Survey of Pollution and Risk Assessment in the Process of Removal of Old Ecological Loads

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Abstract:
The basic prerequisite for the good-quality preparation of risk assessment of contaminated areas in the Czech Republic is to carry out survey work in the scope guaranteeing the acquisition of necessary information. Survey work must be performed in compliance with Guideline No. 13 of the Ministry of the Environment for a survey of contaminated areas, which defines categories A to D of the state of exploration. This Guideline stems from Act No. 62/1988 Coll. on geological work, as amended, and from a set of other related and linked regulations. For risk assessment, survey work of the category of the state of exploration lower than C should not be used; it is usually necessary to use exploratory work of category B. The implemented survey work should exclude the threat of the additional identification of serious new facts and the need of subsequent implementation of supplementary survey work. In real conditions, every survey is, however, loaded with a whole number of factors of uncertainty and induced risks, which must be eliminated to an acceptable level by appropriate procedures.

1. Introduction
Risk assessment is one of the essential instruments for evaluating the seriousness of ecological loads and for managing processes of their removal. It serves above all as the key basis for decision-making of the state administration on measures for correction and in the actual management of remedial work.

Guideline No. 13 of the Ministry of the Environment introduces the categorisation of the state of exploration of sites with respect to the need of acquiring the needed scope of credible and representative data for subsequent activities, for example, for risk assessment, feasibility study, preparation of an implementation project of remediation and the actual implementation of remediation work.

For the individual categories of the state of exploration, the necessary scope of data is defined. The data must be acquired to define, with an adequate degree of probability, pollution in terms of its spatial extent, qualitative and quantitative composition, the balance of contaminants, and possibilities of migration into the vicinity, including evaluation of impacts on potential recipients of contamination. Also the facts concerning conflicts of interests must also be identified, including conflicts with applicable legislative regulations (especially serious threats, or pollution of surface or ground water).

2. Requirements for the Scope of Survey for Risk Assessment
Survey work focused on the verification and detection of the scope and level of pollution of the rock environment is divided into 4 basic categories, A – D, according to the achieved (and achievable) degree of knowledge on pollution. Each of the basic categories represents a certain level of the state of exploration of a site and defines the degree of the informative capability of survey results, or the degree of their representativeness and credibility.

An additional survey is designated as a special 5th category. It may accompany any of the above-given categories of the state of exploration and serves mainly for specifying certain data especially in a non-homogeneous rock environment or, e.g., for conducting monitoring of pollution after the end of remediation work.
For risk assessment, survey work of the category of the state of exploration lower than C should not be used; it is usually necessary to use survey work of category B. A survey in category B is focused especially on the detailed verification of the scope and dynamics of contamination, physical-chemical properties of contaminants and transport parameters of the environment.

Survey work in category B is integral part of a project of risk assessment, and risk evaluation must take place in immediate interconnection with survey work. This degree of the level of survey further serves for the preparation of the bill of quantities for a possible remediation project.

For all categories of the state of exploration it is necessary to prepare a project of geological work and to solve possible conflicts of interests in compliance with Regulation No. 369/2004 Coll. on designing, performing and evaluating geological work, notifying risk geofactors and proceeding in the calculation of reserves of exclusive deposits.

The contents of the project of geological work are set forth in Section 5 of the Regulation above. If we design work connected with any interference in plots of land, part of the project is also a project of technical work in the form of an annex.

3. Concept of Survey Work for Risk Assessment

The essential condition of the implementation of survey work is an initial review of materials from all available sources. The review represents a critical excerption of relevant information, its verification and validation. Possible sources are, e.g., published literature, archive materials, the Internet, records in bureaus, local chronicles, works of art, old aerial and land photographs, films, results of remote sensing, interviews with eyewitnesses, employees and local citizens, etc. It is always necessary to proceed from primary sources; it is not possible to quote indirect information. Important part of the initial phase of survey is the reconnaissance of the area and taking own photographic documentation and/or video recording.

Based on the accomplished review, general chapters of risk assessment are preliminarily prepared, such as natural conditions of the site (geomorphology, geology, hydrogeology, geochemistry, climatology, hydrology), the existing and planned land use (an overview of the existing land use of the site and its vicinity, nature and landscape conservation, interests protected by special regulations, planned changes in the use of the site), the basic characterisation of inhabitation of the area, and relations of property rights. Information on pollution for the given site is evaluated, substances of potential interest are selected, all potential entities and objects, which may negatively affect pollution at the site, in the vicinity of the monitored site are listed, and the history of pollution (and also results of implemented remedial measures, if any) is described. The summary of basic data on the potential pollution of the site is included in a preliminary conceptual model, which is the basis for determining the concept of survey.

The actual survey work can be divided into survey fieldwork connected with any (temporary or permanent) interference in a plot of land and field measurement (mostly connected with the need to enter a plot of land). For the types of work it is necessary to transparently describe the concept of survey, the type and scope of work in the form of a summary of performed work, a detailed description of all methods and technological procedures used in the implementation of geological and analytical work (its description is appropriate in an annex), to describe inaccuracies and deviations in sampling or analysis, to evaluate weak points in survey and to list missing data needed for designing and implementing remediation.

The characteristics and extent of contamination must proceed from results of representative sampling of ground, surface and waste water, soils, soil gas, and structural elements, if any. Sampling must be conducted in an appropriately chosen configuration of sampling objects, which are mainly pits and holes into the unsaturated and saturated zones of the rock environment. For groundwater sampling, it is also possible to use existing objects at the site (holes, wells, springs), which, however, meet the criteria for the collection of representative samples with their parameters. When installing an exploratory working, it is necessary to document the geological profile in detail and to record the encountered standing groundwater
level. Great attention must be paid to the occurrence of phenomena being subject to notification obligation pursuant to Act No. 62/1988 Coll. (see Chapter No. 4).

Essential is the basic description of physical-chemical characteristics of contaminants and their toxicological action, the specification of natural conditions, the list of types of contaminants in connection with technological processes of their use and description of potential paths of leakage into the rock environment (based on the study of energy and material flows, the description of technological processes and the performed literature review), the identification and characteristics of all major pollutants at the site, their forms and any possible products of degradation and data on the LNAPL or DNAPL phase, and the comparison of results of the review with results of survey; all principal data must be identified by a provable manner, i.e. by standard sampling techniques and accredited laboratory methods.

Great attention must be paid to the selection of priority contaminants. Attention is mostly focused on contaminants which occur in the highest concentrations and in the largest amount. In many cases it holds true, in certain cases, however, only admixtures are more important in terms of imminent risks, or minor substances, which are, however, distinguished by far more harmful properties (e.g., PAH and PCB) in terms of the total volume of contaminants, and the like. Hence, the real risk and the erroneous determination of target parameters may subsequently be underestimated.

The description of the areal and spatial extent and degree of pollution must contain a detailed definition of the basic geometry of the extent of pollution on the basis of the critical evaluation of archive data and results of fieldwork, sampling and analytical work, the accurate outlining of the areal and depth extent of pollution in all components of the environment, and a detailed description of the occurrence of the free phase of pollutants at the site.

The balance of pollution must integrate the balance of the occurrence of all pollutants for the saturated and unsaturated zones and in all components of the rock environment on the basis of the critical evaluation of archive data and results of field survey.

Great attention must be paid to the verification of transport parameters of the environment. The direction of contamination spreading may be influenced by the anisotropy of an aquifer and inhomogeneities of the environment.

In the anisotropic rock environment, a multiple aquifer system often exists. Contamination heavier than water can migrate by overflowing (especially in the place of old holes, wells and building actions into deeper aquifers (deeper laid aquifers may not be in hydraulic continuity with a surface stream and contamination may spread beneath watercourse channels).

Unexpected complications are caused by anthropogenic actions, such as old foundations, underground lines and diverse underground structures. Sometimes contamination may spread, e.g., in a privileged way through the packing of underground lines. Broken water mains and sewers may cause water infiltration into the rock environment and cause a change in the concentration of contaminants and affect hydraulic gradients.

In certain cases, contamination heavier than water migrates into the fissure environment of the bedrock, where it may spread in a direction different from the direction of spreading in the Quaternary cover.

In an urbanised area and in industrial premises, contamination is often locked in trap structures beneath buildings, in the place of old excavations, underground tanks, etc. Even with a thorough knowledge of the area, to reveal such trap structures is very difficult or sometimes impossible. Hence, the balance of the total amount of contaminants at the site can be significantly affected.

Pollution migration in the unsaturated zone includes all basic data (grain size, water content, permeability for water and air) important for the description of surface soils and rock environment and subsequent calculations of pollution migration, obtained in archive materials, must be verified and documented by a provable manner (including interpretation procedures used) - this means, e.g., by a venting test.
Pollution migration in the saturated zone includes all basic data (coefficient of permeability, total and effective porosity, transmissivity, in more complicated cases also dispersivity) important for the description of the rock environment and subsequent calculations of pollution spreading, obtained in archive materials, must be verified and documented (including interpretation methods used) by a provable manner - this means, e.g., by pumping and recovery tests, and tracing tests, if necessary; if in the vicinity of the site we can assume a hydrogeological marginal condition with an effect on pollution spreading, the hydrodynamic test must be made so that we can evaluate the marginal conditions.

Pollution migration through surface water includes characteristics of surface water and pollutants from the view of a potential migration between the saturated and unsaturated zones and surface water, provable and documented specification of water levels, flow rates, concentrations and the degree of dilution, and delineation of any possible flood areas.

Prediction of the further development of contamination proceeds from (a) aggregate results of calculations, (b) the prognosis of spreading and attenuation processes of all major pollutants in all components of saturated and unsaturated zones and surface water (for the calculation of the future development of contamination, it is desirable to use verified transport and hydraulic models), (c) the evaluation of any possible effects of tectonics and other predisposed paths for pollutant spreading (it is appropriate to use results of geophysical methods of survey), (d) the critical comparison of archive data for the given site with results of field measurement, and (e) the updating of a detailed conceptual model of contamination of the site.

Important part of survey work is to evaluate the dynamics of attenuation processes for degradable substances with the quantification of flows of substances; for the interpretation of field data, which must be detected and documented by a provable manner, it is appropriate to apply suitable attenuation models.

4. Main Problems and Risks Related to the Implementation of Survey Work

Poor project preparation, breach of legal obligations

Preparation of a project of geological work for the implementation of survey work requires in compliance with Regulation No. 369/2004 Coll. (including a project of technical work if work connected with any interference in a plot of land is carried out) the duration of at least several weeks and, if it is about a more complicated issue and an areally more extensive site, even several months. This also holds true in the event that the requirement for the previous execution of the review is fulfilled before the preparation of project documentation. Submission of poor project documentation often leads to the choice of a bad concept and methodology of survey work, the underestimation of the problem, and the necessity of a change in project documentation during work, mostly with the necessity to prolong the deadline and to increase the total budget.

In fact, to fulfill the obligation pursuant to Act No. 62/1988 Coll. on geological work requires of the responsible manager of a contract during designing:

- to ensure the sending of the project of geological work containing drilling machine-work deeper than 30 m or drilling machine-work, the total length of which exceeds 100 m, to the regional bureau, in the administration district of which the work connected with any interference in a plot of land is to be carried out, at least 30 days prior to the start of work connected with any interference in a plot of land;

- to ensure the delivery of background materials to the Czech Geological Survey for registration within 30 days prior to the start of geological work (the method of registration is governed by Regulation No. 282/2001 Coll. on registration of geological work); and

- to ensure the conclusion of a written agreement on the performance of geological work with the owner of the plot of land or the tenant of the plot of land.
Besides that, at least 15 days prior to the start of geological work connected with any interference in a plot of land, it is necessary to notify the municipality, on the territory of which it is to be performed, of the purpose, extent and expected time of performance of the given work.

During the performance of geological work, the responsible manager must ensure the sending:

a) to a ministry
   1. a report of discovery of an exclusive deposit, stating the amount of its reserves;
   2. a notification of risk geofactors of the environment to the extent set by the Regulation.

b) to the Ministry of Health - a notification of discovery of a source of thermal or mineral water, gas, emanations and peloid; and

c) to the Czech Hydrometeorological Institute in Prague - a notification of discovery of any source of groundwater yielding more than 1.0 l/s or any source of groundwater with the confined level (artesian water) yielding more than 0.5 l/s.

Pursuant to Act No. 61/1988 Coll. on mining activity, explosives and state mining administration, an obligation arises for the district mining bureau to report the start, interruption and end of mining activity or activity performed in a mining manner. Pursuant to this Act, borehole drilling deeper than 30 m falls among activities performed in the mining manner.

Implementation of survey work must also obey relevant generally binding regulations for individual sectors of environmental protection. Within the design preparation it is useful to compile a register of legal and other requirements which relate to the particular site to avoid a breach of certain statutory duties.

**Time-consuming character of survey work**

In a number of cases, the solution of the issue of ecological loads is for the client only a matter of restrictive measures according to a published relevant administrative decision, or is understood as a matter that has no sufficient priority. This leads to the fact that corrective measures of ecological loads are often implemented at the last moment under the threat of failure to meet the date of the administrative decision and subsequent penalties.

Many times the term of survey work performance is set inadequately short and does not match the needed duration of work to solve all spheres of problems. Survey work is then often performed in time stress with the threat of a possible hasty deduction of incorrect or half conclusions. The result is poor and unreliable final outputs with ambiguous informative capability.

**Lack of funds**

A harmful habit in recent years is the choice of the most suitable work supplier, especially in the public tender, on the basis of a decisive or a single criterion, which is the amount of the offer price. This requirement may be tolerable in contracts of material production, which can be executed by a clearly definable working procedure with the knowledge of outputs, energy and material flows and costs, where the threat of decline in the quality of a product at a lower price is mostly compensated by the higher productivity of work. However, this is not the case in geological survey work, when every site is basically a prototype, to which experience from other sites cannot be completely applied. Due to the fact that the volume of funds for geological work is mostly greatly limited, suppliers of remediation work are pushed to unreal prices, for which work in the required scope according to the relevant Guideline cannot be performed. The result is then the threat of the subsequent discovery of essential new facts and the necessity to perform an additional survey. Work for unreal low prices ultimately leads to the considerable increase in price and thus to the uneconomical wasting of funds. Instead of the uncritical price squeezing below the real limit, it would be appropriate to require of the offer submitters adequate guarantees for achieving required outputs. The sharply low price of offered work should be documented by economic calculation.
Provision of entry into plots of land

Entry into not-own real estates and their use is regulated by Section 14 of Act No. 62/1988 Coll. on geological work, as amended. Organisations, when intending to perform geological work connected with any interference in a plot of land, are obliged to conclude a written agreement on the performance of geological work and on related activities and particulars with the owner or tenant of the plot of land prior to the entry into the not-own plot of land. If an agreement is not reached, the relevant regional authorities will decide on the curtailment of rights of ownership of the owner or tenant of the real estate by placing a duty to tolerate the performance of geological work. The decision on the curtailment of rights of the owner or tenant of the real estate can be issued only in the public interest if it is not in contradiction with the state raw-material policy, to a necessary extent, for a definite period of time, for compensation, and if this law does not provide otherwise, pursuant to a special law, for certain listed survey work. Survey work for risk assessment falls into the activity listed in Point d): acquisition and evaluation of geological data for environmental planning and protection.

In certain cases, to ensure entry to plots of land becomes a difficult-to-solve problem, which makes exploration organisations evade the problem and carry out a survey only on trouble-free plots of land. This procedure often also relates to the requirement for an urgent date of solution, which does not provide enough time to solve the situation either in a voluntary or restrictive manner. Hence, the results of survey work become less credible and certain data can be derived only from the interpolation of values between available points. To derive needed values on the basis of the extrapolation is inadmissible for survey work for risk assessment.

Field accessibility

In certain cases, only limited knowledge can be obtained on some sites because of the restriction of access to plots of land, the presence of underground lines and technological structures, land coverage of an area, etc. In such cases, a detailed survey cannot be carried out in the whole extent necessary for category B of the state of exploration and we must proceed only from results of survey of category C. Results can, therefore, be determined only on the basis of the interpolation of available data. At the same time, an increased uncertainty of resulting data and an adequate lesser credibility of performed conclusions must be defined for a precisely delineated part of a site.

Danger of initiation of secondary effects

Survey work implementation made by certain severe methods may contribute to the deterioration of the original situation. A common mistake is, for example, the interconnection of hydrogeological aquifers during drilling work and the creation of migration shortcuts of contamination into places not yet contaminated. Similarly, contamination can be spread as a result of pumping tests.

Wrong interpretation of survey results

The final interpretation of survey work results and the formulation of final outputs can be, even at goodwill, influenced by a subjective opinion and a subconscious (or intended) matching of conclusions to a set conceptual model. The objective interpretation of survey work results should, therefore, be assured by the institutions of control days (site meetings) and external examinations of results of work by an independent expert. It is appropriate to convene control days during survey work implementation at least at monthly intervals under the participation of the client, contractor, relevant water authority, Czech Environmental Inspection, and also other institutions, if needed. Conclusions from the control day are binding for the further progress of work. External assessment would be focused on the rightness of the concept and methodology of survey work, the correctness of achieved results, and the usability of conclusions for further decision-making process.

A report of a detailed survey and, in case of complicated natural conditions (a system of more aquifers, a great extent or combination of various types of contamination, etc.), also a project of this survey must be externally reviewed at least by one independent examiner with the authorisation of the Ministry of the
Environment for remediation geology, who will primarily assess whether the proposed or applied methods of survey and its results match the type and extent of contamination and the type of the rock environment, and whether they meet the requirements laid on the state of exploration of category B.

Limitations and uncertainties
In many cases, a list of all missing data and results necessary for risk evaluation for designing and implementing site remediation is not made, and the description of uncertainties in the degree of knowledge about site contamination, its migration and natural attenuation and other open problems is absent. Hence, the interpretation of results does not record the real situation at a site and may lead to the underestimation of the preparation of remediation work which, in the course of its implementation, can meet unexpected problems and hard-manageable anomalies and heterogeneities, which will have to be addressed individually and by special procedures.

5. Final Outputs
The basic output contained in the final report of survey of category B must be:
1. The time and space delineation of contamination, including the complete outlining of pollution; the spatial distribution of concentrations of significant pollutants and their known products of transformation and degradation in all affected components of the rock environment; the basic description of physical-chemical characteristics of contaminants and their eco-toxic action; the description of the time development of pollution, including its predictions for the future; and the assessment of natural attenuation. Besides hotspots and background values, also the margins of the contamination plume must be verified in all directions. When monitoring pollution migration through groundwater, besides flow directions and concentrations inside the contamination plume, also concentration values at the inflow and outflow of groundwater must be verified.
2. The balance of pollution, including the quantitative balance of pollutants and volumes of contaminated environmental components (especially of unsaturated and saturated zones) in relation to the spatial distribution of contamination and the specification of its occurrence, and the calculation of the volume of pollutants in phase.
3. The dynamics of pollution – the determination of the development of pollution in all components of the rock environment from the past to the present and predictions for the future, at best in the form of a mathematical transport model; the screening evaluation of the effect of processes of natural attenuation; the determination of potentially threatened subjects (people and ecosystems) and objects (buildings, natural barriers or roads, etc.); concentration and geometrical changes in the extent of contamination in the past and assumed in the future; physical and technological boundaries of contamination spreading, and the like.
4. The basic difference of category B from C (of the state of exploration) is that the results between individual point data can only be interpolated, not extrapolated. Pollution must, therefore, be delineated all around (including its depth range) at least by one contamination-free sample.

Final outputs must contain a conclusion and a recommendation with an overview of principal results of survey as compared to the specification (including a list of indispensable supplements which would enable to transfer the survey into a higher category of the state of exploration); a recommendation and clear rationale for further steps (for example, the preparation of risk assessment and a design of remediation or monitoring); a signature and stamp of the responsible manager.

The outline of the final report of the survey of anthropogenic pollution in the rock environment was originally laid down by Guideline No. 13 of the Ministry of the Environment. Early in 2009, it was implemented by Regulation No. 18/2009 Coll. as Annex No. 11 to Regulation No. 369/2004 Coll.
6. Conclusion

The scope and quality of survey work in a contaminated area have a key significance for the preparation of risk assessment and for the subsequent management of the process of disposal of ecological loads.

The result of the detailed survey in category B is a final report containing verified data on the character of unsaturated and saturated zones (and on the contamination of buildings, if applicable), and on the character of contaminants, their spatial distribution and time development. The main goal is a detailed balance of pollution, its detailed spatial definition and the determination of its mobility. Part of the report of implementation of the detailed survey is a statement of uncertainties and the time validity of conclusions. The project of survey and the final report of its results are signed by the authorised manager of the geological task and provided with a stamp with his/her authorisation of professional competence for remediation geology.

The degree of the level of survey B serves particularly for elaborating risk assessment and preparing a bill of quantities, or a “blind budget”, for a possible remediation project. With this purpose, the survey becomes integral part of the project of risk assessment, and risk evaluation takes place in the material and time interconnection with survey work.

The role of survey work in the process of disposal of ecological loads is basically continuous, for in a great majority of cases it is necessary to respond to newly found facts, e.g., in the course of remediation (extent of contamination, new pollutants, unrevealed preferential paths of spreading, geological factors, etc.). This all gives rise to the need of updating risk assessment, and hence to the need of complementary remediation work as well).