hodnotenie environmentálneho a zdravotného rizika. Vypracovanou analýzou rizika znečisteného územia sa nepotvrdili environmentálne ani zdravotné riziká, preto pri súčasnom využití územia nie

je potrebné vykonať sanáciu znečisteného územia. Vzhľadom na potvrdené reziduálne znečistenie zemín v západnej, novovybudovanej časti priemyselnej časti a sporadický výskyt sulfidickej síry v podzemnej vode bolo z princípu opatrnosti navrhnuté v tejto časti územia dvojročné monitorovanie kvality podzemnej vody. Po ňom v prípade priaznivého vývoja kvality podzemnej vody bude lokalita vyradená z registra *Informačného systému environmentálnych záťaží Slovenskej republiky.*

Realizácia tohto prieskumu je ďalším pozitívnym krokom v rámci systematického riešenia problematiky environmentálnych záťaží na území Slovenskej republiky. Jeho výsledky sú podkladom na postupné zlepšovanie životného prostredia vrátane udržateľnosti pre ďalšie generácie.

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