Post-Mining Multi-Hazards evaluation for land-planning

PoMHaz

WP2: Post-mining hazards and multi hazards identification and assessment methodology

D6 - Deliverable D2.1: Database of hazards related to closed and abandoned coalmines and lignite in Europe

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Deliverable 2.1	
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Content

Acronyms

D2.1	Deliverable 2.1
CERTH	Centre for Research and Technology Hellas
Ineris	Institut de l'environnement industriel et des risques
M2.1	Milestone 2.1

1 Executive Summary

The current document is the technical report of Task 2.1, supporting and supplementing the knowledge base created for D2.1. The primary objective of this task was to create a comprehensive knowledge database for the coal mining communities, explicitly focusing on post-mining hazard occurrences. The primary deliverable is an Excel spreadsheet with a knowledge base document describing the hazards affecting abandoned coal mines across Europe. Partners representing each country (France, Germany, Greece, and Poland) have been in contact with various national and regional organizations. They gathered pertinent data, representative examples, and information on hazard management related to abandoned coal and lignite mines.
Section 2.1 provides the database's creation development, while section 2.2 outlines the families categorizing post-mining hazards. Section 2.3 establishes the guidelines governing the utilization of the final knowledge database. Additionally, these guidelines are available as an additional sheet within the Excel file.

2 Background

The deliverable is related to WP2, Post-mining hazards and multi hazards identification and assessment methodology, and more precisely Task 2.1. The aims of the work done is to establish a knowledge base including a shared library between the coal mining communities of post-mining occurrences.
The creation of the database of the mining hazard is presented the following section of the deliverable. The main deliverable is a knowledge base document describing the different hazards that can affect active and abandoned coalmines in Europe. Part of the data and the collected information in Task 2.1 will constitute an input for WP2 (Risk assessment) and WP3 (GIS development and implementation).

2.1 Creation of database

This section provides insight into how the knowledge database was structured based on partners' research and interactions. Furthermore, it presents the initial assumptions and decisions regarding the database's format, context, content, and any modifications and additions made along the milestone M1 acceptance. This section explains the database's development and current structure.
During the consortium's first meeting (8 December 2022), a crucial question arose regarding the database structure and its final format; the database format aimed to ensure universal accessibility for all project partners while maintaining user-friendliness and comprehensibility. Following discussion and with guidance from CERTH (Task leader), the decision was made to create the database using a Microsoft Excel spreadsheet. This structure is preferred for this database as it is practically accessible and easy to use for research and industry and is ideal due to the relatively small size of the database.
The database design was outlined as follows: The first column of the spreadsheet would illustrate a list of identified hazards; the first row would contain the required fields delineated in the project proposal with any necessary modifications. The primary objective was to establish a seamless correspondence between each required field (row-based) and every hazard (column-based). Furthermore, the discussion encompassed the

potential enhancement of required fields and the addition of post-mining hazards. An early augmentation to the hazard column was introduced, specifically including "tailings dams," an object not initially featured in the proposed list.
Additionally, upon the suggestion of Ineris, it was decided to categorize the identified hazards into four main families that are detailed below, as illustrated in column A of the database. Moreover, another piece of information that needed to be added was to mention in which type of mine each hazard can happen (Column C). After the first meeting, partners provided further feedback and made necessary data entries or edits within the spreadsheet cells.
Furthermore, all partners provided feedback on the structure and content of the database, which had been under development for the past two months. Subsequently, a final version of the core structure was collectively defined. Notably, partners modified several descriptions that diverged from the previous versions. These changes encompassed subsidence-related issues, spoil-based environmental pollution, and hydrological issues, specifically water disturbances in underground mines. After a thorough discussion, all partners agreed to retain these alterations.
The three last columns were introduced to facilitate the database update and comparisons among European countries regarding terminology and definitions. Partners provided feedback for each hazard, including its name, the type of mines it occurs in, and whether the proposed description aligns with their national standards (Columns K, L, and M). In conclusion, all partners unanimously endorsed the current database version, marking the completion of milestone M2.1 (Present and discuss the structure of the data base of the hazards).
Before completing the database, partners provided feedback on the national standards and a few additional suggestions for changes, which were approved regarding the new database content. Finally, it was decided to include a report alongside the Excel knowledge database file. The current technical report signifies the completion of D2.1 based on these decisions.
All meetings were conducted virtually, and all partners associated with Task 2.1 actively participated. They offered suggestions, proposed topics for discussion, and were readily available to assist whenever their input was requested.
On date 27/06/24, RFCS has requested the revision of the deliverable by adding some picture or sketch of each hazard (column N) to the excel sheet and by adding a list of reference of the relevant publications (additional sheet in the excel sheet).

2.2 Post-mining hazards families

Four significant families of post-mining hazards were identified to be used for hazard identification. These were ground movement, environmental pollution, hydrological issues/water disturbances, and gas/fire.
<u>Ground movement family</u> concerns hazards that appear due to mining-induced movements or movements of the ground due to changes in stresses, deformation and failure of underground structures or sudden collapse and surface deformation.
<u>The environmental pollution family</u> describes hazards that affect surface and groundwater supplies due to heavy metals and conservative pollutants. Moreover, it includes the case where spoil materials (including sulphide minerals) are placed on the surface, or a failure of the tailings dam in combination with physical weathering causes environmental pollution.

Hydrological issues/water disturbances family describes the hazards due to aquifer rise back (after the halt of mining operations) or the artificial flooding of pit-lakes causing consequences in the post-mining areas.
Finally, the gas/fire family is related to the hazards that can affect the surrounding areas by releasing high-energy radiation or endogenic fires caused by physical-chemical reactions.
Another way to group hazards is through the related mine type. This categorization is done in column C of the Excel file (database) by incorporating four families of mine types. These groups are:
Surface Mines: Surface mines are mining areas that extract coal or lignite from the Earth's surface, often through open-pit or strip mining methods.
Underground Mines: Underground mines are mining areas that access and extract coal or lignite from beneath the Earth's surface, typically through tunnels, shafts, or other subsurface passages.
Pit Lakes: Pit lakes are water bodies that form in abandoned open-pit mines as a result of natural groundwater filling or artificial flooding. They can serve various ecological and recreational purposes.
Waste Embankments: Waste embankments are engineered structures used to contain and manage the by-products and waste materials produced during mining activities, providing a means of safe disposal and environmental protection.

2.3 Guidelines on using the database

This section provides comprehensive guidelines on the final knowledge database in Excel format; it has also been included as the first page of the Excel-based knowledge base. This guidance will encompass key assumptions and instructions regarding the description of columns, lines, cells, and other essential elements within the database. The aim is to ensure that users can navigate and make the most of this valuable resource easily and clearly, facilitating access to crucial information.

Row 1: the first row of the file describes the information gathered for all hazards. These fields are essential for describing, understanding, evaluating the impact, and devising responses to each hazard.

Column A: the four categories of the identified hazards are ground movement, environmental pollution, hydrological issues/water disturbances, and gas/fire.

Column B "Name of hazard": the provided list includes all post-mining hazards identified by the partners, and it serves as the basis for multi-hazard identification and analysis.

Column C "Mine type": the four types used are surface mine, underground mine, waste embankments, and pit-lake. This column illustrates the type of the post-mining area where each hazard has the potential to occur.

Column D "Description": communicates vital information on hazards' based on a format-free description.

Column E "Description of effects and consequences": details the societal, financial, environmental, and any other consequences arising from the occurrence of a hazard.

Column F "Illustration and examples concerning each coalmine hazard": references specific instances where each hazard has occurred in a post-mining area.

Column G "Description of mechanisms leading to the phenomenon occurrence": describes the conditions that can lead (and have been reported to lead in the past) to a hazard occurrence.

Column H "Main variables and factors influencing phenomenon predisposition and/or occurrence and intensity": lists the primary causal factors that increase the likelihood of each hazard occurring or tend to promote their occurrence.

Column I "Main variables and factors influencing phenomenon mapping and monitoring": lists the main variables that can affect the monitoring process of a post-mining area.

Column J "Additional information and comments": includes any supplementary valuable information that did not belong to any of the existing required fields.

Column K "What is the name or term in each country?": the input for this column was obtained from national data concerning post-mining hazards. This information aims to validate the identification of hazards and highlight disparities in terminology across different countries.

Column L "Does it exist at a national level – in what type of mines it occurs?": the input for this column was obtained from national data concerning post-mining hazards. This column provides information about post-mining hazards that may occur in each respective country and specifies the types of abandoned mines in which they can happen.

Column M "Is the given phenomenon description different from the relative national description? If yes, provide the national description": the input for this column was obtained from national data concerning post-mining hazards. This column illustrates descriptions of each hazard at a national level. Any variations from the descriptions provided in the database are highlighted.

Column N "Picture or sketch for each hazard": this column presents pictures and/or sketches, which depict and describe the occurrence or the potential of each identified hazard.

Finally, there is an additional sheet in the database file, named "List of references", which includes all the references cited in the database.

3 References

Project minutes, 8th of December 2022, "E-Meeting for Task 1.1: Knowledge base and library of post-mining hazard".

Project minutes, 1st of February 2023, "Minutes of e-meeting for milestone M1.1: Present and discuss the structure of the data base of hazards".

Project minutes, 3rd of April 2023, "Minutes of the Progress Meeting".

Request for revision of deliverable submission for the projet “POMHAZ (101057326)”, Ref. Ares(2024)4634294, 27/06/2024

What is PoMHaz?

The goal of PoMHaz is to improve methodological and practical knowledge for the assessment and management of multi-hazards, at the scale of a coal mining basin, through the active and continuous engagement of key stakeholders involved in or affected by post-mining activities.

PoMHaz is a project funded by the Research Fund for Coal and Steel programme.

Further information can be found under https://www.pomhaz-rfcs.eu.

For feedback on the PoMHaz project or the published deliverables, please contact contact@pomhaz-rfcs.eu.

The PoMHaz Consortium

ΔΕΗ Public Power Corporation

INERIS maîtriser le risque pour un développement durable

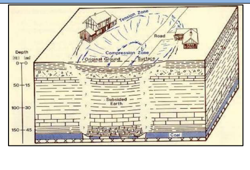
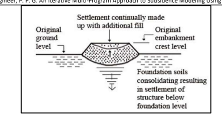
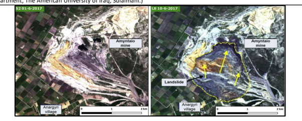
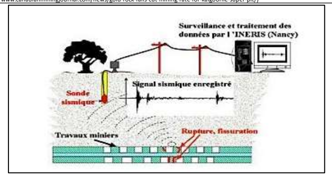
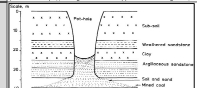
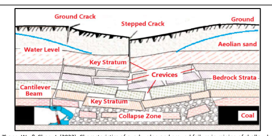
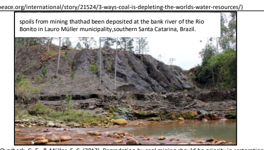
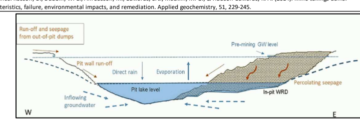
Technische Hochschule Georg Agricola

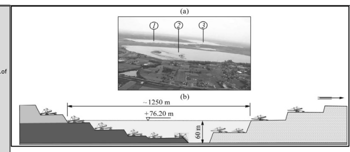
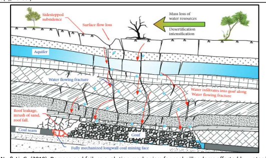
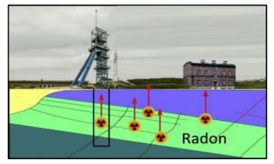
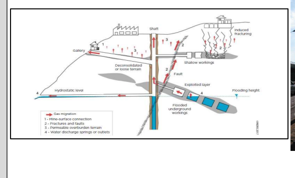
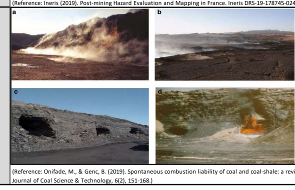
GIG National Research Institute

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

SRK S.A.

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG The University of Resources. Since 1765.

	Name of hazard	Mine type (surface/underground/waste embankments/pit lake)	Description	Description of effects and consequences	Illustration and examples concerning each coalmine hazard	Description of mechanisms leading to the phenomenon occurrence	Main variables and factors influencing phenomenon predisposition and/or occurrence and intensity	Main variables and factors influencing phenomenon mapping and monitoring	Additional information and comments	What is the name or term in each country?	Does it exist at a national level – in what type of mines it occurs?	Is the given phenomenon description different from the relative national description? If yes, provide the national description.	Picture or sketch for each hazard
GROUND MOVEMENT	Subsidence	underground	Mine subsidence can encapsulate all mining-induced movements of the overburden and the ground surface (J.M. Galvin, 2016). 1. A. Kowalski: "Eksploatacja górnicza a ochrona powierzchni. Doświadczenia z wałbrzyskich kopalń" ["Mining exploitation and surface protection. Experiences from the mines in Wałbrzych"]. GIG, Katowice 2000. 2. A. Kowalski: "Deformacje powierzchni na terenach górniczych kopalń węgla kamiennego". ["Surface deformations in mining areas of hard coal mines"]. GIG, Katowice 2020.	Damage to the surface and underground structures, mainly in urban areas e.g. buildings, roadways, bridges, retaining walls, pipelines, etc. Subsidence disturbs the natural balance of the surface and underground water resources and natural and man-made surface drainage systems and causes sinkholes.	Illinois coal mine subsidence (USA), Ostrava-Kavrina coalfield (Czech Republic), Huainan coalfield (China), The Lower Silesian Coal Basin (Poland), The Upper Silesian Coal Basin (Poland)	Subsidence of the ground surface can be regarded as ground movement that takes place because of the extraction of mineral resources or the abstraction of fluids. It is inevitable consequence of underground activities, in the broadest sense, and reflects the movement that occur in the area of exploitation (F.G. Bell et al., 2000). In post mining areas, up to several years after exploitation, there are residual depressions and uplifts of the terrain surface. Theses uplifts are caused by the flooding of excavations and cavings after the closure of mine.	Local tectonics (presence of faults); Coal seam thickness and depth extracted; Geological properties of overburden; Surface topography; Coal properties including strength and dip of seam; Soil movements due to mining operations; High rate of extraction; Unliquidated excavations in the rock mass.	Incorrect topographic measurements; Tilt; Point of flexure; Curvature; Strain; Distance of monitoring; Geological characteristics of overburden. Vertical and horizontal displacements can be measured using classical geodetic measurements: leveling and GNSS. INSAR measurements.	Subsidence is generally slow, progressive and flexible, and takes the form of a topographical depression with no major breaks, giving it a bowl-shaped appearance (Post-mining hazard evaluation and mapping in France (p. 50). Ineris DRS-19-178745-02411A.).	**Ineris (France):** subsidence and general collapse or massive collapse (both induce subsidence in the surface); **THGA (Germany):** mine subsidence; **GIG (Poland):** Subsidence (In Poland, in general, we describe subsidence as surface deformations. Subsidence literally means vertical displacement and it is one of the indices of surface deformations. Other indices of surface deformations are horizontal displacement, horizontal strain, tilt, curvature, and radius of curvature. These are continuous deformations); **CERTH (Greece):** same	**Ineris (France):** all mines / underground mines; **THGA (Germany)** underground and open pit mines; **GIG (Poland):** all underground mines; **PPC (Greece):** In underground mines. There are historical data from closed mines (example Aliveri mine).	**Ineris (France):** same; **THGA (Germany):** in principle, the national definition does not differ from the specified. Alternatively, however, the term "ground movement" is used instead of "subsidence", which also includes horizontal movements as well as possible uplifts, e.g. during mine water rebound; **GIG (Poland):** Continuous deformations are distortions of the terrain surface, which are quantitatively described by vertical (subsidence) and horizontal displacements and their derivatives - tilts, curvatures and horizontal strains. They are expressed by continuous functions, and the indices of surface deformations are: subsidence (w), horizontal displacement (u), tilt (T), vertical curvature (K) and horizontal strain (e). Sometimes a distinction is made between displacements and deformations. 1. A. Kowalski (2000): "Eksploatacja górnicza a ochrona powierzchni. Doświadczenia z wałbrzyskich kopalń" ["Mining exploitation and surface protection. Experiences from the mines in Wałbrzych"]. Katowice: GIG. 2. A. Kowalski (2020): "Deformacje powierzchni na terenach górniczych kopalń węgla kamiennego". ["Surface deformations in mining areas of hard coal mines"]. Katowice: GIG; **PPC (Greece):** same	 (Reference: Dave Hallman, P. E., & Engineer, P. P. G. An Iterative Multi-Program Approach to Subsidence Modeling Using LaModel and SDPS1.)
	Settlement	underground/surface/waste embankment	Settlement is defined as the downward movement of the ground due to changes in stresses within it. Generally, the settlement means a building or other structure vertical displacement caused by subsoil compaction under structure weight. In mining areas of underground mines, the additional settlement of structures occurs in the zones of horizontal tensile strain. The additional settlement is also connected with the cone of depression in open pit mines.	Cracks or even collapse in structures or trigger the instability of a structure.	Witbank Coalfield (South Africa), the Upper Silesian Coal Basin (Poland)	Settlement in coal mining areas could occur due to the dewatering during mining process or due to backfilling, which caused changes in underground stresses.	Local tectonics (presence of faults); Coal seam thickness extracted; Geological properties of overburden; Surface topography; Coal properties including strength and dip of seam; Soil movements due to mining operations.	Large deformation gradients and non-linearity in surface deformation makes difficult the reliable monitoring results; Consolidation of waste dumps.		**Ineris (France):** same; **THGA (Germany):** same; **GIG (Polland):** same; **CERTH (Greece):** same	**Ineris (France):** all mines / shallow and underground mines using goaf method; **THGA (Germany):** underground and open pit mines; **GIG (Poland):** underground and open pit mines; **PPC (Greece):** In underground mines (example Aliveri mine)	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** same; **PPC (Greece):** same	 (Reference: Kawa, S., Hassan, S., & Baban, N. (2019). Organic and peat engineering properties, and their suitability for construction projects. Engineering Department, The American University of Iraq, Sulaimani.)
	Slope movement (slope stability) - (Generalized scale- level of whole excavation)	surface	Slope movement can be defined as the outward and downward displacement of slope-forming material. Slope movements have a widespread distribution since unstable landslide-prone slopes occur almost everywhere. Landslide is a downward movement of the ground along a curvilinear slip surface. Slope slide is a movement of the upper layer of the soil almost parallel to the ground surface; the slip surface is similar in shape to a plane. Wiłun (2007): "Zarys geotechniki" [eng.: "Outline of geotechnics"]. Warszawa: Transport and Communication Publishers.	Serious effects on buildings/structures, services and communications, changes in the stress field, and geological and mechanical properties of the upper stratum.	Fosse Padene open pit (France), Amyntaio and Choremi surface lignite mines of Public Power Corporation (Greece), lignite mine Bełchatów (Poland)	Slope movement is the result of the movement of a landmass along a failure zone defined by a continuous surface (which may be circular, flat or sometimes complex in form)(Post-mining hazard evaluation and mapping in France (p. 50). Ineris DRS-19-178745-02411A.). The sliding surface is expected at the interface of soft clays within lignite or marl.	Soft clays (ϕ≤10°); Weak surface (low shear strength of the extracted material); The materials that cover the slopes and their sensitivity to environmental factors; The action of water (pore pressure); The large slope height and steep slope inclinations.	Inclinometer measurements could show the potential horizontal displacements after an intensive rainfall; Uncertainty in geological parameters estimation leads to inaccurate geotechnical analysis.		**Ineris (France):** deep lindslide; **THGA (Germany):** Land slide/slope slide; **GIG (Poland):** deep lindslide; **CERTH (Greece):** generalized-landslide	**Ineris (France):** open pit mines and dumps, tailling dams; **THGA (Germany):** open pit mines; **GIG (Poland):** open pit mines and dumps; **PPC (Greece):** Open pit mines and dumps	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** same; **PPC (Greece):** same	 (Reference: Valkaniotis, S., Ganas, A., & Papathanassiou, G. (2017). Rapid Mapping of the Amyntaio-Anargyroi landslide (Western Macedonia, Greece) using combined remote sensing techniques. Oral presentation. Safe Athens 2017, Athens, Greece.)
	Slope movement (slope stability) - (Local scale- level of bench)	surface/waste embankment	Slope movement can be defined as the outward and downward displacement of slope-forming material. Slope movements have a widespread distribution since unstable landslide-prone slopes occur almost everywhere.	Serious effects on buildings/structures, services and communications, changes in the stress field, and geological and mechanical properties of the upper stratum.	Shenfu-Dongsheng coalfield (China) Wardha Valley coalfield (India), Kardia and Mavropigi surface lignite mines of Public Power Corporation (Greece), the Upper Silesian Coal Basin (Poland)	A mining landslide refers to a mountain landslide that is caused by the deformation and destruction of the upper stratum (soil) under the influence of underground mining (Li, 2003; Song et al., 2003). However, even slopes with conservative slope designs may experience unexpected failure due to the presence of unknown geological structures, abnormal weather patterns or seismic shock.	Soft clays (ϕ≤10°); Weak surface (low shear strength of the extracted material); The materials that cover the slopes and their sensitivity to environmental factors; The action of water (pore pressure); The large slope height and steep slope inclinations.	Inclinometer measurements could show the potential horizontal displacements after an intensive rainfall; Uncertainty in geological parameters estimation leads to inaccurate geotechnical analysis.		**Ineris (France):** shallow landslide; **THGA (Germany):** Land slide/slope slide; **GIG (Poland):** shallow landslide; **CERTH (Greece):** local-landslide	**Ineris (France):** open pit mines and dumps, tailling dams; **THGA (Germany):** open pit mines; **GIG (Poland):** open pit mines and dumps; **PPC (Greece):** Open pit mines and dumps	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** In details: Landslide hazard - the possibility of loss of stability of slopes of an excavation or spoil heap (dump) as a result of geological and geological-engineering processes; **PPC (Greece):** same	 (Reference: Wang, S., Zhou, W., Cai, Q., Shi, X., Lu, X., & Luan, B. (2019). The coal mining model under slippery slope in Yiminhe open pit coal mines. Geotechnical and Geological Engineering, 37, 3727-3737.)
	Rock falls	underground/surface	Rock fall consists of the detachment, fall, rolling and bouncing of a single rock block or more rock fragments, which mainly interact with the substrate (Preh et al., 2015).	Impact in health and safety of coal miners, one of the most important risk with the most negative effects is falling materials; equipment damage.	Fosse Padene open pit (France) Xinjiang underground steeply dipping coal seam (China) lignite mine Adamów (Poland)	The rock fall phenomenon usually consists of two distinct stages. The initial failure stage can be described as the circumstances under which several blocks are detached from the parent rock, due to natural discontinuities. The post failure stage can be described as the motion of the detached rock blocks along the slope.	Geometry of the slope and pre-detached rock blocks (slope height and inclination, location of the start point, limits of outcropping materials, location of elements at risk, shape and volume of the rock block); Rock mass quality (rock mass classification systems); Mechanical parameters and density of rock mass discontinuities; Climate events (freeze/thaw cycles); Dynamic stresses (e.g. earthquake, mine blasting); Static stresses (overloading on the cliff's crest. Intensity parameters: rockfall kinetic energy, bounce height, endpoints position, volume of falling materials.	Accessibility in the slope exposures and the in situ field investigation (e.g. discontinuities measurements); Data availability of past rockfalls in the study area; Strongly disintegrated rock masses makes difficult the discontinuities measurements and the quantitative characterization of the rock mass.		**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland) :** Underground mining: Rock falls from roof and/or rips-Open pit mines:Rock falls; **CERTH (Greece):** same	**Ineris (France):** open pit mines; **THGA (Germany):** underground mines; **GIG (Poland):** mainly in underground mines and open pit mines; **PPC (Greece)**: n/a in lignite mines	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** In general No. In open pit mines this hazard is associated with the formation of rock overhangs, cracks and fissures as a result of the use of blasting techniques to extract the recourses. The formation of this hazard is also influenced by geological structure, i.e. the bedrock, tectonics, karst phenomena and the directions adopted by mining plants. **PPC (Greece):** same	 (Source: https://www.canadianminingjournal.com/news/gold-rock-falls-cut-mining-rate-for-kalgoorlie-super-pit/)
	Induced seismicity	underground/surface	The rock mass response to deformation and failure of underground structures, including rock mass itself, causing ground movement. Basing on experience from Poland: Many years of observations and analysis in the Upper Silesian Coal Basin (USCB), Poland, have shown the bimodality of mining-induced tremors (Kijko et al. 1987). There is a group of tremors that are directly associated with mining advancement of the longwall face, so-called "exploitation tremors" of seismic energy E < 107 J and a group of so-called "regional tremors", strong tremors of E ≥ 106 J. Regional tremors are associated with mining operations over a large area, covering many longwall panels, and their occurrence is related to greater faults, folds, or overlaps in the area of mining operations. Dubiński et al. (2017) underlined that unfavourable changes of the stress field caused by mining are only a trigger in reducing energy stored in geological structures disturbed by mining. Regional tremors are particularly hazardous for buildings on the surface Pilecka E., Stec K., Chodacki J. et al (2021) The impact of high-energy mining-induced tremor in a fault zone on damage to buildings. Energies 2021, 14(14), 4112; https://doi.org/10.3390/en14144112. Mutke (2019): "Oddziaływanie górniczych wstrząsów sejsmicznych na powierzchnię". [eng. "Impact of mining seismic tremors on the surface".]. Monograph. Katowice: GIG.	Seismicity produces losses in underground mines, damages to equipment, collapse of drifts and stopes, injuries to persons. The impact of mining-induced tremors on the environment is very diverse, from weak – imperceptible by people – to very strong, which often causes specific damage to the existing infrastructure on the ground surface (Dubiński et al. 2001, Pilecka et al. 2017) and sometimes in underground mining workings (Pilecki 1999, Dubiński et al. 2001, Wang et al. 2016). Seismic energy propagation of mining-induced tremors usually causes an uneven distribution of the peak ground velocity PGVHmax in tectonically complicated structures, and consequently, an uneven distribution of damage to buildings located on the ground surface.	Ruhr coal mine area (Germany) Nottinghamshire coalfield (UK) underground: the Upper Silesian Coal Basin (Poland) open pit: lignite mine Bełchatów (Poland)	Changes in the geomechanical conditions in relation to rock properties are primarily responsible for the occurrence of geodynamic phenomena in the rock mass. Changes in the stresses in the rock mass due the mining, cause the release of energy accumulated in geological structures. The current mining operation is only a trigger for the tectonic stress reduction and, as a consequence, the occurrence of the tremor in this region (Chodacki 2020).	Rock properties, geomechanical properties, presence of tectonic compaction zones (e.g. faults) which have greater strength and elasticity because of the increased density of the rock mass. Other factors: depth of the mining exploitation, presence of historic mining, overlaping contemporary mining. Intensity of the termors observed on the surface depends on geological structure of the subsurface layer, tremor mechanism (directivity of vibration emission). (Dubiński J., Mutke G., Chodacki J. 2020. Distribution of peak ground vibration caused by mining induced seismic)	Physical paremeters of peak ground vibration, caused by strong mining tremors induced by coal extraction are measured on the surface: peak ground horizonatal velocity (PGV_H) and peak ground horizontal acceleration (PGA_{H10}). Factors influencing monitoring: number of seismometres (in case of PGV_H) or acclerometers (in case of PGA_{H10}) located on the surface - on ground or on the foundation of buildings. Amplification of seismic waves by surface layer depends on the thickness of that layer (usually loose deposits of Quaternary), geomechanical and physical parameters of the deposits.		**Ineris (France):** Induced seismicity (but it is not a hazard for the mining authority); **THGA (Germany):** microseismic events; **GIG (Poland):** induced seismic activity; **CERTH (Greece):** same	**Ineris (France):** deep mines/goaf method; **THGA (Germany):** underground mines; **GIG (Poland):** in Poland in underground mines, and also in one open pit lignite mine; **PPC (Greece):** In Greece, seismicity is considered as an accidental loading to examine potential hazards, like slope instability and landslide. There may be potential and it is examined in all mines.	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** same; **PPC (Greece):** same	 (Reference: https://www.grand-est.developpement-durable.gouv.fr/surveillances-minieres-a12338.html)
	Sinkhole	underground	Sinkhole is an abrupt depression of the local ground surface which occurs due to sudden collapse of overburden into a mine opening or cavity (Singh and Dhar, 1997), observed both during mine drainage and during mine closure and flooding. Sinkholes are surface, discontinuous deformations.	Dangerous to life and property, damage to existing development and infrastructure; and, in the worst cases, injury or loss of life. The economic impact of sinkhole, in the form of loss of surface and underground property, disruption of work, production loss, cleaning of the sinkhole in affected areas and filling of the sinkhole, is also significant in many cases. Temporary or permanent exclusion of the area from use or the need to displace people. Changes in hydrogeological conditions - facilitating water infiltration and migration of contaminants from the surface. Drainage of groundwater levels. The need for costly subsoil investigations and hazard monitoring in conjunction with hydrogeological monitoring. Use of expensive stabilizing mixtures for underplanting.	Sinkhole in Boopyung (Korea) In North-Westphalia 1196 mining -induced sink holes between 1986-2020 occured close to the surface and 400 sinkholes on former shafts; the Lower Silesian Coal Basin (Poland), the Upper Silesian Coal Basin (Poland)	Sinkholes result from the intermittent, sequential collapse and unravelling of underground mine roofs in localized areas, whereby caving migrates through the overlying strata until the fracture zone intercepts the unconsolidated overburden. In the presence of weak overburden the roof may fail in two basic modes, tensile and shear (Karfakis, 1987). They may also form as a result of reactivation of goafs due to the impact of deep mining operations and shocks of mining origin or in the process of flooding of workings due to a decrease in the strength of the rocks surrounding the workings.	Geological conditions (rock types of the overlying strata); Type of deposit (seam/vein); Changes in groundwater levels; Depth of the extraction areas; Geometry and support systems of underground mines; Geotechnical properties like swell factor; Porosity; Rock pressure; Jointed rock body; Shear angle; Angle of friction (https://www.bra.nrw.de/system/files/media/document/file/gutachten-einwirkungsrelevanz.pdf) The extent of rock mass destruction, the influence of tectonics and the weakening effect of water, removal (leaching) of rocky material from the environment and from backfill material, and as a result of seasonal fluctuations in the water table in the reservoirs of flooded mines and lithological and strength variability of the rocks.	Continuous monitoring of ground movements with remote sensing and satellite images. The use of mapping of the aforementioned together with the location, slope, geometry and information on the filling of the workings, as well as the lithology and strength and deformation properties of the rock environment of the mine workings, as well as with knowledge of the presence of tributaries, accumulation and flow of water or its other influence. In a flooded mine - the position (water table) of the water table in together with the above mentioned - with knowledge of hydrogeological monitoring data.	Invisible hazard, identification via monitoring of ground movements; calculation methods and numerical modelling techniques available (https://www.bra.nrw.de/system/files/media/document/file/gutachten-einwirkungsrelevanz.pdf); the Upper Silesian Information System on Surface Hazards in the Areas of Liquidated Mines (https://zapadliska.gig.eu/); in the Lower Silesian Coal Basin (Wałbrzych), 669 excavations connected to the surface were inventoried, and in the area of Nowa Ruda 246 excavations.	**Ineris (France):** Sinkhole / localised collapse; **THGA (Germany):** same; **GIG (Poland):** sinkhole / surface discontinuous deformation; **CERTH (Greece):** same	**Ineris (France):** -; **THGA (Germany):** near surface underground mines; **GIG (Poland):** it is connected with shallow mining; **PPC (Greece):** not observed in lignite mines	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** same; **PPC (Greece):** same	 (Reference: Singh, T.N. (1986) Coal mining under river beds, Workshop on Protection of Surface Features and Structures in Mining Areas, 24-29 November, CMRI, Dhanbad)  (Source: https://www.theguardian.com/world/2022/aug/02/sinkhole-25-metres-wide-prompts-investigation-near-chilean-copper-mine)
	Crevice	underground	Mine subsidence creates overburden fractures. The surface earth deforms due to these fractures. After mining closure, the long-term erosion of the surface earth can cause the appearance of the crevice on the surface.	Crevices can cause failures in underground pipelines and water supply networks (Franck, C., Salmon, R., Didier, C., Paquette, Y., & Pokryszka, Z. (2019). Post-mining hazard evaluation and mapping in France (p. 50). Ineris DRS-19-178745-02411A.).	Loraine coal basin, France(Franck, C., Salmon, R., Didier, C., Paquette, Y., & Pokryszka, Z. (2019). Post-mining hazard evaluation and mapping in France (p. 50). Ineris DRS-19-178745-02411A.). The Lower Silesian Coal Basin (Poland), The Upper Silesian Coal Basin (Poland)	The predominant initiating mechanism is when water flow mobilizes fine materials on top of or inside the crevice, which then sink to the bottom, bringing with them any surrounding loose earth. The phenomenon is generally sudden, even near instantaneous.(Franck, C., Salmon, R., Didier, C., Paquette, Y., & Pokryszka, Z. (2019). Post-mining hazard evaluation and mapping in France (p. 50). Ineris DRS-19-178745-02411A.).	Presence of compacted rock layer near the surface covered by soil layer; Large scale subsidence.	Heavy raining, flooding, excavation. Classical geodetic measurements: total stations and GNSS, and also archiving observations and records by mining plants can be used to measure e.g. length, width and direction of crevice on the surface.	Invisible hazard, identification related to mine panel configurations; in Poland, two classifications of the suitability of post-mining areas for development (construction) are used: 1. A. Kowalski & J. Kwiatek: "Przydatność terenów pogórniczych do budownictwa". ["Suitability of post-mining areas for development"]. Przegląd Górniczy [Mining Review], nr 5, 2004. 2. Poradnik metodyczny [Methodological guide] (2009): "Zasady dokumentowania warunków geologiczno-inżynierskich dla celów likwidacji kopalń (poradnik metodyczny)". ["Principles of documenting geological and engineering conditions for the purpose of decommissioning mines (methodological guide)"]. Warszawa, Ministerstwo Środowiska [Ministry of the Environment].	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** crevice / linear discontinuous deformation; **CERTH (Greece):** same	**Ineris (France):** deep mines/goaf method; **THGA (Germany):** no; **GIG (Poland):** underground mines, on the surface; **PPC (Greece):** In surface mines, behind the slope crest, and also in other excavation sites. Also, in underground mines, on the surface (Example Aliveri mine).	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** same; **PPC (Greece):** same	 (Reference: Liu, G., Zou, Y., Zhang, W., & Chen, J. (2022). Characteristics of overburden and ground failure in mining of shallow buried thick coal seams under thick aeolian sand. Sustainability, 14(7), 4028.)
ENVIRONMENTAL POLLUTION	Environmental water pollution	surface/pit lake/underground	The presence of heavy metals (e.g., Fe, Zn, Cu, Mn) and conservative pollutants (e.g. SO4, Cl) in both surface and groundwater supplies is a major environmental problem.	The occurrence of toxic metals in pond, ditch and river water affect the lives of local people that depend upon these water sources for their daily requirements (Rai et al. 2002). The possibilities of economic use of water are also influenced by significantly increased content of other components (e.g. sulphates), limiting or preventing the use of underground and surface water, e.g. for drinking purposes.	Central Germany - area of about 140 pit lakes (Schultze M., Pokrandt K-H, Hille W., 2010: Pit lakes of the Central German lignite mining district: Creation, morphometry and water quality aspects. Limnologica, Vol. 40, Iseeue 2, pp 148-155)	Quantity, mineralogical formation, properties of coal waste. It varies depending on the mineral preparation and enrichment process. Formation of acidic mine drainage, wherein iron sulfide in coal mines or sulfur in base-metal mines can be exposed to oxidation conditions. (https://opus.thga.de/frontdoor/deliver/index/docId/9/file/MRG_158_Hyperspektralerkundung.pdf)	Temperature; Specific conductance at 25°C; Dissolved oxygen; pH; Acidity; Alkalinity; Total inorganic carbon; Total iron; Total dissolved solids; Dissolved organic carbon; Total organic carbon; Ferrous iron (Fe2+); Ferric iron (Fe3+), Al, Mn, SO4(2-) , Cl-, HCO3-, Ca2+, Mg2+,Na+, K+, NO3-, Si.	Hyperspectral mapping of effluents		**Ineris (France):** environomental water pollution (but the French State considere this is not a mining hazard); **THGA:** (ground)water pollution; **GIG:** (ground)water pollution; **CERTH (Greece):** (ground) water pollution	**Ineris (France):** all mines; **THGA (Germany):** underground and open pit mines; **GIG (Poland):** underground and open pit mines; **PPC (Greece):** There is potential for water pollution in all lignite mines. However, all necessary measures are taken to protect groundwater and water resources and comply with Environmental terms.	**Ineris (France):** same; **THGA (Germany):** basically, the definition is the same. However, many other substances from mine water are also regarded as contaminants, e.g. mineralization or PCBs; **GIG (Poland):** Water pollution (in Polish "Zanieczyszczenia wód") - Processes leading to changes in the composition or condition of groundwater caused by direct or indirect human activity, making it less useful for one or all of the purposes that it could served in its natural state. In practice, any changes in their chemical composition caused by natural, internal (geogenic) and external (anthropogenic) factors should be treated as groundwater pollution - Hydrogeological Dictionary. Polish Geological Institute; **PPC (Greece):** same	 (Reference: https://www.greenpeace.org/international/story/21524/3-ways-coal-is-depleting-the-worlds-water-resources/)
	Environmental pollution from spoils	surface/underground	The wastes have been excavated and placed on the surface of the earth. Spoil material is conducted from i.a. heavy metals and sulfide minerals. Natural weathering conditions influence spoil material and cause its breakdown. Then, the fine material can be easily released into the environment (Dang, Z., Liu, C., & Haigh, M. J., 2002).	The appearance of spoil material into the environment in combination with the weathering, speed up the release of toxic elements and conservative pollutants (Dang, Z., Liu, C., & Haigh, M. J., 2002). Changes in hydrogeological conditions in the area of the flooding mine may significantly affect the groundwater vulnerability to pollution (including pollution emitted from post-mining waste heaps) Bukowski P., Bromek T., Augustyniak I. 2006 - Using the DRASTIC System to Assess the Vulnerability of Ground Water to Pollution in Mined Areas of the Upper Silesian Coal Basin. Mine Water Environ., 25: 15-22.)	Landslides at the Mae Moh mine in Thailand 1990. 1995, 2015, 2017 Upper Silesian Coal Basin (eg. Grodziec mine)	Pollution from post-mining waste is released into the soil and water environment as a result of washing the waste with rainwater (and/or underground water). Water is a medium for transporting pollutants even over long distances.	Lithostratigraphic structure while the hazard described relates to underground mines around the mined deposit and in the overburden of the deposit, proportions of barren (accompanying) rocks and coal in post-mining waste stored on dumps and heaps; petrographic and mineralogical composition of waste; method of their storage; compaction and sealing; physico-mechanical and hydrogeological parameters of waste (affecting the susceptibility of waste to disintegration); meteorological conditions (e.g. amount of precipitation); development of the heap; the way it is profiled; the state of soil or vegetation coverage; water saturatin of the waste dump; chemical composition of rainwater and groundwater.	Continuous monitoring of ground movements with remote sensing and satellite images in combiantion with in-situ sensors Monitoring the qualitative and quantitative state of groundwater in the monitoring network (pierozmeters, wells) in the direction of inflow and outflow of water from the open-cast excavation; quality monitoring of surface waters in the surrounding rivers and watercourses; qualitative and quantitative monitoring of collective waters (sewage) discharged from the mine.	Prediction models are existing.	**Ineris (France):** same; **THGA (Germany):** Mining Waste Contamination; **GIG (Poland):** Mining Waste Contamination; **CERTH (Greece):** same	**Ineris (France):** all mines; **THGA (Germany):** underground and open pit mines; **GIG (Poland):** underground and open pit mines; **PPC (Greece):** There is potential for water pollution in all lignite mines. However spoil material is deposited following certain technique/ procedure (co-Deposition of fly ash and waste) so as the water pollution is eliminated.	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** Spoils (in Polish "odpady pogórnicze", "odpady wydobywcze") - waste from the exploration, prospecting, extraction, processing and storage of minerals from deposits. Mining waste also includes tailings, i.e. waste in solid or sludge form that remains after the processing of minerals carried out by mechanical, physical, biological, thermal or chemical processes, as well as from a combination of these processes (Act of 10 July 2008 on mining waste); **PPC (Greece):** same	 (Reference: Rocha-Nicoleite, E., Overbeck, G. E., & Müller, S. C. (2017). Degradation by coal mining should be priority in restoration planning. Perspectives in ecology and conservation, 15(3), 202-205.)
	Environmental pollution from tailings dams	waste embankment	The failure of tailings dams can cause significant environmental impact. For inactive impoundments, overtopping has been cited as the primary failure in these incidents. It is likely that a significant contributory factor accounting for the comparative stability of inactive tailings dams lies in the ongoing oxidation and cementation of tailings in the unsaturated zone (Kossoff et al., 2014).	The sheer magnitude and often toxic nature of the material held within tailings dams means that their failure, and the ensuing discharge into river systems, will invariably affect water and sediment quality, and aquatic and human life for potentially hundreds of km downstream (Edwards, 1996; Macklin et al., 1999, 2003, 2006; Anonymous, 2000; Hudson-Edwards et al., 2003) .	The collapse of two tailings impoundments at Stava in northern Italy lead to 250 deaths (Chandler and Tosatti, 1996; Davies, 2001). (https://www.researchgate.net/publication/352933268_Tailings_Dam_Failure_Modes_Recognitions_and_Preventions). Fundao tailing dam - Brasil (Flávio Fonseca do Carmo, Luciana Hiromi Yoshino Kamino, Rogério Tobias Junior, Iara Christina de Campos, Felipe Fonseca do Carmo, Guilherme Silvino, Kenedy Junio da Silva Xavier de Castro, Mateus Leite Mauro, Nelson Uchoa Alonso Rodrigues, Marcos Paulo de Souza Miranda, Carlos Eduardo Ferreira Pinto, Fundão tailings dam failures: the environment tragedy of the largest technological disaster of Brazilian mining in global context, Perspectives in Ecology and Conservation, Volume 15, Issue 3, 2017, Pages 145-151)	Characteristics of and influences on foundation materials that have the potential to progress foundation failure include: Elastic and inelastic compression of the foundation due to surface loads, staged settlement comprising immediate, consolidation, and creep, shrinking and swelling of expansive soils, differential settlement, regional subsidence or movement.	Geological structures; Landslip surfaces; Fissuring in the soil/rock; Presence of clayey; Cohesionless; Dispersive, or soft soils; Presence of weak and weathered layers in the foundation; Predicted seismic activity and flooding (1-in-100 or 1-in-1000 year storm events); Foundation surface inclination/declination; Foundation material characteristics; Including shear strength; Compressibility and permeability; Seepage to groundwater.	Continuous monitoring of ground movements with remote sensing and satellite images in combiantion with in-situ sensors.	Tailing dams design, surveillance and dam safety technologies.	**Ineris (France):** same; **THGA (Germany):** tailing dam failure; **GIG (Poland):** tailing dam failure; **CERTH (Greece):** same	**Ineris (France):** -; **THGA (Germany):** open pit mines; **GIG (Poland):** open and underground mines; **PPC (Greece):** n/a in lignite mines	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** Tailing dam (in Polish "zbiornik poflotacyjny", "staw osadowy", "obiekt unieszkodliwiania odpadów wydobywczych"). Staw osadowy - Tailing pond - a facility intended for the storage of fine-grained mining waste, including waste generated as a result of processing, along with the changing amount of process water, which comes from the processing of minerals from deposits, and from the treatment of process water. Obiekt unieszkodliwiania odpadów wydobywczych - Mining waste disposal facility - a facility intended for the storage of mining waste in a solid, liquid, solution or suspension form, including heaps and tailing ponds, including dams or other structures used to contain, retain, limit or strengthen such a facility (Act of 10 July 2008 on mining waste). **PPC (Greece):** same	 Views downstream of the effects of the tailings dam failure at Stava, North Italy, 1985 (Reference: Kossoff, D., Dubbin, W. E., Alfredsson, M., Edwards, S. J., Macklin, M. G., & Hudson-Edwards, K. A. (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. Applied geochemistry, 51, 229-245.)
	Hydrological disturbances, mining induced floods	pit lake	A common practice to form a pit lake is by flooding the remaining voids after the mine closure. These voids can be filled by artificially flooding or allowing the pits to fill naturally through hydrological and hydrogeological processes such as precipitation or ground water infiltration and inflow.(Burda, J., & Bajcar, A. (2020). Post Exploitation Lakes. Zpravodaj Hnědé uhlí, Most.). Liquidation of opencast workings may also take place by prior partial leveling of the area with the use of post-mining waste and then creating a water reservoir, or by completely filling the open pit with post-mining waste, and then by liquidating the mine drainage system. The flooding of an open pit reclaimed in this way occurs as a result of free recharge with groundwater (lateral and ascending tributaries) and surface water (from watercourses) and atmospheric water (precipitation).	Floods into the pit lake. Pit flooding generally induces groundwater rebound with short and long time consequences, such as soil instabilities causing landslides and subsidence (Burda, J., & Bajcar, A. (2020). Post Exploitation Lakes. Zpravodaj Hnědé uhlí, Most.). Reconstruction of the groundwater table as a result of the sinking of the open pit carries the possibility of ingression of contaminated water in the open pit into the groundwater in its vicinity. On the other hand, the open-pits closure by filling them with post-mining waste and the cessation of mine drainage may cause damming of underground waters and the formation of floodplains on the surface. These hazards may limit the possibilities for development of open pit and adjacent areas.	Concordia pit lake near Nachterstedt (Cała, von Bismarck & Illing, 2014); (Niedbalska K., Bukowski P., 2019: Hydrodynamic consequences of the open pit closure and reclamation in the aspect of laboratory and model tests, International Multidisciplinary Scientific GeoConference: SGEM 2019, Vol. 19/ 1.2, pp 313-320) .	Hydrological disturbance in the lake could be occur due the interaction between the water level of the lake and the hydrologic system and external events (natural or man-made). The increasing of the lake water level can induce the flooding of the adjacent land. Complete filling of the open-pit excavation with post-mining waste may result in a local reduction of the filtration properties in the ground medium, which, after the cessation of mine drainage, may result in uncontrolled damming up of groundwater. As a result, on the surface (in the area of the recultivated excavation) floodplains and wetlands may arise, which may contribute to damage (e.g. in forest, agricultural and built-up areas), and also determine the possible future economic use of these areas. Water reservoirs in open-pit pits will be characterized by a long-term process of physicochemical stratification of water limiting the directions of its use and impact on the surroundings.	The presence of water table communicate with the lake ; The distance between the lake and a river or water current ; The hydrological characteristic of the site (permeability, hydraulic gradients, piezometric pressures); Filtration parameters of post-mining waste used in the reclamation of the open pit; The presence of other local groundwater drainage areas (rivers, lakes, groundwater intakes, drainage network, etc.).	Climatic event ; Heavy raining ; The collapse of hydraulic facilities et infrastructures ; Ground collapse; Seismicity; Wind; Erosion; Monitoring the location of the groundwater table in the local quantitative monitoring network (piezometers, wells); Transformations of the land surface and the course of the water network; The impact of groundwater intakes drainage barriers or isolation changes in surface development; Changes in water quality and the location of the groundwater table in the surrounding area.	Deliberate use of available databases and results of monitoring and satellite, aerial and drone imagery. Prediction of hydrogeological consequences is possible by numerical research methods and using the results of field and laboratory studies of the properties of the surrounding rocks and from hydrogeological monitoring.	**Ineris (France):** same; **THGA (Germany):** pit lake flooding ; **GIG (Poland):** pit lake flooding; **CERTH (Greece):** same	**Ineris (France):** all mines; **THGA (Germany):** surface mines; **GIG (Poland):** surface mines; **PPC (Greece):** all mines	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** "Pit flooding" in Poland is one of the forms (directions) of reclamation of open-pit by flooding. This direction depends on hydrogeological conditions. If mining is carried out from below the water table or in "dry" conditions, but below the natural water table, the pit will fill with water after the cessation of dewatering. The scope of reclamation will include appropriate shaping of the bottom and slopes of the pit (Ostręga A., Uberman R., 2010: Kierunki rekultywacji i zagospodarowania - sposób wyboru, klasyfikacja i przykłady. Górnictwo i Geoinzynieria. Rok 34, zeszyt 4, pp. 445-461). Flooding of the excavation and creation of water reservoirs may also occur by transferring water from surface watercourses; **PPC (Greece):** same	 (Reference: C. Linklater, A. Watson, A. Hendry, J. Chapman, J. Crosbie, P. Defferrard, (2017). Pit lake water quality modelling at Century mine, 9th Australian Workshop on Acid and Metalliferous Drainage.)

HYDROLOGICAL ISSUES/ WATER DISTURBANCES	**Hydrological disturbances, mining induced floods**	surface	While coal mining workings the groundwater is pumped. After the workings are stopped the water table rise back until finds an equilibrium in the new ground conditions.	Regarding the surface coal mine and the aquifer level, the influence of an extreme climate phenomenon- extreme rainfall- can cause floods. The flood can cause severe damage to the equipment, and surrounding infrastructures of the mine and, in the worst case, may injure the workers. Dewatering and flooding of mines will cause effects commonly described in the literature related to lowering or restoring the water table in mine workings and in large areas around the workings.	Kolubara Mining Basin, Serbia (Vujić, S. & Radosavljević, M. & Polavder, Svetlana. (2020). Flooding of Two Coal Open-Pit Mines in Serbia: The Aftermath of Global Climate Change. Journal of Mining Science. 56. 79-83. 10.1134/S1062739120016503)	Hydrological disturbance in the surface could be occurred if the topography (natural or induce, open pit excavation, subsidence), events (natural or man-mad) or the failure of the pumping system. That can induce the flooding of the adjacent land. In a sublevel open pit mine may be initiated among other things: processes of ascension of water of a different quality, altered filtration conditions and directions and hydrogeological properties of the surrounding formations (as a result of upheaval and settlement after dewatering), increase in flow resistance and hydraulic gradients, etc. In an above-ground mine (e.g., quarries), the scale and scope of water problems will be incomparably smaller and involve the drainage of infiltration water and the regulation of the hydrographic network.	The presence of water table communicate with the lake ; The distance between the lake and a river or water current ; the hydrological characteristic of the site (permeability).	Climatic event ; Heavy raining ; the collapse of hydraulic facilities et infrastructures ; ground collapse; seismicity monitoring the location of the groundwater table in the local quantitative monitoring network (piezometers, wells).	We should remember, that other factors may cause hydrological disturbances in areas of location of sublevel open-pit mines (e.g., sand mining, lignite coal mining) however others factors may influence hydrological conditions in the case of above-ground mining (e.g., quarries).	**Ineris (France):** same; **THGA (Gremany):** Polder; **GIG (Poland):** Polder; **CERTH (Greece):** same	**Ineris (France):** all mines; **THGA (Germany):** underground & surface mines; **GIG (Poland):** underground & surface mines; **PPC (Greece):** all mines	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** same (In Polish, polder mean a depressive seaside and river area surrounded by dikes to protect the area from flooding. In Polish conditions, areas flooded as a result i.a.of mine closure and flooding are called "zalewiska" it is mean floodplains or overflowlands)"Zalewiska" - Overflow lands - The accumulation of water in a mining subsidence basin, i.e., in a portion of land lowered as a result of underground mining operations. It is also understood as the sinking of the land surface, i.e. the process and phenomenon of flooding of the surface caused, for example, by surface subsidence or abandonment of drainage. Hydrogeological dictionary. Polish Geological Institute **PPC (Greece):** same	 (a) Flooded Kolubra Mining Basin open-pit mines: 1—Tamanava East Field; 2-Veliki Crljeni; 3—Tamanava West Field; (b) Sketch of machine positions in flooded Tamnava West Field open-pit mine (Reference: Vujić, S., Radosavljević, M., & Polavder, S. (2020). Flooding of two coal open-pit mines in Serbia: the aftermath of global climate change. Journal of Mining Science, 56(1), 79-83.)
	Hydrological disturbances, mining induced floods	underground	After mine closure, pumping is stopped and the aquifer rise back to its origin level. A special case is the need to maintain drainage of an abandoned mine (after damming up water to a safe level) in order to protect neighboring active mines against water hazards, or/and the surface of the land against flooding, or/and against sinkhole hazard or/and against an increase of mine gases pushed out by water.	Potential disturbances or nuisances can affect structures built partially or completely under the surface (e.g., basements, parking garages, underground networks, tunnels, sewers, underground or semi-underground passages). The damming of groundwater during the flooding of mines can cause the migration of mine gases (mainly methane) towards the surface and pose a general threat. Drainage causes depletion of water resources, strengthening of the rock mass and an increase in the main mining hazards (tremors and bumps, fire, methane, etc.). Water damming is the cause of an increase in water hazards for active mines, a change in hydrogeological conditions, a change in the state of sinkhole and environmental hazards associated with the outflow of polluted waters to the surface, the threat of surface flooding, the outflow of mine gases during damming, and the cause of pollution of commercially used aquifers, sometimes an increase in the seismicity of the rock mass in the post-mining area.	Lower Silesian Coal Basin (Wałbrzych area) - eg former Nowa Ruda mine (Fiszer J., Sztuk H., 2004: Water mining damage related to closing down of the Nowa Ruda - Pole Piast bituminous coal mines. Górnictwo Odkrywkowe, Issue 46, No 5/6, pp. 50-54),(Krause E., Pokryszka Z., 2013: INVESTIGATIONS ON METHANE EMISSION FROM FLOODED WORKINGS OF CLOSED COAL MINES, Journal of Sustainable Mining ISSN 2300-3960, Vol. 12 (2013), No. 2, pp. 40–45) MUTKE G., BUKOWSKI P. 2011 - Diagnosis of some hazards associated closuring of mines in Upper Silesia Coal Basin. 11th International Multidusciplinary Scientific GeoConference SGEM 2011, Albena, Bulgaria. Conference Proceedings, 1: 429-436.	The presence of water and hydrostatic pressure in flooded mines limits related to its result in the desorption and migration of methane from the unexploited seams destressed by mining. As a consequence of the water table rising as a result of mine flooding, the following phenomena occur: 1)increase in hydraulic gradients and water pressures, 2) changes in the direction and intensity of water flow, 3) changes in water quality and resources, 4) decrease in strength and increase in deformability of the rocks surrounding the excavations, 5) increase in the threat of rock leaching and sinkholes, 6) changes in water quality and increase in threats to the environment and to the usable water aquifers.	The rate of mine flooding depends on the water capacity of the goafs and the dewatered rockmass as well as the intensity of the water inflow (resultant of local hydrogeological, geological and mining conditions). The rising of the groundwater table during flooding of the mine pushes the mine gases towards the surface. The variability of geomechanical properties of rocks and rock debris in mine workings under the influence of water, rock slakebility, lithological variability, hydrogeological properties of rocks and tectonics of the area, and the method of mining operations affect the reservoir capacity properties of the mine workings and rock mass. The variability of water inflow and outflow conditions, as well as the method of drainage and flooding the mine and the capacity of the mine's free spaces have a definite influence on the course of the flooding process and the prediction of consequences and risks.	Climatic event ; Heavy raining ; the collapse of hydraulic facilities and infrastructures ; ground collapse, seismicity; monitoring the location of the groundwater table in the local quantitative monitoring network (piezometers, wells), monitoring of mine gas concentrations (mainly methane) in research and observation wells, on the surface, in underground installations, etc.		**Ineris (France):** same; **THGA (Germany):** mine water rebound / ground water rebound; **GIG (Poland):** mine water rebound / ground water rebound; **CERTH (Greece):** same	**Ineris (France):** all mines; **THGA (Germany):** underground mines (mine water rebound) or aquifers of mining areas (ground water rebound); **GIG (Poland):** underground mines (mine water rebound) or aquifers of mining areas (ground water rebound); **PPC (Greece):** In underground mines. There are historical data from closed mines (example Aliveri mine)	**Ineris (France):** same; **THGA (Germany):** same; **GIG (Poland):** Mine water rebound (in Polish "odbudowa zwierciadła wód podziemnych") - restoration of the natural (original) state of groundwater level ordinates, i.e. those that existed before the depression of the groundwater table. Hydrogeological Dictionary. Polish Geological Institute **PPC (Greece):** same	 (Reference: Wang, F., Liang, N., & Li, G. (2019). Damage and failure evolution mechanism for coal pillar dams affected by water immersion in underground reservoirs. Geofluids, 2019(1), 2985691.)
GAS/ FIRE	**Ionizing radiation emissions**	underground/surface	The release of high-energy radiation (ionizing radiation) during coal mining.	Miners exposure to radon which causes impact to their health, high concentration of radon in the air is the source of elevated radiation dose.	Ruhr coal mine basin (Germany)Skubacz, K., Lebecka, J., Chalupnik, S., & Wysocka, M. (1992). Possible changes in radiation background of the natural environment caused by coal mine activity. Energy sources, 14(2), 149-153. Upper and Lower Silesian coal basin (Poland) Gliszczynski, G. (1990). Ionizing radiation in mining. Prace Nauowe Lubelskiej Gornictwo;(Poland), 26. Novovolynsk coal basin (Ukraine) Bosak, P., & Popovych, V. (2019). Radiation-ecological monitoring of coal mines of Novovolinsk mining area. News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technical sciences, 5(437), 132-137.	A source of ionization emissions is the Radon. Radon concerns a decay of uranium decay products (radium) which are present in all types of rocks. (M.Wysocka, S. Nowak, S. Chałupnik and M. Bonczyk. 202. Radon Concentrations in Dwellings in the Mining Area—Are There Observed Effects of the Coal Mine Closure? Int.J. Environ. Res. Public Health 2022, 19, 5214. https://doi.org/10.3390/ ijerph19095214; M.Wysocka, K.Skubacz,. I.Chmielewska, P.Urban. 2019. Radon migration in the area around the coal mine during closing process, International Journal of Coal Geology 103253, DOI:10.1016/j.coal.2019.103253; M.Wysocka. 2016. Radon problems in mining and post-mining areas in Upper Silesia region, Poland, Nukleonika 61(3), DOI:10.1515/nuka-2016-0051	Surface: desintegration of rock body due to mining activities (past and temporary), opend pathways for gases in rock, co-migration of methane, CO2 and radon; permeability of subsurface layers and soils.	Radon exhalation from grounds, radon concentration in soil gas, radon concentration in dwelling and othe houses (basements and ground floors). All listed above factors are influenced by physical parameters of soils and rocks, seasons (temperature, humidity of soil, presence of snow layer, heavy rains etc.).	Correlation of effects of subsidence of grounds and elevated radon (gases) migration is observed.	**Ineris (France):** No hazard / related to self-heating and combustion; **THGA (Germany):** Radon exposure / radiation exposure; **GIG (Poland):** Exposure of miners to ionising radiation from radon and its decay products (English). Effective dose 20 mSv/year. Additional doses: 6 mSv/year and 1 mSv/year. Exposure of inhabitants of mining and postmining areas to radon (English). Reference level 300 Bq/m3; **CERTH (Greece):** same	**Ineris (France):** coal mines; **THGA (Germany):** in contrast to other mining sectors, there are no public cases of increased radiation exposure for coal mine workers in Germany. The limit values specified by the mining authority were not exceeded during the active period due to the permanent ventilation in underground mines; **GIG (Poland):** underground mines; **PPC (Greece):** no hazard	**Ineris(France):** same; **THGA (Germany):** Apart from the exposure to miners, it exists as a latent threat in all parts of Germany in varying degrees. Its harmful effects and health risks, however, do not occur outdoors, but mostly in basements or lower levels of buildings. The localities with higher radon risk are already widely known and not limited to mining areas. Apart from a few exceptions, existing leaks at the surface arebound to structural geological anomalies. However, strong (e.g. mining induced) vibrations may cause mobilization and eventually increased concentration of radon and stronger leakages to the ground surface and in buildings. Leakage and concentrations will increase temporarily during the mine water rebound, but will then most likely decrease permanently and will settle in the range of the pre-mining time. Due to short decay times of the various isotopes, radon decays at long flow times or great distance already on the transport path, so that emanation at great depths usually has no significance for the discharge above ground. Radon dissolved in water mostly decays on the way to the surface discharge point; **GIG (Poland):** In the underground mines - No.On the surface: In Upper Silesian Coal Basin (Poland) changes in the rock mass, resulting from coal mining (presence of voids, subsidence, lowering of the water level, rejuvenation of faults, etc.) accelerate the phenomena of surface erosion and karst development, which creates pathways for more intense gas migration. It should be assumed that, in post-mining regions, areas with an increased radon risk occur not only directly above mining excavations or subsidence zones, but also everywhere where rock mass disintegration leads to erosion and karst formation. Elevated concentrations of radon gas are observed in limited numbers of dwelling. However, the average value of radon concentration is higher in post mining area in comparison to areas where minig exploitation did not take place; **PPC (Greece):**same	 (Reference: Wysocka, M., Skubacz, K., Chmielewska, I., Urban, P., & Bonczyk, M. (2019). Radon migration in the area around the coal mine during closing process. International Journal of Coal Geology, 212, 103253.)
	Gas emissions linked to mining	underground	In case of closed down mines, after damming up water to a safe leve (in order to protect neighboring active mines against water hazards) the phenomenon of pushing out of mine gases in some areas is observed. The presence of water and hydrostatic pressure in flooded mines limits the desorption and migration of methane from the unexploited seams destressed by mining. As a consequence of the water table rising as a result of mine flooding, the following phenomena occur: • a drop in the intensity of methane desorption resulting from the effect of increased hydrostatic pressure and filling gas migration with water (residual voids, pores, fissures) • increase of free gas pressure in the workings over the water level, the so-called "piston effect" (Krause E., Pokryszka Z., 2013: INVESTIGATIONS ON METHANE EMISSION FROM FLOODED WORKINGS OF CLOSED COAL MINES, Journal of Sustainable Mining ISSN 2300-3960, Vol. 12 (2013), No. 2, pp. 40–45)	The damming of groundwater during the flooding of mines can cause the migration of mine gases (mainly methane) towards the surface and pose a general threat. Due to hydrogeological disturbances, drainage causes depletion of water resources, strengthening of the rock mass and an increase in the main mining hazards e.g. methan and CO2 emission. Methane is a colorless and odorless gas whose greenhouse potential – the effect it has on the greenhouse effect – is 28 times stronger than that of carbon dioxide (over a hundred years). Moreover in the case of flooding mines, water gradually pushes methane to the surface, which may accumulate, for example, in basements. Penetration of methane to the lower storeys of buildings, garages, as well as telecommunications and sewage channels may cause an explosion hazard at concentrations above 5%, while carbon dioxide may pose a threat to the health and life of residents.	Upper Silesian Coal Basin, Lower Silesian Coal Basin (Poland) (Krause E., Pokryszka Z., 2013: INVESTIGATIONS ON METHANE EMISSION FROM FLOODED WORKINGS OF CLOSED COAL MINES, Journal of Sustainable Mining ISSN 2300-3960, Vol. 12 (2013), No. 2, pp. 40–45) Chećko J., Howaniec N., Paradowski K., Smoliński A. (2021). Gas Migration in the Aspect of Safety in the Areas of Mines Selected for Closure. Resources. 10. 73. 10.3390/resources10070073). (Zawisza L., Macuda J., Chećko J.,: 2005: Ocena zagrożenia gazami kopalnianymi na terenie likwidowanej kopalni KWK Niwka-Modrzejów (eng. Mine gas hazard assessment in the area of the liquidated coal mine KWK Niwka-Modrzejów). Wiertnictwo Nafta Gaz, Issue 22/1, 2005	Coal deposits contain mine gas (mostly methane), when it is influenced by mining activities this gas is emitted into the coal mine (Noack, 1997). The methane release on the surface is a very complex effect that depends on many factors related, among other, on the structure and permeability of the overburden strata, the methane desorption rate from the unexploited gassy coal seams, destressed as a consequence of earlier mining, and the spatial location of these unexploited coal seams in relation to the water level in the flooded mine (Krause E., Skiba J. (2010): Trends of improvement the effectiveness of methane drainage in Polish hard coal mines. International Conference „Advanced mining to sustainable development", Vietnam, Ha Long Bay).	Geological conditions (presence and thickness of the surface impermeable layer), phisical properties of the surface cover (cracks, fissures and pathways of gases and precipitation migration). 1. Gas content and adsorption characteristic of coal (depends on eg. storage capacity of coal which results from coal's internal pore structure) 2. Methane flow capacity of the mine (depends on eg. permeability (K) of the porous media (coal); the area (A) of gas outflow from unmined coal (area of exposed coal); the pressure gradient from the coal to the void space of the mine 3. Mine flooding proces (gas outflow depends on the pressure balance between the gas within the coal and the water in the coal cleat system) 4. Active vents (methane emissions from venting mines are a function of the pressure differential between the vent and the gas in the coal bed) 5. Mine seals (mine seals can impact the rate of flow, they are not considered to be effective at preventing atmospheric methane emissions over time) (U.S. Environmental Protection Agency, April 2004: Methane emissions from abandoned coal mines in the Unitet States: Emission inventory methodology and 1990-2002 emissions estimates)	In situ sampling of soil gases. Detailed isotopic composition of gases (in lab). In situ sampling of soil gase. Controlling the concentration of mine gases in liquidated hard coal mines, mainly methane (so-called AMM - abandoned mine methane) is necessary to assess the risk of, for example, emissions of, among others, greenhouse gases into the atmosphere. The method and frequency of measurements must be adapted to the individually selected direction and method of mine liquidation. Markings should be carried out in mine shafts (if they exist), in boreholes, research holes, piezometers, as well as in basements, sewers, wells. Mine gas content tests can also be carried out in groundwater and soil. The ability to conduct these studies depends on the local climatic and urban conditions, atmospheric conditions - preasure, temperature, moisture.		**Ineris (France):** mining gas; **THGA (Germany):** Mine gas / Firedamp; **GIG (Poland):** gas emission; **CERTH (Greece):** gas emission	**Ineris (France):** -; **THGA (Germany):** (CH4, CO, CO2, H2S, NOx) in underground mines; **GIG (Poland):** (CH4, CO2 ,CO, SOx, Nox, HFCs) in underground mines. In mining and post mining areas elevated emission of gases to atmosphere is observed. The larges contibutors are CH4 and CO2; **PPC (Greece):** In underground mines. There are historical data from closed mines (example Aliveri mine)	**Ineris (France):** same; **THGA (Germany):**same; **GIG (Poland):** same; **PPC (Greece):** same	  (Reference: Ineris (2019). Post-mining Hazard Evaluation and Mapping in France. Ineris DRS-19-178745-02411A)
	Combustion and overheating of mine waste	waste embankment	Mine wastes, the products of mining, are deposited in nearby dumps. Their deposition leading to an endogenic fire as a result of a physical-chemical reaction(Ciesielczuk et al., 2014; Misz-Kennan & Fabianska 2011). In the conditions of access of oxygen to the interior of the heap of post-mining waste rich in organic substance (coal), fires may arise, which are extremely difficult to extinguish.	Uncontrolled fires, the organic matter of the waste materials contains toxic elements, which pollute air, water and soil, such as greenhouse gases and heavy metals. Some of gases emmited as the result of fires and self-ignition pose significant human health hazard (eg. Polycyclic Aromatic Hydrocarbons PAHs) resulting in skin, lung and stomach cancer (Janoszk T., Gogola K., Bajerski A.: Influence of anti-pyrogenic materials on coal mining waste's tendency to self-ignite. Journal of Sustainable Mining 15(2016) 170-174). Other emmited gazes ,influencing environment and inhabitants are: carbon dioxide and monocide, sulfur dioxide, hydrogen sulfide, phenols, benzen, toluen, ethylbenzen and xylen (Smoliński at al. An analysis of self-ignition of mine waste dumps in terms of environmental protection in industrial areas in Poland. Scientific Reports, 2021/04/23, vol.11, 10.1038/s41598-021-88470-7 Such a heap burns point by point, and the process itself can last from several days to even several years. The fire can also move along such a heap. As a result, huge amounts of harmful gases and dust are released into the atmosphere, and the process itself may contribute to the formation of landslides, sinkholes, land subsidence, etc., posing a general threat.	Upper Silesian Coal Basin (Poland) (Różański, Z. Wrona P., Pach G., Niewiadomski A.P., Markowska M., Wrana A., Frączek R., Balcarczyk L., Quintana G.V., de Paz Ruiz D., Influence of water erosion on fire hazards in a coal waste dump — A case study, Science of The Total Environment, Volume 834, 2022, 155350, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2022.155350). Kentucky's coal combustion (USA) Railbelt coal combustion (Alaska)	The release of energy in the form of heat results from physical and chemical transformations inside the waste dump that depend on the supply of oxygen and water to the waste (Gogola K., Rogala T., Magdziarczyk M, Smoliński A. The Mechanisms of Endogenous Fires Occurring in Extractive Waste Dumping Facilities. Sustainability 2020, 12, 2856.)	The tendency of self-ignition depends, among other factors, on way of waste's storage, the granulation of waste material, waste compaction, presence of cracks and pathways enebling gases migration, possibilities of infiltration of water (possible factor of self-ignition). The coal (amount) presence in the wastes is fundamental factor influencing the self-ignition of the mining waste. To sum up, the factors favoring self-heating and self-ignition of coal are: its ability to chemisorption of oxygen (oxyreactivity resulting from the chemical composition, the degree of coalification and fragmentation), poor thermal conductivity of the environment favoring the accumulation of heat up to the ignition temperature of coal, the presence of oxidized pyrite and facilitated access of oxygen and water to coal	The tendency of coal mining wastes to self-ignite is calculeted basing on petrograpic and geochemical analyses of samples collected from heaps. Oxy-reactive thermal analysis (OTA). In situ analysis (observation of changes in the landfill cover (snow and plants), thermovision observation). Mapping and monitoring strongle depends of atmospheric conditions : surface insolation, presence of snow cover, intensity of precipitation, moisture content		**Ineris (France):** self-heating / combustion; **THGA (Germany):** Methane emissions from mining waste dumps; **GIG (Poland):** Endogenous Fires of post-mining wastes, Self-heatinf, Self-ignition; **CERTH (Greece):** same	**Ineris (France):** coal mines; **THGA (Germany):** underground and open pit mines; **GIG (Poland):** Yes, in underground mines - coal self ignition and endogenous fires. On the surface - on waste heaps. With regard to the areas where extractive waste has been deposited, the possibility of self-ignition constitutes one of the most serious environmental threat; **PPC(Greece):** In external dumps.	**Ineris (France):** same; **THGA (Germany):**same; **GIG (Poland):** same; **PPC (Greece):** same	 (a) Coal waste heap during spontaneous combustion (b) symptom of self-heating in large fracture commonly observed in Wuda coal mining area (c) spontaneous combustion of open bords (d) highwall at New Vaal, South Africa (Reference: Onifade, M., & Genc, B. (2019). Spontaneous combustion liability of coal and coal-shale: a review of prediction methods. International Journal of Coal Science & Technology, 6(2), 151-168.)

Guidelines on using the database
Row 1: the first row of the file describes the information gathered for all hazards. These fields are essential for describing, understanding, evaluating the impact, and devising responses to each hazard.
Column A: the four categories of the identified hazards are ground movement, environmental pollution, hydrological issues/water disturbances, and gas/fire.
Column B "Name of hazard": the provided list includes all post-mining hazards identified by the partners, and it serves as the basis for multi-hazard identification and analysis.
Column C "Mine type": the four types used are surface mine, underground mine, waste embankments, and pit-lake. This column illustrates the type of the post-mining area where each hazard has the potential to occur.
Column D "Description": communicates vital information on hazards' based on a format-free description.
Column E "Description of effects and consequences": details the societal, financial, environmental, and any other consequences arising from the occurrence of a hazard.
Column F "Illustration and examples concerning each coalmine hazard": references specific instances where each hazard has occurred in a post-mining area.
Column G "Description of mechanisms leading to the phenomenon occurrence": describes the conditions that can lead (and have been reported to lead in the past) to a hazard occurrence.
Column H "Main variables and factors influencing phenomenon predisposition and/or occurrence and intensity": lists the primary causal factors that increase the likelihood of each hazard occurring or tend to promote their occurrence.
Column I "Main variables and factors influencing phenomenon mapping and monitoring": lists the main variables that can affect the monitoring process of a post-mining area.
Column J "Additional information and comments": includes any supplementary valuable information that did not belong to any of the existing required fields.
Column K "What is the name or term in each country?": the input for this column was obtained from national data concerning post-mining hazards. This information aims to validate the identification of hazards and highlight disparities in terminology across different countries.
Column L "Does it exist at a national level – in what type of mines it occurs?": the input for this column was obtained from national data concerning post-mining hazards. This column provides information about post-mining hazards that may occur in each respective country and specifies the types of abandoned mines in which they can happen.
Column M "Is the given phenomenon description different from the relative national description? If yes, provide the national description": the input for this column was obtained from national data concerning post-mining hazards. This column illustrates descriptions of each hazard at a national level. Any variations from the descriptions provided in the database are highlighted.
Column N "Picture or sketch for each hazard": this column presents pictures and/or sketches, which depict and describe the occurrence or the potential of each identified hazard.

In the following are listed all the cited references in the database:

- Galvin, J. M. (2016). *Ground engineering-principles and practices for underground coal mining* . Springer.
- Bell, F. G., Stacey, T. R., & Genske, D. D. (2000). Mining subsidence and its effect on the environment: some differing examples. *Environmental Geology* , *40* , 135-152.
- Li W X, 2003. Fuzzy models of analysis for rock mass displacements due to underground mining in mountain areas. Mathematics in Practice and Theory, 33(2): 26-30.
- Song Y H, Nie D X, Chen Long, 2003. Analysis on deformation and failure model of excavating slope and prediction. Journal of Calamity, 18(2): 32-37.
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