THE OPERATIONAL PROGRAMME ENVIRONMENT

EUROPEAN UNION
European Regional Development Fund | For Water, Air and Nature

ASSOCIATION OF

OCHRANA PODZEMNÍCH VOD s.r.o.

Fundamental Principles for Investigating and Assessing Risks of Abandoned Waste Facilities

PRAGUE, January 2012

THE OPERATIONAL PROGRAMME ENVIRONMENT

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Content

List of abbreviations

ABA - acid-base accounting
CGS - Czech Geological Survey (project managed by Czech Geological Survey – Geofond until 31 December 2011)
EU - European Union
ID – AWF identification number
MoE - Ministry of the Environment
NNP - Net neutralization potential
NP - Neutralization potential
AWF – abandoned waste facility
PHAWF - potentially hazardous abandoned waste facility
HAWF - hazardous abandoned waste facility
ENV - the environment

1. Introduction

This is a summary of the work methodology "Investigation and Analyses at Selected Sites and Assessment of Hazardous Mining Waste Facilities" of 14 October 2011, which is available online in full Czech text at www.geology.cz.

The principal aim of the methodology is to develop a unified procedure and optimize all investigative and related work for the purpose of developing an Inventory of Hazardous Mining Waste Facilities.

2. Definition of key terms

Key terms used in this methodology:

risk assessment: waste facility assessment procedure; a comprehensive assessment of the conditions of a site and of the impacts of stored mining waste on the environment and the public health in its vicinity;

ministry: Ministry of the Environment of the Czech Republic;

authorized person an individual who is a qualified expert in the risk assessment of mining waste management to the extent specified in § 2, par. (1), h) of Decree No. 298/2005, Coll.

abandoned waste facility: hereinafter AWF, a waste facility, whose original operator or legal successor no longer exists or is unknown – see § 2, par. (2), d) of Act No. 157/2009 Coll., on mining waste management and amendments to certain acts (hereinafter "act");

potentially hazardous abandoned waste facility: hereinafter PHAWF, a site which may, based on the inventory of sites, be legitimately classified as a PHAWF;

inventory: hereinafter IHAWF; a CGS database which contains key information on abandoned waste facilities, assessed as hazardous to public health and the environment, and which is updated continuously – see § 17, par. (4), b) of the act;

hazardous abandoned waste facility: hereinafter HAWF is an AWF, where the results of a risk assessment show that it is an AWF which may pose serious risks to public health and the environment according to the assessment of an authorized person, taking into account primarily the size and location of the waste facility. An AWF may also be classified as an HAWF based on an assessment of the amount of hazardous mining waste stored or the volume of hazardous chemical substances and agents contained in the mining waste stored with regard to the limit set forth in the statutory instrument – see § 4, par. (2) of the act;

mining waste:	any waste which the operator is disposing of or intends to or is obliged to dispose of, and which is generated a) during deposit exploration, mining, processing or storage of minerals and which according to the Waste Act belongs among waste from the extraction or processing of minerals, or b) during the extraction, processing or storage of peat - see § 2, par. (1) of the act;
waste facility	a mine structure which is designated for the storage of mining waste in a solid or liquid state or in solution or suspension, including tailing ponds, and which usually includes a dam or other structure serving to contain, retain, confine or otherwise support such a waste facility, with the exception of excavation voids into which mining waste is replaced after extraction during remediation, reclamation and construction – see § 2, par. (2), c) of the act;
act:	Act No. 157/2009, Coll. (on mining waste management and amendments to certain acts).

3. Legislative scope of the project

Methodical guidance, instruction and information of the EU:

- Directive 2006/21/EC on mining waste management
- Guidance document for a risk-based pre-selection protocol for the inventory of closed waste facilities as required by article 20 of Directive 2006/21/EC; 2/2011

Key regulations regarding mining waste in the Czech Republic:

Government acts and decrees

- Act No. 62/1988 Coll., on geological work, as amended
- Act No. 157/2009 Coll., on mining waste management and amendments to certain acts
- Act No. 167/2008 Coll., on prevention and remediation of environmental damage
- Government Regulation No. 295/2011 Coll., on the method of environmental damage risk assessment and detailed conditions on funding

Decrees

- Czech Mining Authority Decree No. 104/1988 Coll., on efficient use of reserved deposits, on permits and notification of mining operations and activities involving mining, as amended;
- Czech Mining Authority Decree No. 99/1992 Coll., on establishing, operating, safeguarding and liquidating facilities for the disposal of waste in underground facilities, as amended;

- MoE Decree No. 206/2001 Coll., on certification of professional competence in planning, performing and evaluating geological work;
- MoE Decree No. 282/2001 Coll., on registration of geological work, as amended by Decree No. 368/2004 Coll.;
- MoE Decree No. 369/2004 Coll., on planning, performing and evaluating geological work, notification of geohazards and on the procedure for estimating reserves of reserved deposits, as amended;
- Czech Mining Authority Decree No. **298/2005 Coll.**, on requirements for professional qualification and competence in mining or activities involving mining and on amendments to certain legal regulations, as amended;

4. Key concept in risk assessment of abandoned waste facilities

Article 20 of Directive 2006/21/EC on mining waste management (hereinafter "Directive") requires the development of an inventory of closed waste facilities, including abandoned waste facilities, which pose a serious threat to the environment or may become in the short or long term a serious threat to the environment or human health. The inventory must be made available to the public by 1 May 2012.

The "GUIDANCE DOCUMENT FOR A RISK-BASED PRE-SELECTION PROTOCOL FOR THE INVENTORY OF CLOSED WASTE FACILITIES AS REQUIRED BY ARTICLE 20 OF DIRECTIVE 2006/21/EC" was presented in February 2011 for the preliminary screening of AWF in the countries of the EU. The guidance document provides measures, procedures and guidance for the prevention of adverse effects on the environment caused by the management of waste from extractive industries and the resulting risks to human heath or for the highest possible reduction of such impacts, primarily when involving water, air, soil, flora, fauna and the landscape. A pre-selection protocol represents the first decision-making step in eliminating small or insignificant AWF from those AWF sites that pose or may pose a risk to the environment or human health in the short or long term. The development of the pre-selection protocol is a process that separates hazardous AWF from the investigation of many other less significant sites and their possible inclusion in the inventory.

The above-mentioned document allows for a preliminary assessment of the risk potential of AWF by using simple criteria, which are either accessible in existing databases (e.g. the CGS database in the CR), or easily obtained and assessed. This assessment should lead to the elimination of those AWF which do not pose a serious threat to the environment or health neither in the present, nor in the future.

Key criteria for the classification of mining waste facilities in accordance with Annex III of the Directive were specified in European Commission Decision No. 2009/337/EC of 20 April 2009. In order to provide for a uniform assessment of the criteria listed in Annex III of Directive 2006/21/EC, a

methodology must be defined and, if possible, maximum values determined regarding various types of waste management facilities, their behaviour in the short and medium term as well as during their operation.

A Prevention Principle was established, which with the aid of the pre-selection protocol results in the selection of those AWF that upon further investigation will or will not be included in the HAWF inventory. In the case of a lack of information, i.e. in the case of uncertainty, a DON´T KNOW response corresponds to a YES response, and the site must be investigated further, which should confirm the inclusion or exclusion of the AWF in or from the inventory.

When assessing the level of risk to human health, it is particularly important to consider if persons (other than workers working at the facility) that might be affected will be present permanently or for prolonged periods in the potentially hazardous area. If persons will be present permanently or for prolonged periods in the potentially hazardous area, the risk will be assessed as being high if the exposure scenario shows above limit effects on persons due to detected contaminants and if the resulting value exceeds an unacceptable limit in the risk assessment. Risks leading to disability or prolonged illness shall always be considered as serious dangers to human health and a high risk level of AWF. Chapter 10 (Conclusion) includes a table for the classification of the level of risk.

The potential level of risk for an important ecosystem **shall not be considered as being high** if:

a) the intensity of the potential contaminant source will decrease significantly within a short time;

b) the contamination does not lead to any permanent or long-lasting damage to the ecosystem;

c) the affected ecosystem can be restored to its original state through minor clean-up and restoration efforts;

d) the effects on infrastructure can be remedied through minor remediation efforts (simple technical equipment).

The following time horizons have been accepted as definitions for short-term, medium-term and long-term impacts:

Short term ……….6 to 12 months
Medium term 1 to 10 years
Long term greater than 10 years

5. Protocol for preliminary risk assessment of abandoned waste facilities

The potential risk level of AWF from mining – abandoned waste facilities – is assessed in the "**Protocol for Preliminary Risk Assessment of Abandoned Waste Facilities**" (see Appendix 1) according to criteria of an objective and subjective nature. The criteria are sorted according to their importance as follows:

A. Criteria evaluated objectively:

- type of mineral mined (sulphidic ores containing the minerals Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Te, Tl, V, Zn and asbestos);
- presence of the above-listed harmful substances in the mining waste (ore minerals);
- size of AWF (greater than 1 ha);
- depth of tailing pond (greater than 4 m);
- height of AWF (greater than 10 m).

B. Criteria evaluated subjectively:

- signs of damage in the vicinity of AWF caused by mining waste;
- secondary dust nuisance, formation of fine fractions;
- possible contamination of surface water;
- possible contamination of groundwater;
- possible contamination of soil cover;
- possible contamination of the surroundings through emissions originating at AWF;
- overall importance (important AWF, which adversely affect the surroundings, necessary to be treated with appropriate remediation in the case of a real hazard);
- location of AWF in relation to risk receptors – provided with a conceptual diagram.

If data on objectively evaluated criteria, particularly the contents of heavy metals, chemical composition of surface and ground water, etc., are not available, then they must be completed by carrying out field work, laboratory analyses and an evaluation of results, and included in the inventory. This is dealt with in the following chapters.

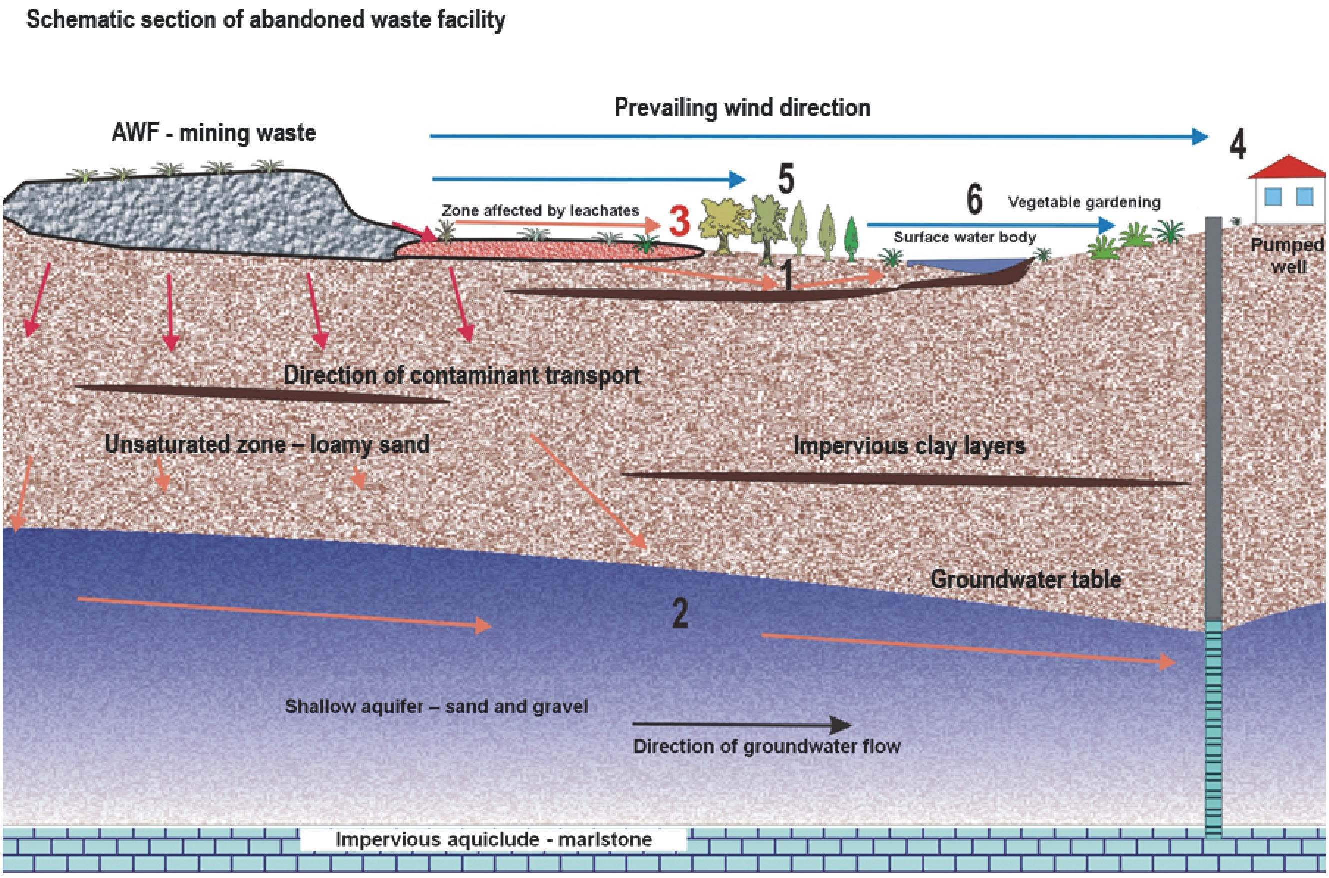
6. Preliminary conceptual model of abandoned waste facilities

The preliminary conceptual model of abandoned waste facilities is an essential part in the development of the project for conducting investigations and risk assessments. The model must be based on an evaluation of the mining history of the site, on the use of the area, available data on contamination of the site, and on an assessment of possible migration and exposure pathways.

The preliminary conceptual model is supplemented gradually with all current facts determined during site reconnaissance. The preliminary conceptual model includes a summary of anticipated exposure pathways from individual sources of contamination via real transport pathways and realistic scenarios of exposure of potential risk receptors, i.e. the population and individual components of the environment. This conceptual model serves as the basis for planning and justifying the extent of field investigations and sampling work. A key criterion for the completeness and accuracy of the conceptual model of a facility site is that it cannot not be inconsistent with any known facts about the site, on the contrary it must logically explain the current situation at the site.

It is useful to supplement the conceptual model with a diagram illustrating the direction of exposure pathways. The following figure illustrates an example of a complete conceptual model of an AWF:

Figure 1: Example of a conceptual model of an abandoned waste facility



Examples of possible exposure scenarios:

Exposure pathway no.	Contamination source	Transport pathway	Reality of exposure	Risk receptors	Note
1	AWF – mining waste	Release of soluble forms of heavy metals into surface water → groundwater transport → drainage into surface water → accumulation of	YES/NO	Surface water and persons involved in fishing (exposure via ingestion)	In a view of the distance and dilution, there is no significant risk if the surface water level is not being drawn down by water pumping

Exposure pathway no.	Contamination source	Transport pathway	Reality of exposure	Risk receptors	Note
		contaminated soil of surface water			
2	AWF – mining waste	Release into and dissolution in groundwater → groundwater transport → water pumping via wells	YES/NO	Population (potable water – exposure via ingestion, dermal contact and inhalation)	The risk is rather hypothetical because of the distance and dilution of seepage water by uncontaminated water from the AWF surroundings
3	AWF – mining waste	Release into and dissolution in seepage water → drainage into wetlands and surface water → accumulation of contaminated soil → ground and surface water transport	YES/NO	Forest ecosystem	The risk has already occurred and acidic leachates from the AWF continue to have an effect – part of the forest has died
4	AWF – mining waste	Emission of dust with toxic metals into the atmosphere → air pollutant fallout on arable land → decrease in soil fertility and contamination of crops	YES/NO	Population (consumers of crop products – exposure via inhalation)	Unlikely, the AWF is already overgrown
5	AWF – mining waste	Emission of dust with toxic metals into the atmosphere → air pollutant fallout on forest land	YES/NO	Forest ecosystem	The risk is rather hypothetical – the AWF is already overgrown
6	AWF – mining waste	Emission of dust with toxic metals into the atmosphere → air pollutant fallout on agricultural land	YES/NO	Population (consumers of crop goods - exposure via ingestion)	Unlikely, the AWF is already overgrown

7. Theoretic aspects of sampling abandoned waste facilities

Sulphide oxidation is the basic process which produces acid mine drainage followed by adverse effects on the surroundings of AWF.

The basic procedure for determining the nature of mining waste and its liability to produce acidic leachates is acid-base accounting (ABA). The method according to Sobek is commonly used (Sobek et al. 1978, EPA-600/2-78-054).

Determination of pollutants in aqueous extracts

This method is used as a substitute for unobtainable water samples and for determining the amount of relatively loosely bound contaminants (e.g. via adsorption, cation exchange or in soluble precipitated salts). However, a release of more strongly bound contaminants, such as contaminants precipitating together with hydroxides and iron oxides, does not occur.

Advantages: Provides relatively good information on easily mobilized contaminant fractions and thus substitutes analyses of water samples, if these are not available. The pH level of the extract represents a longer term parameter in comparison to paste pH.

Disadvantages: At a neutral pH, only loosely bound contaminants are released from the surface of the solid phase. However, if a significant change in pH and Eh conditions occurs, the released amount of contaminants may be much higher. In the case that the pH of a collected sample was already low, the released amount of contaminants may be relatively representative.

Field determination of pH and conductivity in aqueous extracts – paste method

This method is used to quickly determine if the neutralization capacity of the solid phase has been exceeded. The exchange sites on the surface of the solid phase are occupied by H^+ ions, which are released into the extract, just like precipitated highly soluble minerals. As in the case of the aqueous extract method, this method is a substitute for missing water samples. Even if water is available, this method may be used as a supplement to water sampling and analyses.

Advantages: A very quick and inexpensive method of determining whether acidic and highly mineralized water was already produced.

Disadvantages: Represents a short-term indication, i.e. if the sample contains neutralizing minerals, which dissolve slowly (e.g. dolomite), the pH value may be underestimated in comparison to a longer term extract.

Determination of pollutants in surface and groundwater

The most common method for determining the mobility and concentrations of contaminants, which are transported primarily in the aqueous phase. It provides information on direct acidity (connected with the pH of the solution) as well as on indirect acidity (connected with dissolved Fe^{2+} and Al^{3+}), which is generated during the precipitation of hydroxides. It serves as a basis for geochemical calculations and for predicting how far a contaminant cloud can migrate from waste.

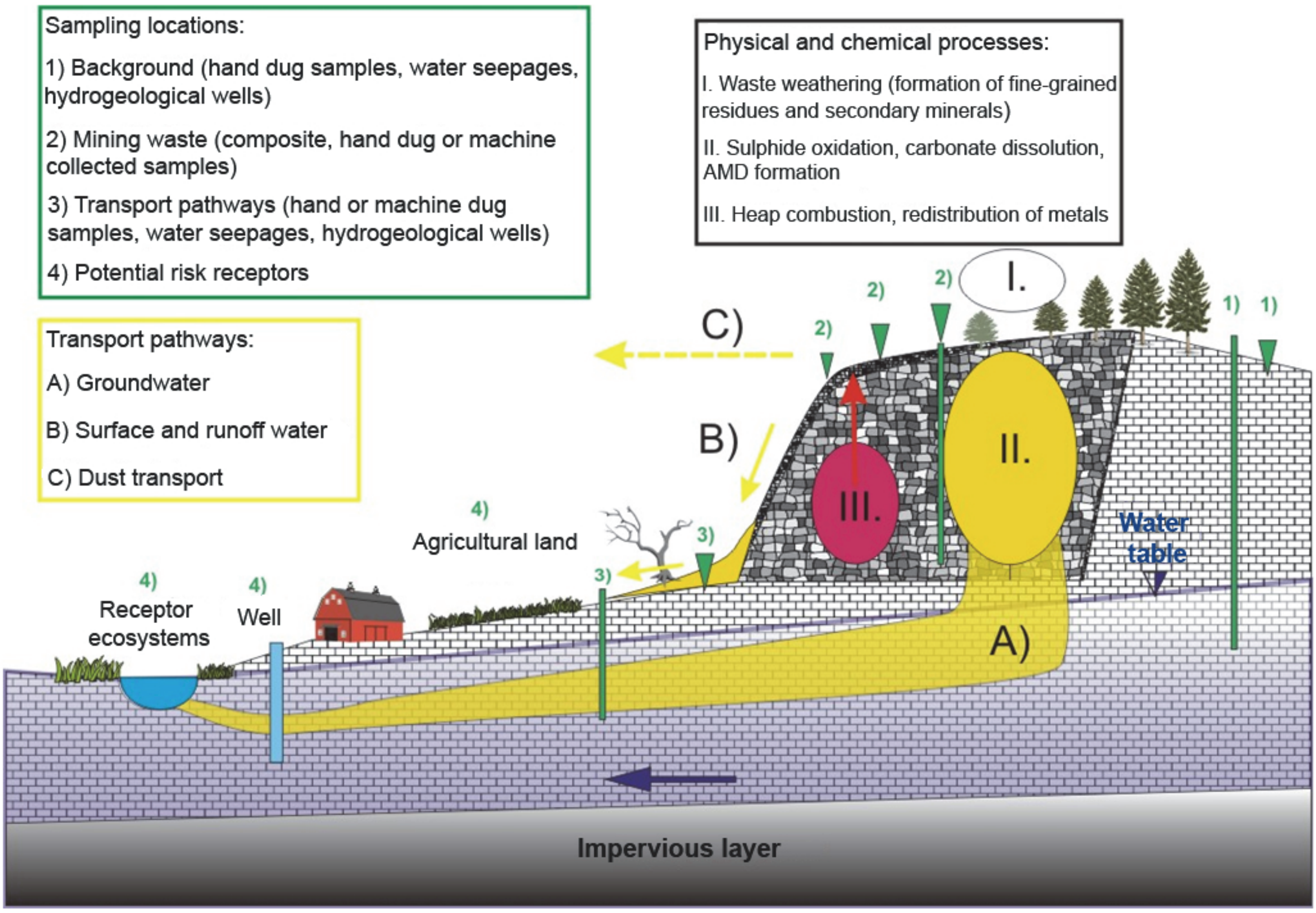
Advantages: This method directly indicates the formation of acid mine water. It is relatively less expensive because a decomposition of the solid phase does not have to be carried out.

Disadvantages: If the pH is currently almost neutral, it cannot be determined if a depletion of neutralizing minerals (mainly carbonates) in the mining waste will not occur in the near future and if therefore the state is only temporary in the case of neutral water with low contaminant concentrations. Another problem lies in the fact that, particularly in the summer period, water used for sampling cannot be found at many AWF. However this does not apply to tailing ponds, which down from a certain depth always contain water.

8. General concept of sampling

Based on the site assessment included in the scope of the preliminary conceptual model and on a selection of realistic scenarios of anticipated exposure pathways from individual contaminant sources to potential risk receptors, adequate soil and water samples must subsequently be collected and analyzed. For the purpose of unifying the methods of sampling at facility sites with various types of mining waste, the following sampling design is proposed:

Figure 2. Sampling locations at abandoned waste facilities



In the case of solid materials, sampling at the majority of sites shall include:

1) **one soil sample representative of the unaffected background around the AWF or tailing pond** (location **1)** in Figure 2.
2) **one sample of materials stored at the AWF** (location **2)** in Figure 2.
3) **one sample from the AWF surroundings representing the affected AWF surroundings**, from the potential contaminant transport pathways, i.e. from areas identified during field reconnaissance as areas most likely to be affected by AWF. An indication of transport pathways is, for example, possible based on the presence of fine-grained material washed out from the AWF, of gravitationally displaced waste, signs of damage to vegetation, etc. (location **3)** in Figure 2.

9. Investigation methodology for assessing potentially hazardous AWF

The assessment of potentially hazardous abandoned waste facilities consists of performing field, sampling, laboratory and other technical work and its evaluation. The extent of the work performed must correspond to the required output, i.e. a conceptual model of the waste facility with a summary of possible exposure pathways (i.e. pathways of contaminant migration from the source to the receptor) shall be developed for each AWF. The outcome shall result in a report on the investigation of a PHAWF, which shall primarily contain key data on a facility site, a summary of work performed, an evaluation of results, and a preliminary assessment of the AWF in terms of risk potential. In the case of hazardous AWF, the report shall recommend other investigations and site assessments regarding the level of risk.

Recommended investigation procedure:

I. Initial work

Archive research and preparation of work according to legislation currently in force.

II. Field work

II.1. Geobotanical assessment

In this work phase a geobotanical assessment including an evaluation of the vegetation cover, particularly with regard to the indication of a primary pathway of pollutant migration, shall be carried out at each site.

II.2 Sampling

It is assumed that, on average, three exploration boreholes shall be drilled at each site, specifically with a hand auger set to a depth of 2 - 7 m (depending on conditions). If it is impossible to drill the boreholes manually (e.g. rocky terrain), trial pits shall be dug to a depth of approximately 1 - 2 m.

The probe holes shall be located at the AWF and in its vicinity below the site, i.e. downstream of the anticipated flow of surface and groundwater in a way to detect any possible leachates from the materials at the facility, and above the AWF, so as to possibly characterize the unaffected background.

The probe holes shall be backfilled after documentation and sampling is carried out.

Soil and water samples shall be collected according to the recommendations of norms. While sampling is carried out, measurements of the physical-chemical parameters of water or aqueous extracts (temperature, pH, conductivity, possibly redox potential) shall be made.

II.3 Engineering geologic assessment

In this phase it is assumed that basic engineering geologic field observations and measurements shall be carried to an extent sufficient enough to create an engineering geologic assessment of the AWF. All the instability elements of the AWF and its closest surroundings shall be documented.

II.4 Surveying

Determination of the locations of probe holes and surface sampling shall be made.

III. <u>Laboratory work</u>

Chemical analyses of soil and water samples shall be performed by authorized laboratories.

The minimum scope of chemical analyses of soil and mining waste includes:

- total sulphur and inorganic carbon
- heavy and toxic metals (primarily Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Te, Tl, V, Zn) and asbestos (if it may occur at the AWF) – see EU documents, e.g. Guidance Document;
- petroleum hydrocarbons in the range of $C_{10} – C_{40}$ – a minimum is one sample, which shall be the only composite sample of mining waste, if there are no perceptible indications of these contaminants at the site.
- total and soluble cyanides (only in the case of tailing ponds, if they may occur there)
- leachate pH and conductivity.

The minimum scope of chemical analyses of aqueous extracts from soil includes:

- heavy and toxic metals (particularly Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Te, Tl, V, Zn) and asbestos (if it may occur at the AWF) - see EU documents, e.g. Guidance Document;
- petroleum hydrocarbons $C_{10} – C_{40}$ – only one sample in the case that an above limit content of these pollutants above 500 mg/kg of dry matter is detected in the solid matrix.
- total and soluble cyanides (applies only to tailing ponds, if they may occur there)
- leachate pH, conductivity, alkalinity, sulphates, chlorides, Ca, Mg, Fe, Mn.

The minimum scope of water analyses includes:

- basic chemical analysis;
- heavy and toxic metals in filtered samples (particularly Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Te, Tl, V, Zn) and asbestos (if it may occur at the AWF) - see EU documents, e.g. Guidance Document;
- petroleum hydrocarbons C_{10} – C_{40} – a minimum of one sample, which shall be the only sample from the AWF or areas below it, if there are no perceptible indications of these contaminants at the site.
- if applicable, total and soluble cyanides (applies only to tailing ponds, if they may occur there)
- hydrochemical data (temperature, pH, conductivity, possibly redox potential).

IV. Documenting investigations

Geological documentation of investigations must correspond to legislation currently in force.

V. Assessment of basic investigation work

The assessment of investigation work shall be carried out in accordance with legislation currently in force. A report with a risk assessment of the AWF, containing the determined and evaluated geological, geobotanical, hydrogeological, engineering geologic, geophysical, geochemical data and data related to possible risks, shall be prepared for each PHAWF.

VI. Risk assessment approach

All the data obtained during the preliminary investigation of potentially hazardous abandoned waste facilities shall be assessed by experts and in an appropriate manner. Limits set according to acts, decrees and other guidelines, concerning the impact of abandoned waste facilities, shall be used for the preliminary assessment of laboratory results regarding risk potential.

The conceptual waste facility model prepared for each site shall include realistic diagrams of the possible adverse effects of the stored mining waste on the surroundings, and shall specifically illustrate the direction of exposure pathways – see Chapter 6.

If realistic exposure scenarios are identified, specific legislative limits shall be used for a given scenario.

The preliminary risk assessment of abandoned waste facilities shall be summarized according to the table given as an example in the following chapter.

The preliminary assessment of the total risk level shall result in a determination whether the work performed did or did not identify negligible, low, medium or high risk levels connected to the existence of an abandoned waste facility.

The final output of the basic investigation work and assessments performed is an investigation report with a preliminary assessment of the AWF risk level.

10. Methodology for final investigation and assessment of hazardous AWF

Potentially hazardous abandoned waste facilities, where realistic scenarios of risk to the population or ecosystem shall exist, shall be investigated in such a manner, so that a quantitative assessment of risk levels and subsequent proposals of follow-up measures (including proposed AWF monitoring) can be prepared.

I. Initial work

Initial work (e.g. project preparation) must correspond to legislation currently in force.

II. Technical work

Technical work, its execution and liquidation must correspond to legislation currently in force.

III. Sampling and field measurements

Sampling shall be performed in accordance with legislation, norm recommendations and internal guidlines (see Appendix 2).

III.1. Soil sampling

One rock (soil) sample shall be collected from each investigation site, a water sample shall also be collected if groundwater is encountered. It is assumed that a total of three samples of soil (possibly mining waste) shall be collected.

III.2 Water sampling

Water samples shall be collected from each investigation site if the water table is encountered. Water samples from surface watercourses, located near a site, shall also be collected. The sampling location shall be situated in the surface water body, located downstream of the possible flow of surface and groundwater from the waste facility, so that the sample may be representative of the water, potentially contaminated by leachate from the waste facility. Water samples shall also be collected above the waste facility in such a manner, so that changes in water quality may be recorded.

It is assumed that a total of six water samples shall be collected in this work phase.

III.3. Samples for engineering geologic purposes

One soil sample shall be collected for engineering geologic purposes from each exploration borehole. It is assumed that a total of three samples shall be collected at each site investigated for the purpose of a basic classification analysis.

III.4. Sample delivery to laboratories

Samples shall be placed in a cooler box (depending on climatic conditions) and delivered to a laboratory, accredited for a given type of analysis, immediately after being collected.

III.5. Gasometric measurements

The drill core shall be monitored using the gas analysis during the course of drilling, if needed (for AWF contaminated with oil products or related to coal mining).

III.6. Hydrochemical measurements

Field measurements of physical chemical parameters (temperature, pH, conductivity, possibly redox potential) shall be made while groundwater samples are collected from exploration boreholes as well as from surface watercourses.

III.7. Rapid hydrodynamic test

A rapid hydrodynamic test (SLUG test) shall be carried out at each hydrogeological well (SLUG test). It is assumed that a total of three hydrodynamic tests shall be performed at a single AWF.

IV. Engineering geologic work

In this phase, engineering geologic comparisons and measurements shall be made in the field to the extent necessary for the determination of the basic EG characteristics of the waste facility and its basement with regard to stability. Engineering geologic measurements (determination of grain size and classification) shall be made on collected samples in a laboratory. All the instability elements of the AWF and its closest surroundings shall be documented.

V. Geophysical work

Geophysical field work shall be performed at each site investigated for the purpose of detecting contaminants and clarifying the intensity of radiation exposure in this investigation phase. The gamma-ray spectrometry method shall be used and performed with standard equipment. Other geophysical measurements may possibly be made in order to determine the most suitable locations for hydrogeological wells or to determine the spontaneous combustion spots of AWF.

VI. Surveying

Measurements of trial pit, well and sampling locations shall be made in accordance with legislation currently in force.

VI. Geobotanical assessment

In this work phase a follow-up geobotanical assessment may be performed at each site and shall include a vegetation cover assessment, which can indicate AWF impacts on nearby surroundings.

VII. Laboratory analyses

Chemical analyses of soil and water samples shall be performed solely in laboratories with the ČIA (Czech Accreditation Institute) accreditation for relevant types of analyses, specifically according to the extent given in Chapter 8.III.

VIII. Documention of work

The geological documentation of investigations must correspond to legislation currently in force.

IX. Assessment of investigation work and preparation of preliminary risk assessment

The assessment of investigation work shall be performed in accordance with legislation currently in force. A final investigation report and an AWF risk assessment, corresponding to legislation currently in force, shall be prepared for each HAWF.

Geological, geobotanical, hydrogeological, engineering geologic, geophysical, geochemical data and data related to possible health risks shall be obtained and assessed as part of the comprehensive investigation of hazardous waste facilities. An estimate of the total amount of contaminants at AWF shall be made as well.

The total risk assessment regarding individual impacts of mining waste stored at an abandoned waste facility is summarized in the table as exemplified below.

Total risk level assessment – example

Type of risk	Level of risk	Brief explanation
Geological conditions	negligible	The composition of the mining waste corresponds to the rock environment in the basement.
Hydrogeological conditions	low	The mining waste may adversely affect the quality of groundwater in the vicinity of the AWF, no aquitard is present.
Geochemical and hydrogeochemical conditions	high	The mining waste and groundwater contain high levels of some heavy metals and toxic elements. A very low pH level was detected in one case regarding groundwater. Oxidation of sulphidic minerals and generation of acidic leachate occurs and will continue to occur in the future at the AWF.
Engineering geologic conditions	medium	A realistic landslide threat exists for the exposed slope in the southern part of the AWF.
Assessment of impacts on human health and ecosystems	high	The AWF adversely affects the population in the surroundings in the short-term (dust with heavy metals and toxic elements), in the medium-term as well as long-term (primarily in terms of acidity

		and toxicity of groundwater).
Total risk level	**high**	**The AWF adversely affects the surroundings in the short-term, medium-term and long-term, remediation is necessary**

The assessment of the total risk level shall result in a determination whether the work performed did or did not identify negligible, low, medium or high risk levels connected to the existence of an abandoned waste facility.

The final output of the investigations and assessments performed is a final investigation report and an assessment of AWF risk level, including a remediation proposal.

11. Conclusion

The work methodology presented for investigating abandoned mining waste facilities is a general guideline in the Czech Republic for performing field and evaluation work during the assessment of risks at abandoned mining waste facilities. The following criteria were accepted for the purpose of unifying the levels of risk:

Risk level classification

Risk level	*Probability of harmful effect*	*Severity of consequences due to AWF impact (applies if at least one criteria is met)*
High	Definitely, or with a high degree of certainty	**Impacts on components of ENV and infrastructure:** • irreparable damage or damage very difficult to repair has occurred to the ecosystem or rock environment, hydrogeological and hydrological structures; • major unstable features (landslides, etc.); • major damage to structures, infrastructure, etc., has occurred or may occur **Impacts on public health:** • danger of severe illness of permanent residents; • danger of adverse effects on the health of persons temporarily present; • danger of serious or fatal injury to persons due to the angle or stability of slopes.
Medium	Legitimate probability	**Impacts on components of ENV and infrastructure:** • the ecosystem or rock environment, hydrogeological or hydrological structures have been affected considerably; • significant unstable features (landslides, etc.);

		• minor damage to structures, infrastructure, etc., has occurred or may occur **Impacts on public health:** • verifiable adverse effects on the health of permanent residents; • danger of minor injury to persons due to the angle or stability of slopes.
Low	Low probability	**Impacts on components of ENV and infrastructure:** • the ecosystem or rock environment, hydrogeological or hydrological structures have been affected; • less significant, yet visible unstable features (landslides, etc.). **Impacts on public health:** • public health may be affected.
Negligible	Low probability, unlikely to occur	**Impacts on components of ENV and infrastructure:** • did not occur, or cannot be observed and measured. **Impacts on public health:** • public health is unaffected.

The investigation and assessment of each AWF will result in its inclusion in the negligible, low, medium or high risk level category. The resulting risk level for an AWF always constitutes the highest level of risk determined during the assessment of individual exposure scenarios and adverse effects on the components of ENV and infrastructure or on public health.

The final outcome of the work is the development of the Inventory of Hazardous Waste Facilities in the Czech Republic, containing information on the types and levels of risk of individual abandoned mining waste facilities.

Appendix 1. Protocol for preliminary risk assessment of abandoned waste facilities

Field notes:	Researcher initials and number:		
AWF no. according to inventory ID	AWF ID		
Name of AWF			
AWF category ***DEP*** *–mining waste*; ***HAL*** *–active heap*; ***ODK*** *–tailing pond*; ***ODV*** *–inactive heap*; ***SEJ*** *–placer*; ***VYS*** *–spoil heap*; ***SKR*** *–overburden*			
Locality *(name)*			
Name and no. of cadastral area			
District			
Polygon *(yes – no)*			
Area *(v m²)*			
Volume *(v m ³)*			
Maximum height of AWF above ground level *(m)*			
Average thickness of AWF *(m – perpendicular to the ground)*			
X *(GPS)*)*			
Y *(GPS)*)*			
Z *(GPS)*)*			
Method of determining altitude ***B****-the Baltic;* ***L****-the Adraitic-Líšov;* ***M****-taken from map;* ***P****-the Baltic prior to levelling;* ***S****-the Adriatic-Strečno;* ***V****-the Baltic after levelling;* ***X****-undetermined;* ***Z****-surveyed*			
Type of GPS		**Measurement accuracy**	
Type of AWF ***1****-conical,***2***-domed,***3***-terraced,***4***-tabular,***5***-ridge-mound,***6***-other,***11***-with loosely filled dams up to the final height,***12***- with a loosely filled base dam and other loosely filled dams gradually built up on deposited sediment,***13***- with a loosely filled base dam and other height-increasing dams built up by deposition*			
Position of AWF ***1****-elevated,* ***2****-located on a slope,* ***3****-located in a valley,* ***10****-located in natural or artificial depressions,* ***11****-flat, with perimeter dams,* ***12****-located in a valley with one or more valley dams*			
Mineral mined			
Termination of operations ***1****-unknown,* ***2****-20th century up to 1945,* ***3****-20th century after 1945,* ***4****-19th century,* ***5****-prior to19th century*			
Recorded site use status *N-unused;* ***R****-liquidation in progress;* ***F****-active;* ***K****-preserved;* ***X****-undetermined*			
Predominant petrographic type			
Potential use of material from AWF			
Predominant grain size fraction			
Reclamation *(****1****-reclaimed;* ***2****-unreclaimed)*			
Description of reclamation			
Year of and entity in charge of safeguarding and reclamation (if posted, etc.)			
Landscape character (code) *1-forest; 2-agricultural land; 3-mixed (L-Z); 4-protected buildings; 5-industrial; 6-other*	**Code no.**	**Landscape character description:**	

Landscape character *(**1**-blends in with the landscape; **2**-does not blend in with the landscape)*			
Current status of AWF *(brief description)* *Vegetation, stability, migration pathways, secondary processes, etc.*			
Major contaminants *(brief description)* *Sulphides, asbestos, heavy metals*			
Minor contaminants *(brief description)* *Other adverse effects, e.g. secondary minerals, water discharge , etc.*			
Secondary contamination *(brief description)* *E.g. municipal waste, mine water discharge, etc. - description, amount, distance from AWF*			
Pre-existing impacts in the surroundings (up to 100 m) *(brief description)*			
Unusual site conditions *(brief description)* *(Military area, site access, buffer zone,..)*			
Sampling performed *(**1**-without machinery; **2**-with light machinery; **3**-with heavy machinery=machine drilled boreholes, machine dug trial pits)*	**Soil**		
	Groundwater		
	Surface water		
Additional description *(recommendation or explanation necessary for performing investigations– conflicts of interest, e.g. utility networks, roads…)*			
Date, company, and researcher´s signature			
Appendices *(maps, photo documentation, samples)*			

*) In the case of polygons, list their centre

Appendix 2.1. Sampling documentation – soil

Waste facility	*Company, researcher initials and number*
AWF no. according to inventory ID:	
Sampling conditions: Temperature (°C):	Precipitation:

Trial pit designation:	*Sample number (Z):*	
Coordinates of the sampling quadrat centre = sampling location – GPS		
X:	*Y:*	*Accuracy (2D,3D):*
Sampling location - description		
Field measurements: pH	Conductivity:	
Geological documentation of borehole / trial pit / ditch	*from-to*	*description* *Water table encountered: standing:* *Sample collected from a depth of (from-to):* *Number and total length of trial pits:*

Trial pit designation:	*Sample number (Z):*	
Coordinates of the sampling quadrat centre = sampling location – GPS		
X:	*Y:*	*Accuracy (2D,3D):*
Sampling location - description		
Field measurements: pH	Conductivity:	
Geological documentation of borehole / trial pit / ditch	*from-to*	*description* *Water table encountered: standing:* *Sample collected from a depth of (from-to):* *Number and total length of trial pits:*

Appendix 2.2. Sampling documentation – water

Waste facility	*Company, researcher initials and number*
AWF no. according to inventory ID:	

Sampling location designation:		***Sample number (V):***	
Sampling location coordinates – GPS			
X:	***Y:***		***Accuracy (2D,3D):***
Level from SP (m):	***SP height above ground level (m):***		***Total depth (m):***
Sampling location and sampling point (SP) *(description)*			
Borehole documentation *(if it differs from the SOIL form)* ***and sampling method***			***t (°C):***
			pH:
			Conductivity (µS/cm):
			Eh (measured mV + electrode-specific correction):

Sampling location designation:		***Sample number (V):***	
Sampling location coordinates – GPS			
X:	***Y:***		***Accuracy (2D,3D):***
Level from SP (m):	***SP height above ground level (m):***		***Total depth (m):***
Sampling location and sampling point (SP) *(description)*			
Borehole documentation *(if it differs from the SOIL form)* ***and sampling method***			***t (°C):***
			pH:
			Conductivity (µS/cm):
			Eh (measured mV + electrode-specific correction):