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INVENTORY OF CLOSED AND ABANDONED MINES

Methods for performing the inventory and for
risk classification with diverse data availabil-
ity levels

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DESCRIPTION

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Abstract <p>The traditional mining techniques have not been aware of the importance of the long term effects that the mining activity can cause: the main being represented by Acid Mine Drainage where chemical changes in sulphide rich tailings can bring in solution heavy metals, penetrate through the containing structure access and accumulate in the environment. The abandoned and unstable facilities located on the site can by their own represent risks for people and animals accessing the area. Several countries have been active in drafting an inventory of the sites in order to understand those that can represent a severe risk and on which it is prioritized a further intervention.</p> <p>The approach adopted by European countries, making the inventory in response of the updated "Mining Waste Directive", Directive 2006/21/EC has focused on the waste facilities representing a severe risk, while the methodology adopted by Extra-EU countries has included the whole mining site. In the thesis it is given an overview of methodologies adopted by selected European and extra European countries to understand which would be the best approach for performing an inventory in different data availability areas, which tools could be used and which results could be expected.</p> <p>The main approach would be to perform a risk based inventory using source-pathway-receptor model including the whole mining site. The main steps would include collection of bibliographic data from conventional and alternative sources, giving high importance to map and information relative to previous incidents, kind of mining techniques and refining processes, metals extracted and chemicals used during the process. These would help mainly in forecasting risks associated to chemicals. Map relative to geographic position, hydrology, geology, land cover would help in understanding the paths and the possibility to reach receptors. Comparison of historical images, correlated to bibliographic data, could help in understanding the impacts given by the mining activity during the time. In this framework GIS has been recognized as valid working tool.</p> <p>Besides the analysis of bibliographic information, that can be few in low data availability countries, field examination helps in defining the risks related to safety and pollution. When the data are not even enough to understand a mining site, it is probably important to perform two field inspections, the first to define the area and the second to perform the tests. Visual examination, field basic tests and laboratory tests are listed, considering that depending on the data availability of the area could be reached a Tier 0 or Tier 1 during the inventory. So the first basic collection of data over which the site could be recognized to pose a severe risk or not, constituting a base for further site assessments and decisions.</p>			
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1 INTRODUCTION

Closed and/or abandoned mine sites have been recognized for representing a possible risk to humans and the environment as the extensive environmental damages caused by waste dumps collapses in Spain and Romania in the turn of the last century. It can be told that different hazards and impacts are related to different mining activity, structure, geology, environment, materials and techniques adopted that characterize each specific site. Earlier the authorities' focus has been mainly on mitigating accident. Lately, it has turned to prevent potential impacts and accidents and in perceiving them in the planning and permitting phases. An overlook of the situation in European and extra European countries introduce the approaches adopted to face the problems.

In the EU the "Mining Waste Directive" - Directive 2004/35/EC updated into Directive 2006/21/EC has been created to homogenize the requirements for mining waste dumps after the occurrences of accidents in some European Member States. The directive and the relative commission decisions have been implemented in the European countries and have influenced several aspects connected to mine sites, as soil use, dumping, environmental protection and rescue requirements.^{/1/} The directive focuses on classifying the waste from extractive industry, considering the risks derived by problematic waste facilities, not including those derived by the whole mining site. The main risks have been attributed mainly to instability of the containing structures (dams, pad...) and the quantity and quality of hazardous and dangerous materials stored. ^{/2/}

According to the directive, all the countries have to identify the waste facilities that pose a relevant risk to human beings and the environment, performing in this way a large scale inventory covering the countries territories. A survey of the methodologies used in the EU countries has been performed in 2007 while a guideline for performing the inventory has been produced within the EU countries' cooperation and has been published in 2011. The methodology, though, has been enriched depending on the knowledge and resources available as well as on the factors considered relevant for prognosticating a risk for specific conditions. The list had to be published in May 2012 with freedom of format while the final reports could be published later. Within the EU it is therefore interesting to have an overview of the guidelines proposed and

to compare the way the countries have undertaken the task, to evaluate the different risk models adopted and the way of communicating the results.

More important would be to compare the methods adopted in the EU with those adopted from Extra-EU countries, including developed and developing countries. The research focused on those countries that have performed an inventory since several times specific risk assessment or environmental studies have been performed for specific mine sites but no general program has been established for having the wide picture of the situation. Instead of only comparing or analyzing the specific risk assessment methods, the large scale methodology is then searched.

Some countries in fact have also been doing inventories during the last years either in independent way or in cooperation with the EU countries; some examples are Namibia, South America, the USA, Canada and Australia. Thanks to the heterogeneity of backgrounds, of approaches and of motivation that had driven the inventory it is possible to compare the efficacy of the actions, the results got and the feasibility of studies both for developing and developed countries.

2 DEFINITIONS AND RISKS ASSOCIATED TO ABANDONED AND CLOSED MINE SITES

Short list of abbreviations, overview of mining techniques and of definitions adopted by member states and expressed by the EU directive are needed to better understand the frame in which the inventory has been done. Along the text abbreviations are going to be used that are generally belonging to normal technical field knowledge, as for example:

Ag: Silver	As: Arsenic	Ba: Barium
Be: Beryllium	Cd: Cadmium	Co: Cobalt
Cr: Chromium	Cu: Copper	Hg: Mercury
Ni: Nickel	Pb: Lead	Sb: Antimony
Se: Selenium	Sn: Tin	S: Sulfur
Te: Tellurium	Tl: Thallium	U: Uranium
V: Vanadium	Zn: Zinc	
AMD: Acid mine drainage		
ARD: Acid Rock Drainage		

ARGIA: Analisi relativa di Rischio per la Gerarchizzazione dei siti Inquinati registrati in Anagrafe

AMLIS: Abandoned Mine Land Inventory system

APAT: Agenzia per la protezione dell'ambiente e per i servizi tecnici

BLM: Bureau of land and management

BOD: Biological oxygen demand

BRGM: Bureau de Recherches Géologiques et Minières

COD: Chemical oxygen demand

EC₅₀: median effective concentration

GIS: Geographic information system

GTK: Geologian Tutkimuskeskus - geological survey of Finland

IRIS: Integrated Risk Information System

LC₅₀ : Median lethal concentration

NERAS: Northern environmental risk assessment strategy

NOEC-NOAEL : No observed effect concentration -no observed adverse effect level

TDS: Total Dissolved Solids

TSS: Total suspended solids

WHO: World Health Organization

7FP: 7th Frame Program

2.1 “Closed” and “abandoned” - definitions

The definition of closed and abandoned mine waste facilities have been mostly “interpreted” by the European countries since the directive does not define closed or abandoned waste facilities as also stated in the European Guidance Document created by G. Stanley et.al /3/. In this guideline the interpretations of closed or abandoned waste facilities are:

“... a closed waste facility is a facility where mining activity has ceased. Closed waste facilities are facilities with an identified former owner or licensee and closed according to former licenses or regulations. Abandoned waste facilities are facilities without an identified former owner/licensee and/or not having been closed in a regulated manner.”

From the fact that the waste facility should belong to a site where mining activity has ceased most of the European countries have considered that the closed waste facilities

should have belonged to closed mining sites. Considering the example of Ireland within the main European mining countries, it can be seen that it has interpreted its compliance to the European directive including historical mine sites in the inventory, defined as:

“A historic or closed mine site can be defined as one where minerals are not being worked, the mine site is not in the process of rehabilitation and is not under active management (addressing health and safety, and environmental issues) by a competent person.” and specifying that *“... the term historic mine site will be used to refer to closed mine sites that are not regulated by a current permit(s) under mining, environmental or planning legislation and which encompass infrastructure related to a mine, including, but not limited to, adits, shafts, pits, tailings facilities, waste rock dumps, buildings and mineral processing areas”* as defined in G. Stanley et al. /4/

Outside the EU the definitions are similar and the studies have not solely been focused on the waste areas but have been comprehensive of the whole mining site. Latin American countries in recent workshops and forums have identified and discussed the abandoned and historical mining activities /5/, while for Canada it is spoken mainly of orphan/abandoned mine sites in the National Orphan/Abandoned Mine Initiative /6/. In Australia an inventory of abandoned mines has been performed, as well as in the USA, where the inventory of abandoned mines sites belonging to the public land and being under the Bureau of Land Management responsibility is under constant development /7/. It is therefore important to have an overview of the risks that are posed by the waste areas and by the whole mining site.

2.2 Description of a Mining site

A brief overview of the kind of mining techniques and of the activities that characterize a mining site can help to understand better the possible hazards. An example of mining site is shown in Figure 1.

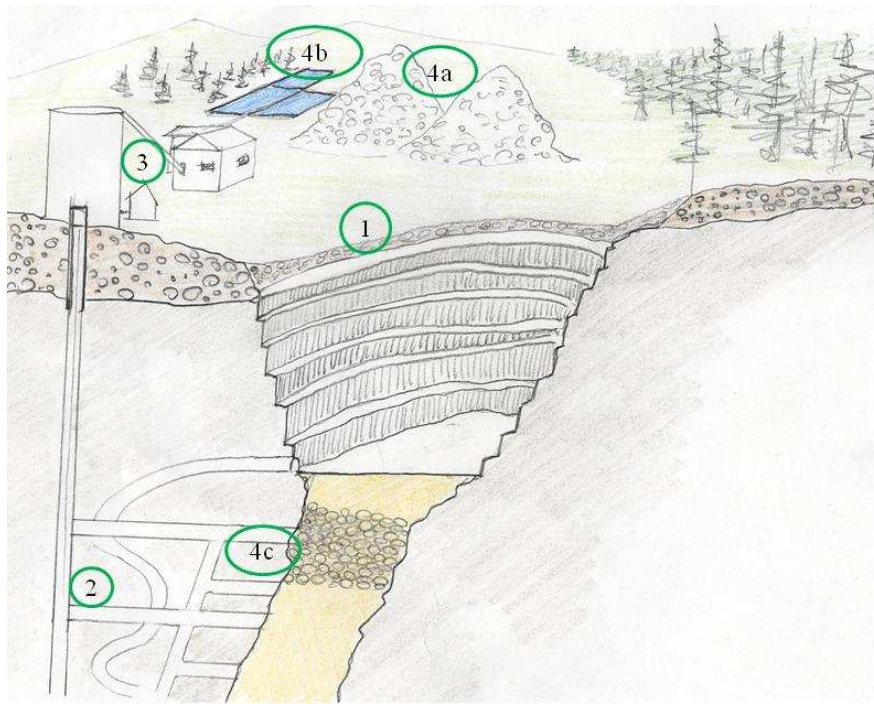


FIGURE 1. Drawing of a mining site, started as surface mine (1 is an open pit) and developed as underground mining (2)

As also visible from Figure 1 a mining site can present /5/:

- 1) **Surface mining**, in which the ore body is extracted directly in open air, excavating the side rock and possibly working on the ore body itself. It can be done as terrace mining, strip mining, open pit and comprehend also in situ leaching.
- 2) **Underground mining**, in which the ore is mined and extracted as efficiently as possible through tunnels. The system of mining is different according to the geometry of the deposit and of ore grade. The mining can be supported or unsupported, caving or bulk mining.
- 3) **Ore processing facilities**: where the excavated ore is stocked and is mechanically and chemically treated undergoing the processes for concentrating the ore to a commercial level
- 4) (4a, 4b, 4c) Areas for **waste disposal**, that generally collect the side rock, the rock poor in minerals but that has to be excavated for continuing the operations and a tailing area that collect the waste from the process. Safety conditions might change during time because of extreme events /8/. Liabilities are allocated in different way according to national legislation. They can be under local authorities' duties as for France /8/ or fall under state responsibility as for Hungary, or can be under land owner's duties as for Poland, or up to local communities as for Slovenia /9/.

Typologies of mine waste disposal include:

- Waste rock heaps/ stockpiles (4a in Figure 1) generally formed by coarse material stored on conical shape over a low permeability bottom layer to avoid percolation in case of material that has a pollution potential as told by P. Vesseron et al./8/. Sometimes waste rock heaps had been landscaped into hills becoming part of the cultural heritage of an area as in France and in Estonia.
- Tailing ponds (4b, in Figure 1), also defined as terrestrial impoundments, contain the tailings (the fine waste from processing ore) that might contain also chemical substances used during the concentrating processes (flotation, magnetic separation or gravimetric separation) as described by P. Charbonnier /10/. The tailing pond is used as a settling pond, collecting small fraction of material and clearing up the water, allowing its reutilization into the process /8/. Further actual water purification, i.e. water clarification is usually done in a separate water pond for which purified water is discharged into a natural water way (creek or lake). Both the tailings and water ponds have vulnerable parts, i.e. dam and pad structures, which need to meet requirements of stability and safety accepted by the national authorities and regulations.
- Underground backfilling (4c in Figure 1) when the waste, formed by waste rock and/or tailings with stabilizing additives such as cement, is put back into the deposit, improving its stability. It is feasible only in deposits that do not confine with aquifers /10/.
- Deep water disposal of tailing and waste straight to water bodies, according to P. Charbonnier it is still proposed for sulfidic tailings under controlled conditions /10/

An example of an inactive site that had been recognized to pose a relevant risk because of presence of waste containing Cadmium, Cyanide, Lead and Zink in Sardinia, Italy is visible in Figure 2 according to the Italian inventory /11/. The mine had been operating as underground mining from 1861 to 1991 extracting Blenda (Sfalerite), Argentiferous Galena and Cerussite. From the map are visible the waste facilities, the mining facilities, the environment and topography of the area, the inhabited zone, the water paths and the vicinity to the sea.



FIGURE 2. Satellite map from Google Maps of a high risk posing site in Sardinia (Masua), the width of the picture correspond to approx. 1,6 km /11/

2.3 The risks related to closed/abandoned mining sites and waste areas

Generally it is recognized that old and abandoned mining sites have mainly not been operated following the recent environmental concerns. During the processes old methods for extraction, treatment and disposal have been applied; often the activities have not been clearly documented and have ignored the long term environmental effects as noticed in the inventories' reports from several European Countries. Even though much concern is given to mining sites closed in the last century, also scattered historical mining sites forming larger mining complexes or districts that had been developing techniques and processes along the mine life have been of concern, being difficult to evaluate and quantify their overall impact on the environment.

The closed and abandoned mine sites can cause impacts on the landscape having abandoned open pits or erodible and instable tailing dumps. They often have impact on ground water quality and regime; they represent a risk for contamination or determine changes of properties of soil, surface water and sediments. /5/. Risk for stability

(of the waste dumps but also of mining structures), together with safety and health hazards have been the greatest concern also because of the uncontrolled accessibility to dangerous areas by common people. Persons could be exposed to risks related to encountering wild animals as bats and get diseases from contact with their excreta; health effects are also given by exposure to radon and radiations as reminded by the warning campaign carried out in the USA - Stay out stay alive /12/. Gas and lack of oxygen together with presence of toxic chemicals are also within risk elements that can be found in abandoned mine sites as pointed out in the Handbook produced by the Bureau of Land and Management (BLM) /13/. Moreover problems associated to abandoned and closed mine areas could also have impacts on the community, on the heritage and on the economy of the area where they are located. In Figure 3 the main hazards related to an abandoned mine site are schematized.

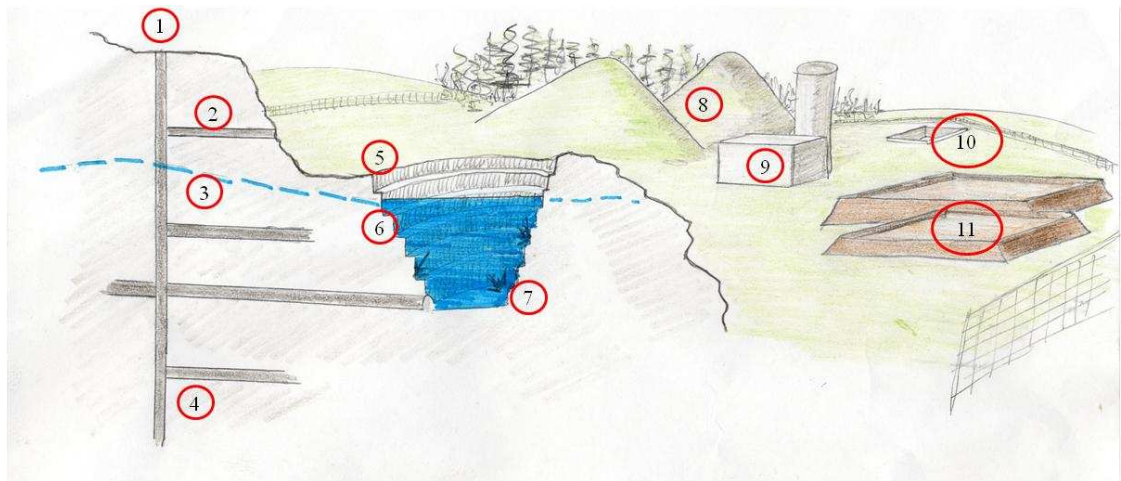


FIGURE 3. Schematic draw of the main risks associated to an abandoned or closed mine site

In Figure 3 numbers refer to the following hazards /13,14/:

- 1) Open shafts non protected represent a risk for persons and animals
- 2) Accessible adits that might present rotten structures, holes, fallings from walls, presence of animals like bats and snakes, presence of gas. Adits are also characterized by darkness and low air circulation that might lower the orienteering ability of a person
- 3) Saturated area might damage the structures of the galleries and structural capacity of the complex
- 4) Danger of collapses of the lower galleries because of presence of water and deterioration of the supporting structures

- 5) Vertical edges of open pits filled with water represent dangers of drowning for animals and persons that fall into the water, not able to climb back
- 6) On surface mining as open pits there can be detachments from the walls and slope failures
- 7) In the submerged open pits there might be abandoned equipments from the mining activity as nets, ropes, iron bars....
- 8) Waste heaps could hold hazardous waste, radioactive material, could leach, generate dust, generate fire depending on their composition. Moreover they represent safety hazards for people that have accessed the areas both from direct contacts with the waste and for risks of falling
- 9) Old structures connected to mining activity and processing are generally not maintained and could collapse. People that have accessed the structures could also be injured by other accidents as falling from high levels
- 10) Open pools used for treatments during mining activity if not fenced could represent a danger because of the steep edges difficult to climb by fallen animals and persons
- 11) Tailing facilities and dams could present stability problems and could pollute the environment, they could also present safety hazards for people to fall from the dams.

In the European Union the main focus has been given to the waste areas since they could pose the highest risk of failure and contamination within the mining area. The main concerns has been relative to stability of the dams, being constructed and increased during mining operations, might not have been dimensioned to support the total mass contained for long time without maintenance. External stresses such as heavy rains, earthquakes or landslides as well as local geological configuration might increase the risks of leakage of water through the walls and the basement.

The failure in stability of tailing structures includes /15/:

- rotational slide, when the slope of the dam slides in some parts leaving a curved shaped hole,
- foundation failure, in case the facility had been built over a sliding layer
- overtopping and erosion, happening during high rainy periods, when the movement of runoff waters over the dam's top abrade the structure. The action

is enhanced if the pore pressure within the dam structure is increased. Erosion is given also by abrasion actions over base structure of the dam.

- Liquefaction determines the suspension in water of the fine, equi-granular, non compacted sands contained into the impoundment, becoming a viscous material able to move in all its mass out of the dam even through small openings. The phenomenon is magnified by presence of earthquakes and high water table, and when the structure presents high pore pressure.
- Piping is the creation of voids in the dam caused by the passage of seepage water through it. Seepage water creates paths characterized by lower pressure than the rest of the structure, which collect and conduct water through the dam, creating a progressive flow able to erode the structure. In Figure 4 are shown the possible leakages from a dam.

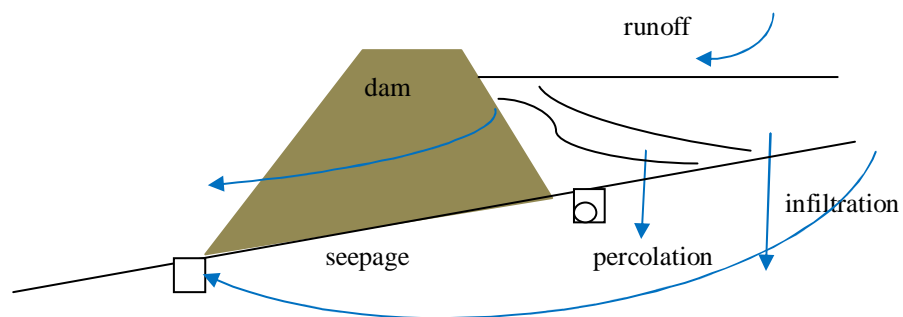


FIGURE 4. Scheme showing the water affecting tailing dams, picture reworked from P. Charbonnier /10/

In case of dam failure as described by K. Kreft-Burman et al. /9/, the impact on the surroundings would not just be loss of lives given by the fast unpredicted mud wave, but also damages to the local ecosystem, to the affected aquifers, to the crops and possibly to the nearby farms.

Physical performance associated to the main concern of uncontrolled chemical changes of the waste stored under specific conditions (acid mine drainage AMD, dilution of heavy metals...) represent a higher risk to the environment in case of leaching./10/ Relative to the contamination potential of a waste facility and a closed or abandoned mine site the inventorying guideline produced for Namibia easily points out that iron pyrite is the main acid generation source /14/. Sulfide bearing minerals could oxidize at different speeds depending on the mineral, on oxygen concentration, on humidity

and presence of oxidizing bacteria. During time the pH of the water contained in the tailing or the ground water in contact with the material of the abandoned mine would be lowered, even reaching values as low as 1,5.

A second risk of acid mine drainage and changes in pH of the tailing or rocks is determined by the enhanced mobility of other metals, generally heavy metals, that come more or less easily in solution according to the pH. For example even in high pH (over 7,8), one has to pay attention to Al, and further to Zn, that are mobilized./14/. Heavy metals are often associated to the metals extracted and represent an important aspect of the tailing and mine waste.

The effects of the composition of tailings on AMD have been studied in Finland on waste produced by two mine sites characterized by high and low sulfide minerals. Those with high sulfide minerals had higher tendency to generate acidic seepage water than those with low sulfide minerals, but presence of buffering minerals were able to lower the acidic water generation, and accordingly lower the metal mobility. Seepage water quality though had shown annual and seasonal variations. Moreover the areas more affected to sulfide oxidation were those in unsaturated zones. /16/. These findings are important to understand that the waste facilities can behave in different way according to their composition and to the way they had been created, considering that the whole mass of tailing changes properties according to the zones and to the time of year.

Other risks connected to waste facilities are relative to the fact that waste heaps could contain burnable material as the spoil heaps in France where it has been evaluated that about 150 sites in the mining region of Nord - Pas-de-Calais have been on fire during the times, as referred by P. Vesseron et al./8/.

Toxic and hazardous waste is also within the hazards connected to abandoned mines. The main load is given by mining waste facilities and can be derived by ore mineral composition, presence of asbestos or radioactive minerals, or by chemicals used for processing ending up in the tailings. Also process leftovers abandoned on the mining site, explosives and flammable chemicals, oil and PCBs are a source of risk./14/

Performing the inventory, the difficulties to evaluate the possible loads given by mining activities have been multiple not only because of lack of reliable documentation as happened in Italy /11/ but also because of site's location, geographical organization and construction of the waste facilities. An example is the Lignite mining district of Lusatia-Germany where it has not been easy to understand the effects of the interaction of the whole historical mining district characterized by successive mining operations causing relevant ground water changes as described by B. J. Graupner et al. /17/. In this case the challenges to identify the possible pollutant sources and paths have been high also because the field characterizations failed to give the full picture of the dumping area because of the high heterogeneity of the material stored. To overcome the difficulties in understanding such difficult complexes, new models and methodologies are needed to be implemented /17/.

3 THE EU METHODOLOGY

The technical adaptation group of the directive presented 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" written by G. Stanley et.al /3/. The general method was based on previous bibliographic knowledge and on a questionnaire leading to yes/no answers applying precautionary principle in case of doubt of risk, to be solved later with a site inspection./3/

The pre-selection is meant to eliminate the closed/abandoned waste facilities that "*do not cause ... or (do not) have the potential to cause a serious threat to human health and the environment*" /3/. It is therefore important to define what is "serious threat", that related to human health is mainly focused on "*disability or prolonged states of ill-health*" as well as loss of life /3/. The Directive, though, does not define serious threat to the environment. What is not serious has been taken as opposite finding out that for the environment serious threat occurs when /3/:

- " a) *the intensity of the potential contaminant source strength is not decreasing significantly within a short time;*
- (b) *the failure leads to any permanent or long-lasting environmental damage;*
- (c) *the affected environment cannot be restored through minor clean-up and restoration efforts."*

The pre-selection is based on gaining the basic information on the quantity and on the dimension of the waste facility, on the geology and geography, on the presence of minerals or of dangerous materials, on historical knowledge about risks or impacts, on the vicinity to areas to be protected... The questionnaire was created to proceed from sources that can generate impact by the mining waste facility both from its chemical and physical/stability characteristics, evaluating the pathways for reaching possible receptors in the area and the impact themselves. The general scheme is visible in Figure 5 as described by the Guidance Document /3/.

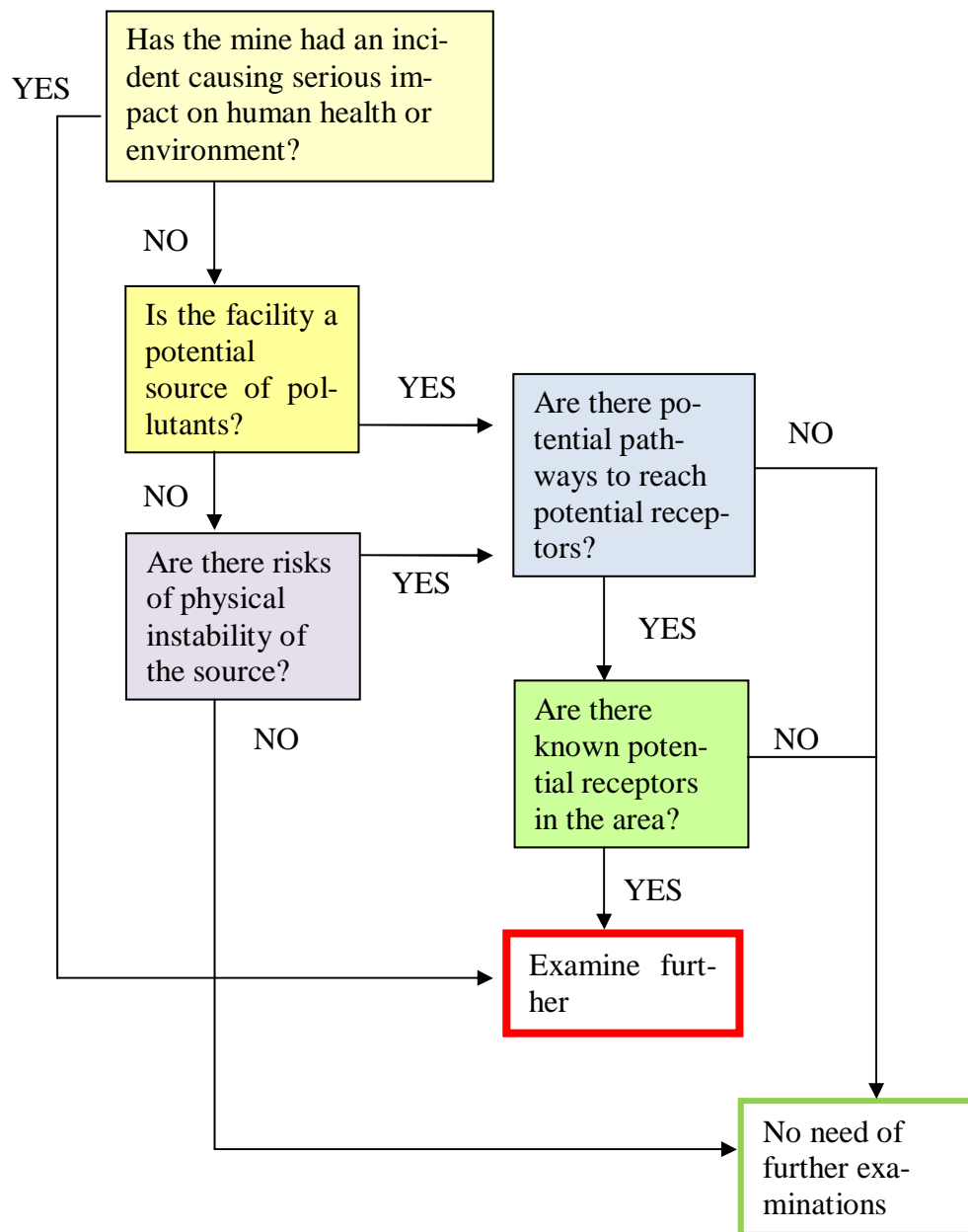


FIGURE 5. The Flowchart for the pre-selection of mining waste facilities that represent a high risk for human health and the environment as presented in the Guidance Document by G. Stanley et.al /3/

The general scheme visible in Figure 5 is then characterized in detailed by the questionnaire /3/:

- 1) *Is the closed mine waste facility known to have had an incident which has had a serious impact on human health or the environment?*
- 2) *Did the mine work sulphide minerals or produce a waste containing sulphide minerals?*
- 3) *Were any of the following produced from the mined mineral - Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Te, Tl, U, V, Zn or asbestos?*
- 4) *Did the mine use dangerous chemicals to process the mined minerals?*
- 5) *Is the waste facility a tailings lagoon or a waste heap?*
- 6) *Is the area of the tailings lagoon greater than 10,000m²?*
- 7) *Is the height of the tailings lagoon >4m within 50m of the facility?*
- 8) *Is the area of the waste heap greater than 10,000m²?*
- 9) *Is the height of the waste heap >20m?*
- 10) *Is the slope of the foundation >1:12?*
- 11) *Is there a water course within 1km of the mine waste facility?*
- 12) *Is there a high permeability layer beneath the mine waste facility?*
- 13) *Is the material within the mine waste facility exposed to the wind?*
- 14) *Is the mine waste facility uncovered?*
- 15) *Is there a human settlement with >100 people within 1km of the waste facility?*
- 16) *Is the waste facility within 1km of a water body which is of less than good status?*
- 17) *Is there a Natura 2000 within 1km of the waste facility?*
- 18) *Is the waste facility within 1km of agricultural land or livestock?*

Some threshold values have been free to be chosen by the different countries depending on specific environments or knowledge. Also the introduction of new questions and new aspects has been allowed always aiming to identify in a precautionary way the risk areas.

The questionnaire can also be visualized by further flowcharts as shown in Appendix 1. From those can be seen that a risk ranking is also given in the European pre-inventorying guideline even though it is not officially pointed out. The sites posing a

pollution risk are considered posing the highest risk independently on the kind of facility and size. Presence of heavy metals and dangerous chemicals and risk of AMD were then evaluated for receptor reachability, so pathways. Those that didn't pose a risk for pollution were afterwards evaluated for stability in relation to dimensions (height and size).

Pathways have been identified through surface water, groundwater, air and direct contact (questions 11, 12 1,3, 14). The scheme is a simplified way to evaluate that the sources actually have an impact on receptors and in the cases of "no", the pathways have been in some ways interrupted, lowering the risks. The fact that a receptor has to be reached is important in the evaluation of the risk during the inventory, since it allows to exclude all those sites and facilities that even representing a source do not reach receptors. In fact if the pathways analysis showed that there was no possibility to reach a receptor then there was no further analysis.

If instead there were pathways pointed out, presence of receptors was analyzed through the question 15, 16, 17, 18. Interesting is that the guidance document consider that there is a risk if nearby the facility there is a settlement composed by more than 100 people, after having defined serious threat to be risk of death.

The inventory included also information about owner or operator, location as district and topographic map. In order to understand the risk, it was also useful to know the type of mining and of waste disposal, processes that produced the waste minerals and the way of handling and disposing it. A guide to the collection of these data, about the presence of minerals associated to ores extracted and the evaluation of risks associated to waste disposal and their interaction with the hydrogeology of the areas is given in the appendixes of "Management of mining, quarrying and ore processing waste in European Union" document /10/ where also an overview of the waste mining legislation for European countries was pictured showing that the awareness of the risks had been taken into consideration and regulations had been implemented even if at different levels in all European countries.

From the questionnaire it is visible that environmental aspects related to waste disposal are given by the geometry and stability of dams, by their geotechnical properties including height, slope (recommended max 15-20 degrees, 27-36%), degree of com-

paction, permeability, compression strength of embankment and its foundations. Also presence of earthquakes, high intensive rain falls in landslides areas and steep slopes as foundations should be considered for stability purposes /10/. From chemical point of view hazardous waste and leaching have been the main environmental concern affecting the surroundings and the water bodies. AMD, production of soluble salts, metal and chemical transportation have been the main aspects effecting water quality and the paths have been recognized being seepage through side and pad structures, percolation and overflow. /10/

Risk assessment based on Source-Pathways-Receptor model could have been done using a “forward” approach (from a known source the path and the target impacted are evaluated) or a “backward” approach (knowing the impacts on the receptors, understand the pathways and find the sources) as defined in the guidance document published in 2007 /2/. Also probabilistic modeling to evaluate uncertainties was suggested /2/ while the pre-selection guide of Stanley et.al /3/ does not present a detailed probabilistic risk assessment method, so each country had to create own standards and methodologies.

4 THE EUROPEAN COUNTRIES

The European countries and even the entering countries have performed the inventory following generally the pre-selection guide of Stanley et.al /3/ but in some cases adding new requirements or information if relevant for the local or national conditions. The risk evaluation and risk ranking has then been related to the expertise of the body that performed the work, on the data available, on the previous knowledge and on the budgeted work. In evaluating the risk, in many cases, possibility of acid mine drainage (AMD) generation and type of facility, such as tailings, had been those characteristics considered posing the highest risks.

4.1 The pre-selection of risk areas

As told in advance, the pre-selection protocol guidance by Stanley et.al /3/ has generally represented the basic principles followed by the European countries. The main problems came from lack of information relative to structures and kind of facilities closed in the past. UK with about 100.000 closed or abandoned mines in England and

Wales did not have enough information to apply it for creating an inventory /18/. In fact H. Potter and D. Johnston declared in the report that they missed documents relative to mining and waste activities, processes and infrastructures and had to tackle complexes of small mining sites that constituted a larger mining district. Therefore they decided not to have any pre-selection and all the mine sites were included in risk evaluation and risk ranking./18/.

Many countries based their pre-selecting work over known bibliographic data even though it was not easy to collect. As an example in Italy about 2.990 mining sites, operative from 1870 to 2006, were found as visible from the document by the Environmental and Landscape protection Ministry /19/. According to the report, acquisition, verification and homogenization of bibliographic data from bulletins, mining journals, mining census Dicma 1989, mining legislative decrees and concessions was performed for the creation of the database /19/. The work has been handled by the APAT, regional agencies for the protection of the environment. Already in the pre-selection the results have been shown using an indicator, grouping the sites according to rate of cultivation of each mineral at regional level. The index Herfindahl-Hirschman - HHI – is shown in formula 1 /19/:

$$HHI_{norm} = \frac{\left(\frac{\sum_{i=1}^{20} n_i^2}{n_T} - \frac{1}{20} \right)}{1 - \frac{1}{20}} \quad (1)$$

Where:

n_i = number of regional sites

n_T =number of total sites

HHI near 1 would indicate that there have been several sites exploited in the region, HHI near 0 would mean that there have been very few. The cut off value separating a concentrated distribution from a non concentrated had been equal to 0,20. Successively, risk ranking evaluation has been performed according to the national guideline ARGIA and site visits have been done to the most important sites whose results have been included in the database itself.

Others, as Finland, used the pre-selection protocol as a base, excluding those closed or abandoned sites, in many case historical sites, that presented too small dimension to represent a risk for the receptors. But for the characterization of risk areas new infor-

mation has been added to the questionnaire and from ore data the AMD potential of the site has been highlighted. Similar policy has also been followed by Hungary, that considered the tailings and those facilities that have AMD potential as risk posing sites independently from other threshold values.

4.2 Risk assessment

In the framework of making an inventory the risk assessment has been based on the available information, even if incomplete. It differed largely from a site risk assessment since it does not consider in detail the site (the soil, the properties, saturation, , the combined effect of multiple pollutants, interaction between minerals ...). It has always been pointed out that the outcomes are only an indicative result of sites that need further assessment.

Therefore the risk assessment done for environmental purposes could be told to represent either a Tier 0 or 1 in a probabilistic risk assessment program, where accordingly to bibliographic references and in some cases to fast field/laboratory tests the inventorying sites are screened. Sites that represent a risk are identified mainly in a qualitative level: if the sources could affect the receptors and if the levels are higher than established or normative threshold values. Being the lowest tier it is cheapest and easiest but also the one that presents highest uncertainties. /20,21/.

Next level, generally corresponds to a Tier 2, in which quantitative simple site risk assessments is done. It considers specific parameters as soil properties, geochemical and mineralogical properties, water distribution and quality, geometric and stability factors. A model of the interactions of the different parameters on the site is created to forecast future behaviour and quantify the risks. /20,21/

The highest level Tier 3 would include detailed quantitative risk assessment, where site specific complex models are created including sensitivity analysis, toxicological evaluation and ecological risk assessment /20,21/. An example of a higher Tier than the one referred for inventorying purposes is the one developed and applied in an abandoned pyritic mining site in Spain described by E. Moreno-Jiménez et al. /22/. The main risks have been given by tailings rich in heavy metals. The principles of chemical risk assessment, as described in the Technical Guidance Document based on

the Commission Directive 93/67/CEE on risk assessment of new notified substances and the Commission Regulation (EC) 1488/94 on risk assessment for existing substances have been the base to make the evaluations /23/. First hazard quotients (HQ) as a ratio is defined (formula 2) /22/:

$$HQ = \frac{\text{exposure concentration (environmental concentrations or total daily intake)}}{\text{toxicity values on target organisms (Ref.Doses or Acute toxic Doses)}} \quad (2)$$

Then a list of Risk Indexes based on chronic exposure NOEC (NOAEL) (RI: 0 -4) and on acute exposure LC₅₀ and EC₅₀ (RI:5 -7) are defined. The total potential impact (Impact Index (Iml)) is then calculated as the sum of RI chronic and RI acute. A ranking of 5 classes from Negligible risk (Iml≤1) to Very high impact (Iml>9) is defined /22/.

In the study, soil, water and plants are tested for chemical composition and bioaccessibility. Soil microorganism, plants and earthworms, algae, invertebrates and fish, pigeon, wren, vole, shrew and sheep are selected to evaluate the exposure impacts. /22/.

There is large knowledge of site risk assessment while there is little experience of risk assessment for inventorying purposes, therefore each country in Europe adopted own procedure and parameters to point out the sites that need further inspections, either calculating the risk, or evaluating it, or using geographical information system tools. The risk is evaluated according to the magnitude of impacts given to human beings and the environment and the source-pathway-receptor model is present in all the countries examined.

This approach was already introduced in the project “Innovative Industrial Technologies for the Rehabilitation of Land Contaminated from Polymetallic Sulphide Mining and Processing Operations“ (ROLCOSMOS) as described by the Deliverable 2.1 of project Safe Management of Mining Waste and Waste Facilities (SAFEMANMIN), a project done under the Sixth Framework Programme /24/. The report referred to the need of having an experienced scientist in understanding the risks and the linkages since “*the interpretation of risk is based largely on intuitive judgement*”, even though quantitative data constitute an objective base for risk assessment, qualitative analysis complete the process/24/.

According to SAFEMANMIN report /24/, different risks are identified connected to mining sites and waste areas that have been later included in the pre-inventory process as content and size of the waste area, geological and terrain features, seismic activity, hydrological configuration and vulnerability, climate effects and evaluation of stability adding also impacts generated by underground mining activities and explosions. Climate change has also been listed because increase of extreme climatic events in all the World as dry/wet seasonal period and cold/hot ones. These affect the ecosystem, mining structures and behaviour of soils from chemical, physical, biological perspective /24/.

4.2.1 The UK

In the UK the risk assessment methodology has been different for coal and non-coal mine sites and since it is based on the impacts given to the environment, mainly to surface waters, the whole mining site has been included because the impacts have not been easy to correlate to the sole waste. The risks are focused on water and soil pollution, on instability, on particulate and suspended solids and on fire. The hazards are defined in the report of the Environment Agency, H. Potter and D. Johnston as visible in Table 1./18/.

TABLE 1. Evaluation of the hazards for the selection of mining sites representing a risk extracted by H. Potter and D. Johnston /18/

Pollution affecting the waters	Contaminated land	Instability	Fire	Particulate
Surface water quality fails the EQS at distances higher than 500 from the source	Defined to give significant harm to receptors	Defined upon site inspection and affecting receptors	Combustion happened within 10 years and not definitively remediated affecting receptors	PM2.5 and PM10 in such concentrations to fail the Air Quality Objective
Surface water not achieving the good ecological status				
Groundwater affected at distance 50 m for primary aquifer and 350 m for secondary aquifer				

In Table 1 EQS means Environmental quality standard, and the receptors are: human health, ecology, buildings, services, crops, livestock, pets and wild animals. In the

same report it is told that previous legislation had already charged local authorities to inspect for stability issues and to evaluate fire risk arising in collier tips. Also polluted land had been researched but through different approach and by different authorities. /18/. In some areas detailed surface water assessment had already been done because of the Surface Water Directive's requirements and had already been done detailed studies of pollution potential as with the project related to abandoned non-coal mines' pollution potential (NoCAM project) /18/.

Non-coal mining areas and impacts have been analysed with GIS mainly focusing on the impacts to surface water. Finally totally 148 closed and abandoned mining waste facilities have been identified to affect water. Water as important source of information relevant to pollution risk has also been recognized in the report from SAFEMANMIN /24/ where the correlation of high water electric conductivity in the watershed and the distance from mining waste area has been described.

4.2.2 Ireland

In Ireland 220 historic mine sites have been screened using previous knowledge and expertise supported by bibliographic information on the mining and processing methods, geology and history within the Historic Mine Site – Inventory and Risk classification project (HMS-IRC) /4/.

According to G. Stanley et al. /4/, similar kind of evaluations as those included in the pre-inventory methodology were carried on: presence of dangerous materials in the waste areas, presence and amount of Pb, Zn, Cu, Ni, As, Cd, Hg, Acid Rock Drainage/Acid Mine Drainage potential and environment characteristics. The preliminary screening was based on a risk ranking done in 1996 where 128 mine sites were attributed a PIN – pollution index number, ranking from 1 for highest risk to 9 for lowest risk.

According to the report by G. Stanley et al. /11/, not all the sites were ranked for geochemical properties since some had mineral content constituting no risk for the environment. Following the European guideline a source-pathway-receptor model was identified. Within the sources adit discharges, seeps, waste piles, tailings impoundments and stream sediments were listed, while within the pathways, as for other coun-

tries, air, surface water, direct contact, groundwater, stream sediments were listed./4/ The receptor was focused on human beings both as neighbours, workers and as people accessing the mine area, indirectly also through farm animals since some compounds are bioaccumulative and can affect those who consume animal products as referred by G. Stanley et al. Aquatic ecosystem from rivers and estuaries as well as groundwater quality were accounted, together with protected areas (national parks, national heritage areas, special protection areas, special areas of conservation and natural reserves). The main significant pathway was surface water, while the least, air; direct contact affected mainly punctual sites where access was possible /4/.

4.2.3 Risk assessment using the pre-selection information

Finland and Hungary, as an example have determined the risk and have ranked it according to information got from the pre-selection protocol adding national information and using own knowledge and expertise to evaluate the risks. As for example, Finland had added some specifications to the list of questions proposed, as defined by the national report (1):

- Has the waste water impacted the ground water and soil pollution?
- Has the waste mining area been affected by acid mine drainage, AMD?
- Are there radioactive minerals present in the waste?
- Are there other minerals than those listed (sulphide minerals, Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Te, Tl, U, V, Zn or asbestos ...) that are susceptible to chemical changes?
- Does the extractive waste show leaching or acid generation potential in short or long term?
- Relatively to the dam safety issues had also been added a question concerning the likelihood of collapse of the dam if the water would rise to the surface of the waste pond.
- Information about being located near an aquifer and at which distance, or over ground water area and at which distance from the suction plants, and if the routes of discharges from the waste areas are identified.
- Are there nearby inhabited buildings or animal shelters other than cattle shelters?

As told in advance, the main screening tool had been the size, while the presence of sulphide minerals and the potential of AMD generation, besides dangerous materials and radioactivity were the main risk evaluating tool. In this case expert knowledge of the sites, of the geochemistry and ore mined was the base to evaluate the areas that pose a high risk to human and the environment.

The knowledge of the geochemistry and of the site was very important in estimating the future trend and the risks in several studies. For example in Slovenia the preinventory based on the guideline pointed out a risk areas such as Meža Valley, where large mining activity of Pb-Zn ore had created about 30 waste areas located in abandoned mine sites, in the form of heaps placed on steep slopes of narrow valleys potentially effecting the stream water. The impacts of AMD and metal mobilization have been confirmed later by site assessments /25/.

Site assessment included laboratory analysis on stream sediments of the rivers affected using scanning electron microscopy and energy dispersive spectroscopy (SEM/EDS) as described by M.Miler and M. Gosar /25/. Results showed that the rivers had high concentrations of Pb-Zn bearing minerals and so the mobility of metals and toxic elements from the waste materials was studied. Miler and Gosar's study revealed that the majority of "*Pb and Zn-bearing primary ore minerals, such as cerussite, smithsonite, and sphalerite*" did not tend to release substances in the environment under the present conditions of high pH, while the secondary weathering products, as Fe-oxyhydroxides, could stabilize Pb and Zn, but under the conditions of the sites, they were unstable and could then be released./25/.

4.3 GIS in risk evaluation

GIS has been used differently by the countries that adopted it as tool for risk characterization and ranking and data management. The parameters chosen, the way of interrelating the layers and the calculation of the risk has been the main difference. Some countries have mainly used it for publishing the data.

4.3.1 Pre-selection purposes and risk interpretation – Finland

According to the information gained by the Geological Survey of Finland /1/, the data have been collected from previous working and studying experience. Records of minerals extracted, the materials used in the processes, the environmental impact assessment of the waste areas and other information has been collected from publications, environmental permits, mine and environmental decisions, databases, research activities, studies and mining journals.

Using ArcMap, information of ground and surface water, including rivers, lakes and sea areas, of groundwater extraction and relative distances has been collected on the base map of the waste mining areas. Also information of inhabitants and presence of inhabited buildings, ecological condition of the waters, vicinity of Natura 2000 areas or other areas relevant to be protected (bird water areas, Ramsar areas, international important water flow areas IBA), presence and kind of animal shelters have been collected as told in the national report /1/.

The geographic information system has been a tool that supported the selection of the sites by researchers that have already firsthand knowledge of most of the sites. They delivered the data to the competent authorities in a form of excel sheet. The sites in Finland have not been ranked, those representing a risk, including also those of unknown characteristics, to be checked later through field assessment, have been pointed out /1/.

4.3.2 GIS for risk analysis and ranking - UK

In UK the approach has been instead more oriented to use of GIS as a screening and scoring tool. According to W.M. Mayes et al. /26/ more than 300 sites have been screened, identifying those sites that have highest risk to impact water quality. Information from literature and water and waste water testing have been used to compile the layers. The main parameters chosen were /26/:

- chemical - geochemical data of mine sites (As,Cu, Cd, Fe, Mn, Ni, Pb, Zn, Sn),
- the kind and location of the main mining commodities during the time
- size and proximity of the mining site and waste areas to surface waters

- river networks, properties of stream waters and of sediments
- flows and concentration interpolated to calculate an annual (summer) mass flux in tonnes/year for each contaminant at each site as described by W.M. Mayes et al.

The tool has been complicated including also rainfall, vegetation, topography, type of soil and local geology and a simplified version has been adopted, also including areas of low data availability as Devon and Cornwall as described in H. Potter and D. Johnston /18/. According to W.M. Mayes et al. /26/, when some information has been missing, it has been evaluated from correlation curves, as for Fe and Mn, noticing that with highest Fe release from high Fe content mining, Mn followed the same trend since Fe has been associated with Mn. Zn has also been found in surface waters and Cd, being high risk metal for its toxicity, persistence and bioaccumulation tendency has been correlated to Pb and Zn /26/. In this way information gaps have been covered and a general view of the risk sites has been created.

4.3.3 Germany – GIS using geochemical – geological model

Germany used ore data to extrapolate information on possible waste material composition, as Finland also did, but GIS was used as a working tool. In Germany, the inventory included also the lignite mining district Lusatia where GIS helped to quantify and predict the pollution from the district's mine dumps. /17/.

According to B. J. Graupne et al., the software HistoGIS was used to compile, collect and later relate geological and geochemical data from boreholes from the 90's (mainly those available and relative to S content: total sulfur and sulfate sulfur). According to their article, the old boreholes data had some uncertainties related to the tests methodology performed and to the handling of the samples and new tests were needed to quantify the relevance of the old data. /17/.

A geological model was added of the information of the geochemical properties and geometrical-geographical information. Mass balances modeled accordingly, were used to calculate the site dump composition while the oxidation process of pyrite releasing sulfate was the main element to evaluate the potential for emissions for the dump site. /17/.

4.3.4 Information open to the public - Ireland and Hungary

In Ireland, GIS has been used to create an open database with a navigable map page accessible from the environmental protection agency (EPA) web pages relative to historic mining sites. Envision Mine Viewer /27/ collects information about mines, downloadable GIS data and detailed reports for each site including geochemical investigations.

Hungary paid attention to have accessible information in English and in Hungarian, detailing the information according to the topographic map scale. ArcGis was used to handle the attributes of the mine sites and of the waste areas and to calculate the relevant parameters, but the information given in ArcGis was converted to KMZ/KML format for public consultation and “maps.google.com” and “Google Earth” were used to show the results on navigable maps as described on their site. /28/.

4.3.5 GIS combined with other platform –The EU entering countries

The EU entering countries in 2004 were preparing for hazard mining inventory through a project PECOMINES where remote sensing and GIS were used to coordinate, link and compare information. The data also in this case was collected through questionnaire and bibliographic data (field archive data too) that was included into a database where also geographic information was given, so that they could be linked with GIS to other national and European data and spatial layers as CORINE LC mineral extraction sites as described in the project report /29/. Slovakia and North-West Romania have implemented it on part of their territory on specific mining sites and a scheme of the interaction of information through GIS is visible in Figure 6. /29, 30/.

In Figure 6 FPCS means Feature-Oriented Principal Component Selection Method according to A-M. Vîjdea et al. /30/, where selected bands of different FeOx and OH bearing minerals have been chosen because they can easily be identified by their features simplifying in this way the analysis.

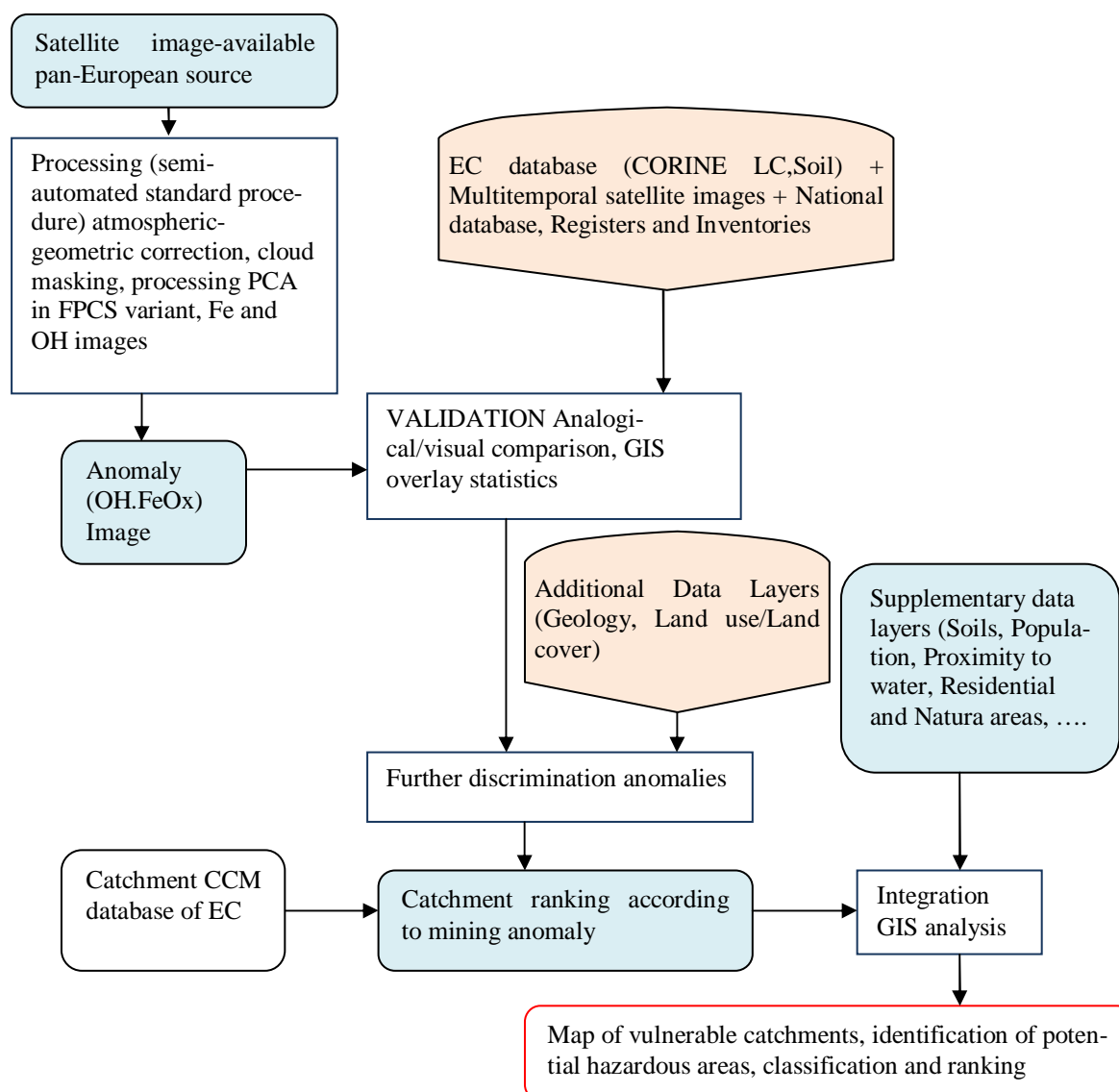


FIGURE 6. Scheme of the interaction of different information to build the risk evaluation tool for mining waste areas for the entering countries within PECOMINES project /29/ and A-M. Vijdea et al. /30/

According to A-M. Vijdea et al. /30/ the anomalies, interpreted as higher superficial concentrations, of FeOx minerals and OH-bearing secondary minerals, could represent possible hydrothermal alteration that could be indicators of potential acidification processes (AMD) in the waste facilities. The method, explained in detail for band selection, matrix and analysis, successfully identified those areas characterized by anomalies caused by extractive industry, with the limitation that the area should have at least the anomaly large as 1 pixel to be detected. /30/. In this case the load given to pollution potential through water is higher than that related to air when had not practically been considered from image analysis.

In figure 7 are visible the results got from Smolnik site during the project as shown in PECOMINES report /29/. The minerals visible as anomalies in the first picture (taken during active mining activity) are changing during the closure time and vanishing after the remediation process, showing that there is no risk of AMD from the site.

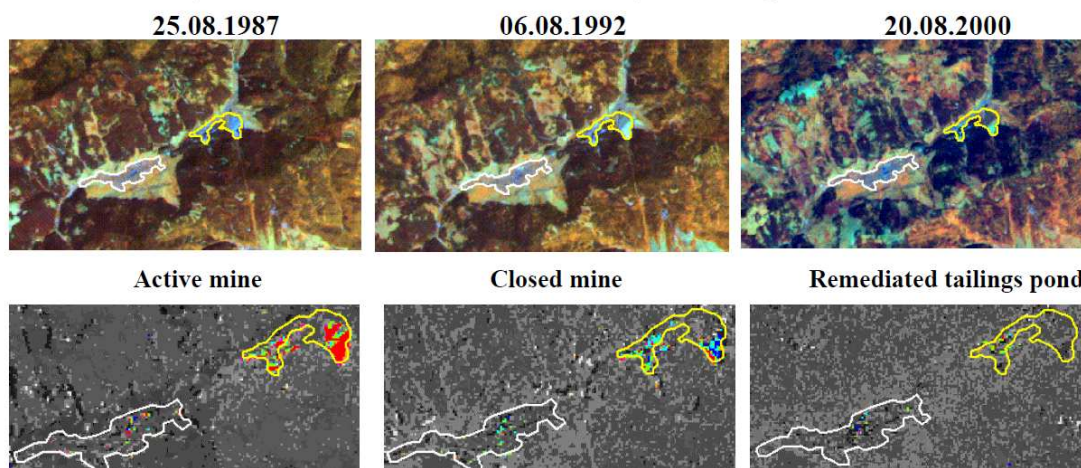


FIGURE 7. Changes in anomalies during the time because of the remediation activity undergone on the site. PECOMINES project /29/

4.4 Risk ranking

Risk ranking and site prioritization has also been a part of the inventorying process for many countries, since it helps to define future actions to be taken on the different sites and their priority. The way of making the ranking has been chosen by each country according to national situation and some did not create a ranking, but only pointed out the risk areas, as for Finland.

4.4.1 The UK

A. J. M. Turner et al. describe in detail how the risk and risk ranking was done in the UK. Remembering that relevant parameters (metals, proximity of the waste facility to the water, dimension, slope of drainage...) had been evaluated for each mining site using also tools as ArcHydro software, each parameter was put on ArcGIS and XTools as a layer and each parameter layer was given a “weight” that mean a number showing the importance of that input parameter in comparison with the others. /31/.

Each mining site got a score for the severity of risk for each parameter so to each layer a risk scoring scale was attributed. For example the vicinity to surface water was scored attributing risk level 6 to the areas in contact, having the “extreme” risks; risk level 5, very high, for those having distance 2-5 m; risk 4, that means high, for the areas within 100-250 m; risk 2 for those between 250 and 500 m and scoring 1, those more than 500 m away representing a low risk. For the slope and area similar systems were used. The total risk was calculated as the sum of risk score (1-6) multiplied by the weight of the layer /31/.

The sites defined as extreme risk were evaluated against historical data and discussion with experts of the local Environment Agency. Site inspections were carried on those sites posing the highest risks. About 200 sites were assessed evaluating, as described by W.M. Mayes et al. /26/: *“Presence of mining wastes, Proximity to streams, Potential to impact water quality, Observation of potential instability and/or erosion of wastes,... Sample water quality upstream and downstream of wastes (including 500 metres downstream where possible),...Sample any mine water discharges to allow assessment of contribution from mine water versus mining wastes, Short written record of site visit including photographs.”*

4.4.2 The EU entering countries

According to SAFEMANMIN project, in Romania the risk scoring ranking was done according to the possibility of impacting human beings mainly, attributing highest risk scores to vicinity of houses and social buildings, second scoring to vicinity of industrial buildings, transport axis and big rivers and lower scoring risk to low traffic transport axis. Even lower risk has been associated to areas without construction and rare person circulation. /24/.

According to PECOMINES project report /29/, the ranking of mine waste hazard for inventory purposes was created using GIS and it was based on water pollution potential where a parameter of “iso-hazard” (IH) is defined as: $\log(\text{number of standard exceedances}) + \log(\text{emission rate m}^3/\text{day})$ and its value has a meaning of a “*potential to pollute equal amount of good quality water per day*”.

4.4.3 Ireland

According to the report published by the environmental protection agency and the geological survey of Ireland /4/, the hazard scoring system adopted was derived from the "Abandoned and Inactive Mines Scoring System" (AIMSS), created by the United States Environmental Protection Agency (US EPA) and used in Montana. The ranking system was individuating the source, making measurements on it, and making the scoring for each source and each mine, ending with the combination of the scores to give the final scoring of the waste area.

The hazards and their magnitude were defined for each site according to G. Stanley et al. /4/ on the base of:

- the chemical composition of the sources and the relative toxicities of their constituents: based on data for humans from the USA and the UK's database/guidelines. Sources included also water flow discharges and stream sediments. Data collected during the past and from new sampling were used for the risk assessment. About 1400 in situ analyses and field tests have been performed using field-portable x-ray fluorescence (FP-XRF) analyzer. About 10% of the samples had further laboratory tests by x-ray fluorescence (XRF) and atomic emission spectrometry (ICP-AES) after having been subjected to multi-acid digestion as described in the report. Water analyses included total metals, dissolved metals, total and dissolved mercury, and major cations (Ca, Mg, Na, K), major anions (PO₄ and SO₄), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS) and total suspended solids (TSS), upstream and downstream analysis with XRF and leachate tests done on solid waste were also performed not overlapping previous data
- the volume or area of the sources
- the likelihood of release, forecasted based on the past performances. The presence and reachability of receptors were scored according to defined tables. The main factors are schematized in Appendix 2.

As told in the report, Excel was used as a working tool. The total score was finally given by multiplying hazard score by likelihood and by the receptor score and summing up those from different pathways. Six classes were created to rank the main features and characteristics of the mine sites. /4/.

4.4.4 Spain

The main points were similar to those proposed by the European guidance document: correct localization of the closed, active and abandoned mining sites in the province, digitalization of the information, evaluation of the effects on the environment and the risks of the mining sites on the province, ranking in function of risks and impacts, and actuation of remediation of the sites prioritized as expressed by C. Subirón Garay and C. Alcalde Molero /32/.

As an example, the mining inventory performed in the province of Cáceres in 2007 by the Dirección General de Ordenación Industrial, Energética y Minera de la Junta de Extremadura, found preliminary 404 sites on the base of bibliographic information as metallogenic map, aggregates guide of the region and register of mines. Later these were assessed for their impacts and their risk ranking and prioritization was evaluated. Eighteen sites have been found to pose intolerable risks for safety and critical impacts on the environment /32/.

Sites of small dimensions were not considered while the larger ones were visited producing description of the main technical data, precise localization, environmental description, photographic report, evaluation of security related to vicinity of inhabitants, infrastructures and ecosystem. The risk for safety was ranked according to probability of happening of an accident and magnitude of consequences (damages) caused by the accident as shown in the table 2./32/.

TABLE 2. Risk ranking for safety according to C. Subirón Garay and C. Alcalde Molero /32/.

Qualification of risk		Magnitude of consequences			
		Light	Moderate	Great	Very great
Probability of happening	Very improbable	Irrelevant	Irrelevant	Low	Low
	Improbable	Irrelevant	Low	Substantial	Substantial
	Probable	Low	Substantial	Intolerable	Intolerable
	Very probable	Low	Substantial	Intolerable	Intolerable

The risk for the environment was ranked based on the incidence and extent of the degradation caused by mining activity and closed/abandoned mine sites. In order to evaluate it, sources and receptors were identified. The described assessment was based on /32/:

- Intensity of the processes (source): very low (1), low (2), middle (3), high (4) and very high (5).
- Territorial impact of the effects produced by each process: point (0), focused (1), local(2), extended (3).
- Intrinsic value of the element affected

The risk ranking was calculated as shown in table 3, with the effect calculated by multiplying the magnitude with the territorial impact (extension).

TABLE 3. Risk ranking for environmental issues according to C. Subirón Garay and C. Alcalde Molero /32/

	Environmental factor	Magnitude-intensity	Territorial impact- extension	Effect
Physical medium	Relief	5	3	15
	Soil	5	3	15
	Surface waters	5	3	15
	Ground water	5	3	15
	Atmosphere	5	3	15
Biotic	Vegetation	5	3	15
	Fauna	5	3	15
	Landscape	5	3	15

4.4.5 Italy

As described in “Gerarchizzazione dei siti minerari censiti”/11/, risk assessment and risk ranking were mainly addressed to health-ecological risks, not considering the structural ones because of lack of known and experimented methodology for indexing the risk and also because of the uncertainty related to the available data from the sites. The methodology adopted was the ARGIA (Analisi relativa di Rischio per la Gerarchizzazione dei siti Inquinati registrati in Anagrafe) created for the contaminated sites and following the European guideline for characterization of:

- the sources (polluted soils and waters),

- the transportation paths (through contact, ingestion, and inhalation from soil, underground and surface water, indoor outdoor air)
- human and natural/artistic receptors (on site: 0-100 m; off sites 101-1000m , 1001-3000 m and 3001-5000 m).

The method does not show the absolute risk and is not correlated to that either, as specified in the manual of ARGIA /33/. The basic methodology has been to evaluate the “risk= magnitude x probability” and the “probability = probability that an event occur x probability that will affect the targets” /33/.

The contaminants were classified in carcinogenic and noncarcinogenic taking toxicological information from the main databases, as for example the Integrated Risk information System (IRIS) as described in the national report /11/. Carcinogenic substances were given a weight higher than noncarcinogenic ones, and for them the toxicity scores were proportional to the “slope factors-SF” that is the slope of the curve dose-effect at low doses between 0 and 0,1 of risk, expressed in mg/kg-day, while for noncarcinogenic substances toxicity scores were inversely proportional to the “reference doses-RFD”, that is the maximum daily exposition that does not produce effects on the organisms in mg/kg-day /11/. Toxicity parameter: $T = SF \cdot 10^6$ (for carcinogenic), $T = 1/RFD$ (for noncarcinogenic).

As defined in the national report /11/ the risk index IRI_m relative to the m^{th} contaminant m^{th} of the primary source j is a dimensionless number (formula 2):

$$IRI_{jm} = \sum_i PtS_{ijm} * PtT_i * PtR_i \quad (2)$$

Where:

PtS , PtT and PtR are the scores relative respectively to the secondary sources, transportation paths and receptors.

i are the different elements (underground waters, surface waters, soil, indoor air and outdoor air)

j different primary sources on the site

m polluting substances considered for the primary source

The total risk index of a site is the sum of the relative indexes of the different primary sources on that site $= \sum_j IRI_j$. An extract of the toxicity scores listed in ARGIA is shown in Table 4 /11/.

TABLE 4. Toxicity scores according to Gerarchizzazione dei siti minerari censiti /11/

Substance	Carcinogenic score	SF	Non carcinogenic score	1/RFD
Cd	$1,64 \cdot 10^6$	$6,3 \cdot 10$		$1,75 \cdot 10^4$
Co			$8,96 \cdot 10^2$	$3,45 \cdot 10^3$
Pb	$7,6 \cdot 10^3$			$2,86 \cdot 10^2$
.....				

For the mining sites a matrix was created: Extracted mineral vs. Polluting substance with reference data obtained from bibliographic documents as from L. Usoni – “Installations de preparation des mineraux en Italie” edited in 1963. Table 5 shows, as an example, a synthesis of the values listed in Gerarchizzazione dei siti minerari censiti /11/.

TABLE 5. Matrix to identify and risk rank polluting substances according to the extracted minerals as defined in Gerarchizzazione dei siti minerari censiti /11/

		Polluting substance							
		Sb	Ag	As	Cd	Ni	Pb	Zn
Mineral extracted	Sphelarite	250			300			5000	
	Galena		3				2000		
	Chalcopyrite			250	450	650			
								
	Default	25	0,3	25	30	65	200	500	...

For each site only the mineral presents in the site was selected. For those that are present but do not represent a risk a default value equal to 1/10 of the minimum value of its column has been given /11/. A primary source, accessible and not restrained was considered for each site. The dimension of the source depends on the dimension of the mine site, on the duration of extraction and the time laps from the extraction to nowadays, since it has been assumed a decay during the time /11/.

In this approach, 5 classes of risks have been produced (low risk, mean low risk, mean risk, mean high risk, high risk), ranging between $2.930 \cdot 10^{-18}$ and $8.9457 \cdot 10^4$ having most of the site showing mean risks /11/. The national report reminds that if a common risk method is used, as in Italy, all the parameters introduced have to have a similar degree of precision, otherwise the ranking results can be affected. If, for example, a default value has been used because the measured values have not been reliable, and for one site the real values have been available, it would have anyway been better to use default values also for that site not to jeopardize the final result of the inventory. /11/.

In Figure 8 is shown as example the map of Sardinia, a region of Italy, where the number of minerals accounted per site had been higher than the national level and the number of sites showing a potential risks has been the highest in the country, reaching 242 sites just in the region, of which 209 represent a high, mean high or mean risk /19/. Figure 8 shows on left the map concerning the number of sites present in the region and, on the right, the map showing the risk level ranking of the areas after the risk evaluation has been performed. The colours are not representing the risk level of single mines but the density of the mining activity.

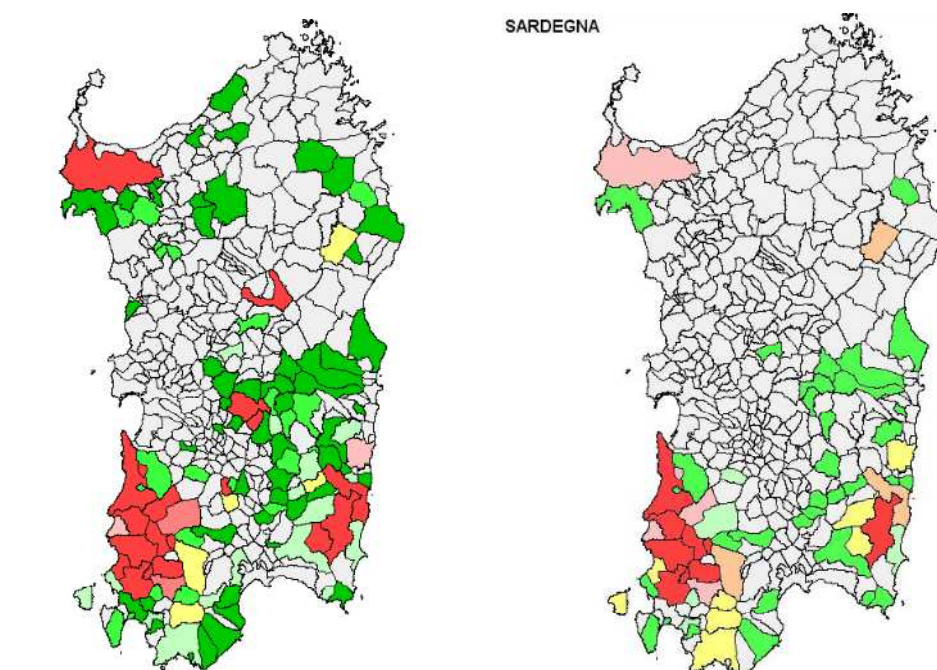


FIGURE 8. Density maps of the closed and abandoned mining sites and mining waste facilities: on the left the map of the existing facilities (in red more than 6 sites, in dark green only 1 site), on the right the map of those representing a mean, mean high and high risk (in green 1 site, in red more than 6 sites). The maps are extracted from the reports edited by ISPRA /11/

4.4.6 Hungary

According to the report “Inventory and risk classification of closed mine waste facilities for Hungary” /28/, the Hungarian approach has been using the available databases to compile the relevant information: ”GIS Database – OTAB, Digital Cartographical Database – DTA-50, Digital Elevation Model– DDM-50, Land cover and land use – CORINE, National nature conservation areas –NATURA2000, Water Management Atlas – VGA, Population registration data – KSH) ... MBFH mining-specific data sets” .

The ranking has been based on the information listed on the pre-inventory guideline using screening parameters such as dimensions, topographic characteristics, type of waste facility, contaminant sources number and characteristics.... A second ranking has been then applied, according to the fact that the site has been undertaking remediation actions or not, considering that remediation actions should have reduced the risks. In Figure 9 is shown a diagram of the ranking system. /28/.

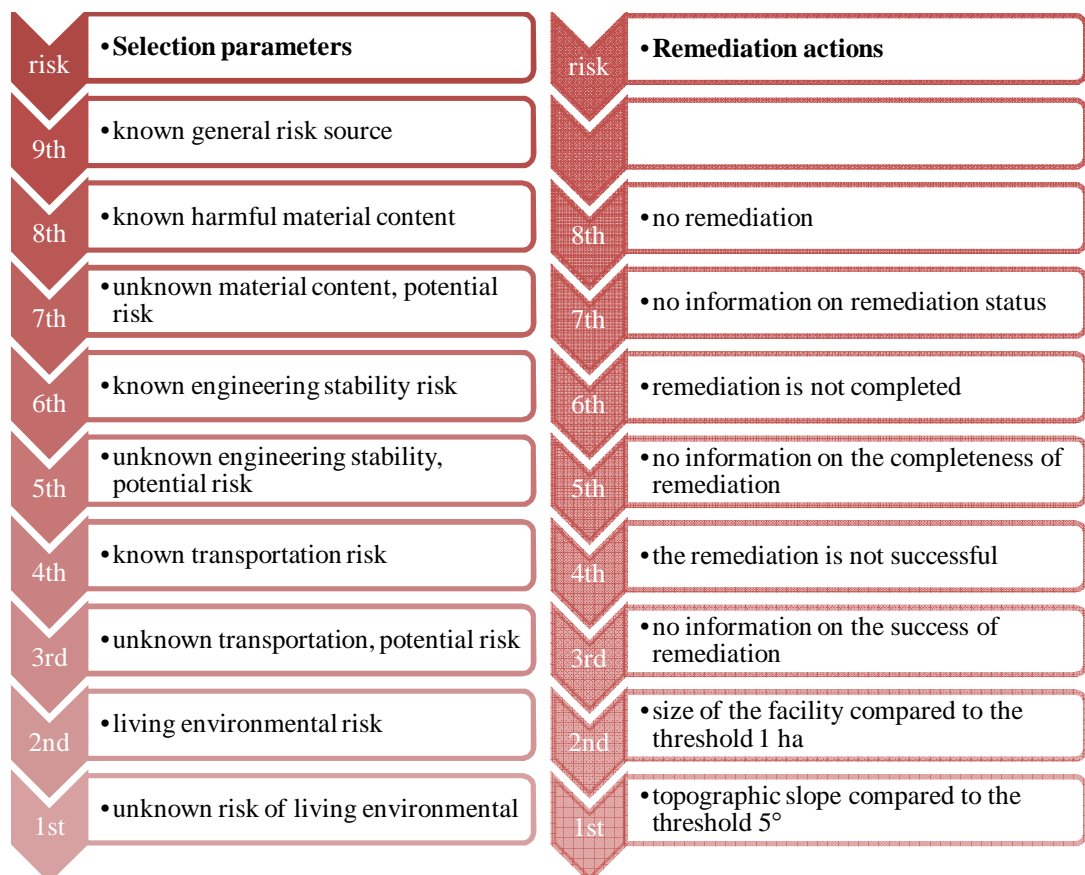


FIGURE 9. Scheme of the risk ranking parameters adopted by Hungary, where 1st risk level is representing lowest risk and 9th the highest risk /28/

The risk has been evaluated following the source-pathway-receptor model, attributing highest risk for site presenting multiple risks. The ranking had been based on number of YES answers to the questions proposed in the European Pre-selection guideline, while for tailing ponds and waste heap the threshold value for considering them representing a risk is given merely by their dimensional and topographic characteristics (slope $>5^\circ$, and size $> 1\text{ha}$). The preliminary ranking according to the two concepts is shown.

The main points that characterized the European risk assessment and risk ranking procedures are grouped in Appendix 3 in order to simplify and compare the methodologies.

5 OUTSIDE THE EU

Having an overview of the program done in the extra EU countries, one can look at South America, the USA, Canada and Australia. Most of these represent areas from which data can be found. Then can be analyzed what has been done in Africa where seems to be low availability data. Worldwide, several countries in fact have already been active in making inventory of the abandoned sites as for example the Indian Bureau of mines that in the inventory carried out in 2003 identified 297 abandoned mine sites out of which 82 have been recognized to need reclamation and rehabilitation actions as described on the agency's web site /34/. Often the final list, navigable map, program are available, while rarely the methodology adopted can be found.

5.1 South America – Latin American countries

In the last years the Latin American countries have been very active in establishing and implementing an inventory of closed and abandoned mine sites as shown on the pages of the local geological surveys, for example in that of Brazil /35/, while other information can be found also from pages of international cooperation with Japan, as those of JACA Japan International Cooperation Agency /36/.

The Asociación de Servicios de Geología y Minería Iberoamericanos (ASGMI) based on the cooperation of professionals and geological surveys from Peru, Venezuela, Mexico, Argentina, Spain and Chile, has edited in 2010 under the coordination of

Chile's expertise the "Manual for the inventory of abandoned and closed mines"/37/. According to the Manual, the whole mining area is considered and not only the waste areas, and, as for the Spanish guideline, closed mines are those in which activity has ceased for temporary or definitive time in which there are not operations ongoing typical of an active mine. It comprehends the inventory of closed and abandoned mining sites, the characterization, evaluation and classification of the risks to the environment with consequent prioritization and proposals for remediation of those posing the risks. /37/

According to the Manual /37/, the methodology includes first the collection of basic information through a questionnaire, in some parts similar to that proposed within the EU countries - name of mine site, owner, position, but also accessibility to the site and accessible openings, kind of mine and mineral extracted, conditions of the mine (under water, quality of water, buildings, processes and treatments undergone during mining and processing operations on the site). Evaluation of the waste areas included dimensions, color of the soil and waste, presence of dangerous substances (Magnesium, Cyanide, Sulfuric acids, others). Description of the relation of possible risk posed to the environment and the human beings included: position of inhabited buildings, road infrastructures as tunnels and roads, agricultural and forest areas, natural areas and important ecosystems to be protected as well as cultural heritages. The geology and position and use of water in the mine area and proximity, effluents, precipitations, climate and bioclimate, including those peculiar of some areas are also evaluated. The bibliographic data collection and field visit have been complemented by laboratory analysis in those cases where it was assumed a risk of pollution, AMD and of chemical changes.

Field assessment allowed also to evaluate water contamination, dust generation, degradation of vegetation, flooding, sliding, subsidence, seismicity, erosion and all the other factors that could represent a hazard for safety, as possibility to fall in openings, slopes, accidents in open galleries, detachments of walls or slopes, accidents in the water mass or in the abandoned facilities. /37/. For safety, as for Spain, the probability is ranked, giving a value of 0 to no probability, that mean that cannot occur, to 1 low, 2 median if there is possibility that will happen, and 3 high if surely will occur.

Contamination of water is evaluated visually and with field measurements using for example pH meter, conductivity meter and a kit for evaluation of water quality. Also laboratory measures for Cd and As are suggested if a risk of presence is assumed. Generation of dust is also evaluated through field observation as well as the assessment of the ecosystem and the environment - change in vegetation, possible movement of material from the mine site to adjacent areas and the rivers. Possible soil contamination is considered an indicator of ground water contamination risk and it precludes to field and laboratory analysis for both the elements.

5.1.1 Chile

In the Republic of Chile a methodology created in cooperation with Japan was applied within the Project for Institutional Capacity Strengthening in the Environmental Management of Mining (FOCIGAM) /38/ based mainly on questionnaire and field evaluations, checking the state of 216 mine sites in 2 years. The methodology adopted in South America has been created on the base of the one previously implemented in Chile.

Chile has thousands of closed or abandoned mines as recognized by the project FOGICAM /38/ and has a majority of small mining company, generally reaching 80 workers. It is known that a least 52% of mining sites are abandoned sites and many are located in arid areas. /5/ The inventorying methodology carried in 2007 according to “Catastro de faenas mineras abandonadas o paralizadas y análisis preliminary de riesgo” written within the project by the National Service for Geology and Mining and hereby referred as Chile’s Inventory, had a similar questionnaire for collecting information as the one adopted in other Latin American countries. The procedure has been similar to the one used in Spain, where each element constituting a risk has been scored for probability of happening of an accident and for magnitude of consequences. The risk had been evaluated from the product of probability and consequence. /39/

Probability of happening was evaluated for contamination, stability, security and land use, while magnitude of consequences has been evaluated for human health and life, infrastructures (transport paths, public installations, cultural heritage,...) and natural resources (mainly as forest or agricultural land, water courses, national parks, flora

and fauna) as shown in Chile's Inventory/39/ The ranking of probabilities and consequences is visible from Table 6 as defined by the same manual.

TABLE 6. Ranking probability of happening and magnitude of consequences according to Catastro de faenas mineras abandonadas o paralizadas y analisis preliminary de riesgo /39/

Probability:		Consequences:	
0= no	source of risk does not exist, or 100% cannot occur	0= null	without consequences
1= low	maybe will not occur	1= low	low state or minor damage
2= medium	will possibly occur	2= regular	serious state, or recoverable damage
3= high	exist or surely occur	3=high	fatal or irrecoverable damage
		5= catastrophic	loss of life and mass damages to the environment

Therefore, for example risk associated to contamination has been related to probability of contamination of water, dust generation ... and the magnitude of consequences has been evaluated on health and life, infrastructures and natural resources. In Appendix 4 is shown the table applied in Chile's inventory. /39/

5.2 The USA

As visible from internet web site and bibliographic references, in the USA an inventory of abandoned and inactive mines that represent a risk for human health and the environment affecting federal lands was carried out. According to the Montana Bureau of Mines and Geology /40/, the inventory was done by first collecting systematic information of the sites on the chosen territory (location and coordinates, ownership), then by evaluating the risks for each site based on previous data (water and soil characterization), ending with the identification of the mines on federal land that represent a risk.

The USA has not yet carried out an inventory of the all territory and has promoted site assessments of parts of territory or specific mine sites, creating in this way a large risk based characterization. The National Association of Abandoned Mine Land Programs

and the National Coalition for Abandoned Mine Reclamation have been coordinating several financial programs in favor of site risk characterization. As a result, within others, an internet database has been created about the inventory of abandoned mine land-AMLIS- that comprises about 31.000 sites of the approximate 500.000 existing on the territory, that had been assessed, of which 5% could represent a risk to the environment, mainly for water pollution, according to Ch. Wolkersdorfer /7/. While 25% of the sites that represented a risk related to health and safety matters have been under some actions, the rest 75% should need further detailed investigations as stated by The Bureau of Land Management from the Department of Interior (BLM)/41/. On the other side, BLM, has estimated that most of the sites are 5-10 acres, so, small and mid-size abandoned hard rock mines of average complexity that are not posing great impacts, while there are some 13.000 abandoned coal mines, mostly small and mid-sized in the East that could cause health and safety problems /5, 42/.

BLM updates the information and undertakes specific inventories depending on the risks associated to a site, and on fact that the site has been changing intensity of use, or has been planned a recreational or municipal use or has posed more risks compared to the past. /13/ As described in the BLM Manual /13/, the first risk evaluation is done upon bibliographic elements relative to the mine site upon which experts determine the “time-critical nature” of a release. If the risks are negligible the site will not be taken into consideration for further studies, if it poses a risk a site investigation will be performed evaluating presence of hazardous substances, safety risks, surface water, vicinity to inhabited areas and accessibility to people. Site characterization will then be performed to quantify the risks. The sites have then been scored to prioritize those that need more urgently remediation actions. Water quality and physical safety are the main issues addressed.

Prioritization relative to water quality includes largely administrative and legislative priorities, threat to public health or safety, and to the environment, location and cost efficiency. While addressing physical safety, scoring for remediation actions included occurrence of death or injury connected to the abandoned mine site, high use of the site as recreation purposes, accessibility, location, and cost efficiency as defined in the Conservation Based Strategic Plan for Abandoned Mine Lands Program./42/

Geographic information system is used to coordinate the information between the interested authorities (site identification, location-GPS, site characteristics and risks, hazardous materials, reclamation status) and should be also accessible to public to some extent even though some restriction had been imposed in the beginning of 2013.

5.3 Canada

According to C. Unger, et al. /6/ the Canadian Federal Government in the year 2000 already recognized the need to identify and quantify the risk posing areas under federal jurisdiction, but the work has not been proceeding as planned because of unclear responsibilities and roles, lack of policies and problems in budget allocation, so much information on contaminated sites is still lacking. It is reported that in the same years a National Orphan/Abandoned Mine Initiative (NOAMI) worked to create recommendations on inventory, community involvement, transparency and legislative barriers relative to abandoned mine rehabilitation /6/. The provinces didn't work with the same efficiency on the matter but for example British Columbia has been one of the fastest and in 2004 started a "contaminated site program" to point out the risk areas and to create prioritization of the sites /6/.

An idea about a methodology adopted in Canada is available from Nova Scotia that started the characterization of the abandoned mine openings since late 90's. According to the government site /43/ the inventory has been based on bibliographic information: bulletins, mineral occurrence cards, geological maps, annual notes from the geological survey of Canada and assessment reports. The sites have also been scored for hazard degree. The inventory didn't include the need of performing a site assessment, was not comprehensive of all the mine sites and even if it is enriched of new information in a continuous way it does not assure updated data of previous inventories. The information has been organized in a database and through navigable map as visible from the government web site /43/.

From The Aboriginal Affairs and Northern Development Canada's web site /44/ it is possible to see that Contaminated Sites Program (CSP) has been established. It carried out an inventory of polluted sites. Moreover another inventory took place under agreements of Canada, YTG and the Council of Yukon First Nations. The list of sites comprising sites that pose a risk, those that are going under remediation activities and

those that did not pose risks was created. According to the web site /44/ the Northern Environmental Risk Assessment Strategy (NERAS) has been used and it included a first identification of the site, a historical review based on bibliographic data, field evaluation and initial testing. After a first classification of the site was done, on those sites recognized to pose a risk a detailed testing program was performed to reclassify the site in a more precise level in order to allow the development of a remediation/risk management strategy. NERAS included also the step relative to the remediation actions: their implementation, follow up with field testing and evaluations in a long monitoring program./44/.

A broad range of priorities affected the ranking of the sites: health and safety issues, environmental impacts, legal and Aboriginal land claims obligations and other priorities of other stakeholders, within which, First Nations, Northerners and Inuit /44/.

5.4 Australia

Australia has been active in addressing abandoned mine sites risks even though according to C. Unger et al. /6/ only Queensland, New South Wales and Tasmania have been implementing an abandoned mine program while in December 2010 a Strategic Framework for managing Abandoned Mines in the Minerals Industry has started. According to the report of the strategic framework /45/ the work addressed “*site inventories and site data management, improved understanding of liability and risk relating to abandoned mines, improved performance reporting, the standardisation of processes and methodologies, knowledge and skill sharing across jurisdictions*”

In Australia already 50.000 sites have been assessed. The assessment methodology and philosophy were similar to the USA : moving from the identification of hazard, quantification of the risks to evaluation of opportunities /45/. The importance of involving the communities and the stakeholders is a central element in their assessment methodology as visible in Figure 10. In fact “threat and opportunities” play an equally important role in abandoned mine assessment and management /45/. The community is relevant because it can benefit from an alternative use of the site, getting opportunities for economical, cultural and social development, and at the same time it controls and minimizes the threats to health and safety.

The magnitude of the consequences and the probability of incidence defined the level of risk, as seen for Spain and Latin American countries, and also in this case the quantification is not just upon quantities but also upon qualitative analysis. After it has been done the prioritization of the risk, a plan to mitigate unacceptable risk is developed implemented. Afterwards the efficacy of the measures is assessed and the risk are re-evaluated /45/.

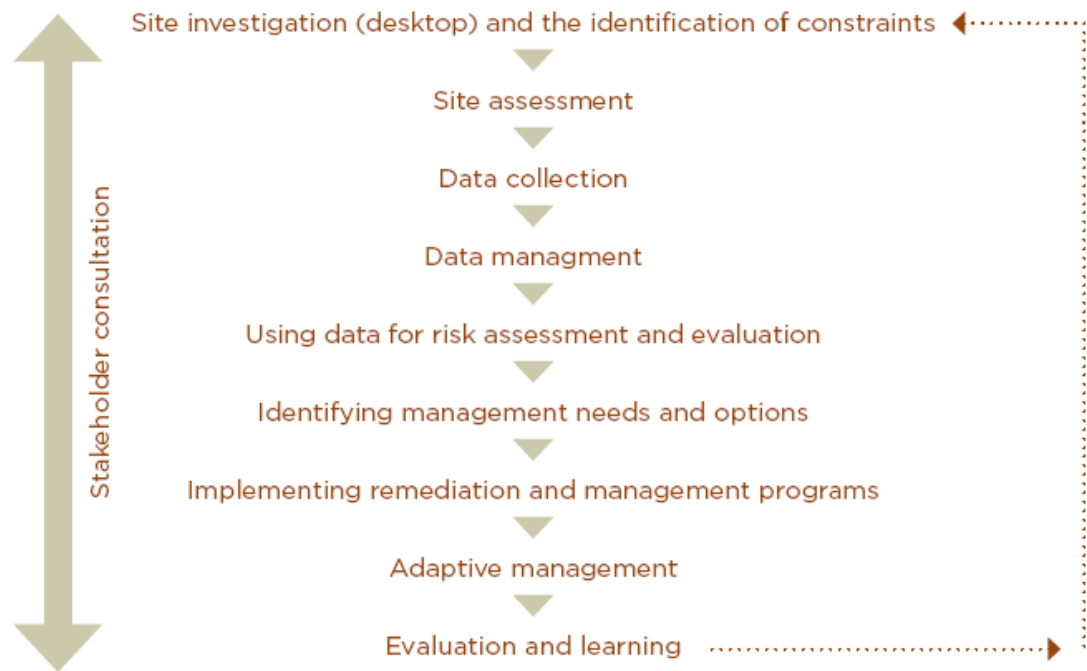


FIGURE 10. Australian risk assessment methodology /45/

According to C. Unger et al. future economical aspects (mineralization, other use for the site....), health, safety and environmental impacts and historical values have been evaluated. Several data sets have already been collected in different states but the original scopes have been different from state to state, in some cases addressed to evaluate the re-usable resources, other times to health and safety threats /6/. The database leaves in these cases gaps: different aims needed the assessment of different aspects. Data might not be comparable also because of lack of precision in providing spatial data since the instruments used have been evolving during the time and the expertise has been different. For example, according to the framework report /45/ the Geological Survey of Western Australia has been performing an inventory since 1999 implementing a database with detailed mining site report georeferenced, encountering challenges because in 1999 the precision of the GPS was of 2 m and other traditional

methods had to be used to complement the data. Moreover states had also been using different terminology and classification systems. /6/

5.5 Africa

In the state of South Africa and in Namibia inventorying activities have already been going on and it is possible to see the methodologies and the results obtained. In Namibia the methodology adopted by the Geological Survey of Namibia (GSN) operating under the Ministry of Mines and Energy has been first created within the cooperation of Germany and Japan with Chile, implemented in Chile and adapted to Namibia's environment and published in 2010/14/. While in South Africa a national program had been established: the "National Strategy on derelict and ownerless mines". Within it the Department of Mineral Resources (DMR) financed a project in 2012 to create and maintain a database to handle and rank regional derelict and ownerless mines, aiming to plan and prioritize rehabilitation actions as visible from Council for Geosciences web pages /46/.

Beside it, in 2011, another project "Assessment of the impact of mining and mineral processing on the environment and human health in Africa" aimed to study the geological and geochemical information to distinguish natural anomalies from those caused by mining activity. /47/ From the web site of the Council of Geosciences /46/ there is not a methodology available but is it visible that the inventory is performed also visiting the sites as for Namibia's methodology /46/.

According to K. Kreft-Burman et al. /9/ in South Africa since 1976 there has been mining regulations and the Department of Minerals and Energy (DME) has been in charge to implement the legislative frame ruling mining activity including some pieces of legislations as: Minerals Act established in 1991, Mine Health and Safety Act in 1996 and Water Act in 1998. These are ruling the opening, management and closing of mining operation in regards to health and safety and to environmental impacts and are typical of modern mining legislation /9/. Similar legislative frame has also been established in other African countries.

In Namibia the hazard scenario, the receptors, the likelihood of occurrence, the magnitude of consequences have been identified. A risk matrix similar to the one adopted in

Spain and in Latin American countries helped to identify the sites representing a significant risk. According to the Namibian methodology, economic activities as aquaculture, fishing and tourism have also been included within the receptors. A “detailed risk assessment” has been performed for those sites that presented high uncertainties and a “cumulative risk assessment” has been performed for districts and contiguous sites /14/. If the site presented significant risks it was ranked in the prioritization process. A scheme is visible in Appendix 5.

The source-pathways –receptor model is in this case important too because it allows to rank the sites also on being reachable, a relevant factor being a country with low density of population. Collection of bibliographic documentation has been fundamental, like in the European methodologies, and included besides site identification, location and mining/processing information also climatic, seismic, hydrology and geological data. Maps at the scale 1:50 000, aerial photographs and satellite images from Landsat or Google Earth plate 3.1 have been essential /14/.

The inventory required a field visit to evaluate the site and the risks. It has been possible to perform a simplified risk assessment allowing non expert to identify with available data and visual inspection the risks of an area relatively to pollution and safety issues. Relatively to safety, a list of questions to be answered on “mine subsidence, open pits, tailing dams, tailing and heap leach dumps, waste rock dumps” is organized on separate pages on an excel file as visible from the annexes of the Namibian methodology /14/. Possible hazards are observed and listed. A list of possible observation results to which has been given a risk score allows to calculate the total score of an area. For example in case of seismic areas, a question about the inclination of the slope higher or lower than 52° , determine partial score for risk calculation of 3 or 0 to be added then to the others and inserted finally in the risk matrix. Simplified risk assessment methodology is formed by several guides to interpret the hazard, the cause and estimate the risks.

Detailed risk assessment methodology for assessing selected sites can deepen some aspects as seepage, water quality, stability of dams recognizing that the simplified assessment already provides a complete picture of the situation /14/. Instead the detailed risk assessment relative to contamination is much more complicated and is directed to health risk assessment experts and toxicologists. Risks related to AMD and

to toxic chemicals are evaluated through laboratory tests and the methodology provided also tools for interpreting the results. /14/.

Detailed site and laboratory testing, waste areas structures and waste stocking techniques are described in the Namibian methodology as guideline for the local Geological Survey. Also K. Kreft-Burman et al. /9/ in his report about African legislation identified the main reasons that determine a dam failure, as foundation and drainage problems, overtopping and problems associated to the pipes and promoted the use of satellite images to monitor tailing characteristics as dimension and position to evaluate possible movements-enlargements and risky locations and wetness of slopes.

According to K. Kreft-Burman et al. /9/, site assessment should be carried out making visual inspections of the site and of the structures to evaluate if they are damaged or their performance has been or might be jeopardized. Next main water characteristics such as color, turbidity, pH, conductivity, total nitrogen, total phosphorus, COD, heavy metals, presence of organic harmful substances should be evaluated or measured, performing if needed also acute toxicity tests with *Daphnia magna*. In the tests pore water and seepage waters should be used /9/.

Namibia, as visible from the report by J. Zeidler /48/, has been active in several aspects of climate control actions, including land use. Probably also the inventory and rehabilitation of risk mine sites has been driven by this need. From the report it is otherwise visible that the country has a well organized system in which responsibilities and activities have been allocated, and stakeholders individuated. From the activities undertaken Namibia can no more be considered a low data availability country even though some information might still be difficult to be found.

6 PROBLEMS

Reports and methodologies have shown in some cases the problems encountered in implementing the inventory. The cases about African countries have not been pointing out the challenges but comparing the results obtained and the guidance provided one could notice some gaps, bearing in mind that this was probably the first step of an inventory in the country.

Latin American countries, European countries and other researches have evidenced some relevant aspects. The most important aspect is the availability of reliable data. As reminded in the Italian ARGIA manual, the quality and reliability of the evaluation depend of the quality of the input data /33/. Several times it has been seen that bibliographic data has been incomplete. From the Spanish experience described by C. Subirón Garay and C. Alcalde Molero /32/, bibliographic data has been not precise and the information relative the location has not been correct, so in many cases it has been difficult and expensive to localize the sites. Moreover, there have been problems to identify the land owners since the contact information has not been found in the land register and in case of site inspection in several cases it has been difficult to access the sites. /32/

If GIS is used to evaluate the anomalies, as for the EU entering countries, areas to be detected should be at least as large as 1 pixel according to A.-M. Vîjdea et al. /30/. 1 pixel using NASA Landsat satellite images depending on the bands ranges from an approximation of 18 m to 120m as visible from Geoscience Australia's web site /49/. As stated by A. J. M. Turner et al. /31/ also the use of ArcGIS models could produce uncertainties mainly related to low precisions of the data input, errors in creating the model and wrong assumptions while assigning risk scores to the input attributes.

Field assessment could also be affected by human errors in evaluations as reminded in the methodology applied in Namibia. Also laboratory measurements are not free from uncertainties. Some of the methodologies require further laboratory testing on heavy metals, as for the Chilean methodology and contamination risk assessment methodology of Namibia. Problems in quantifying a risk through laboratory testing could be seen from a case studied in Southern Katanga. According to C.L.N. Banza et al. /50/ the population living near mining and smelters had shown high levels of As, Cd, Co, Cu, Pb and U in the urines while the levels of those elements in the water has been under the limits given by World Health Organization (WHO) guidelines. The metals have being accumulating in the body from multiple sources, including dust and fish consumption. The sole testing done on the waters has been in this case probably not enough to characterize the risk. /50/

Uncertainties related to input data have not generally been quantified probably because the system has been built following a precautionary model, overestimating the

risks and impacts more than underestimating them. Human deficiencies during a site visit underestimating the risks according to the Namibian methodology might increase the risks for the receptors because risk areas might not be included into a remediation program to control and lower the risks. Ranking and prioritization precision instead has been considered important because it can represent an economical loss if a remediation is performed on sites that do not pose severe threat on the receptors.

7 RISK BASED INVENTORY GUIDELINE

Most of the methodologies evaluated have been done in developed countries in which data and GIS platforms have been implemented for several years as in the EU, the U.S.A. and Australia. Inventorying activity has also been carried out in South America, in South Africa and in Namibia, where there has not been rich substrate of data even though the mining activity has been lively. Also in high data availability countries, in many cases it has been seen that complete information of the abandoned and closed mining areas has not been available leaving a certain rate of uncertainty when evaluating the risk posed by the mine.

7.1 Background for establishing risk management

For countries where data availability is low there are not just higher risks because of the mine itself, but also because of lack of procedures to handle unpredictable situations and lack of responsible persons that should control and assess the risks towards the population. A simple visualization of the correlation between data availability / government approach and risks level associated is given in Figure 11 extracted and interpreted from the report of C. Unger et al. /6/.

Highest uncertainty in risk assessment and risk management is posed in those countries in which there is no information about the mining sites, no responsibilities are allocated and neither a financial program nor legislation is addressing the problems. Lowest uncertainties and so lower risks in making the risk assessments and mainly in running a risk management program are in those countries where there is a detailed, up to date, homogeneous, accessible database with information comparable to other sites and abroad, with roles and responsibilities defined and financial program allocated able to identify and manage the risk in a continuous way.

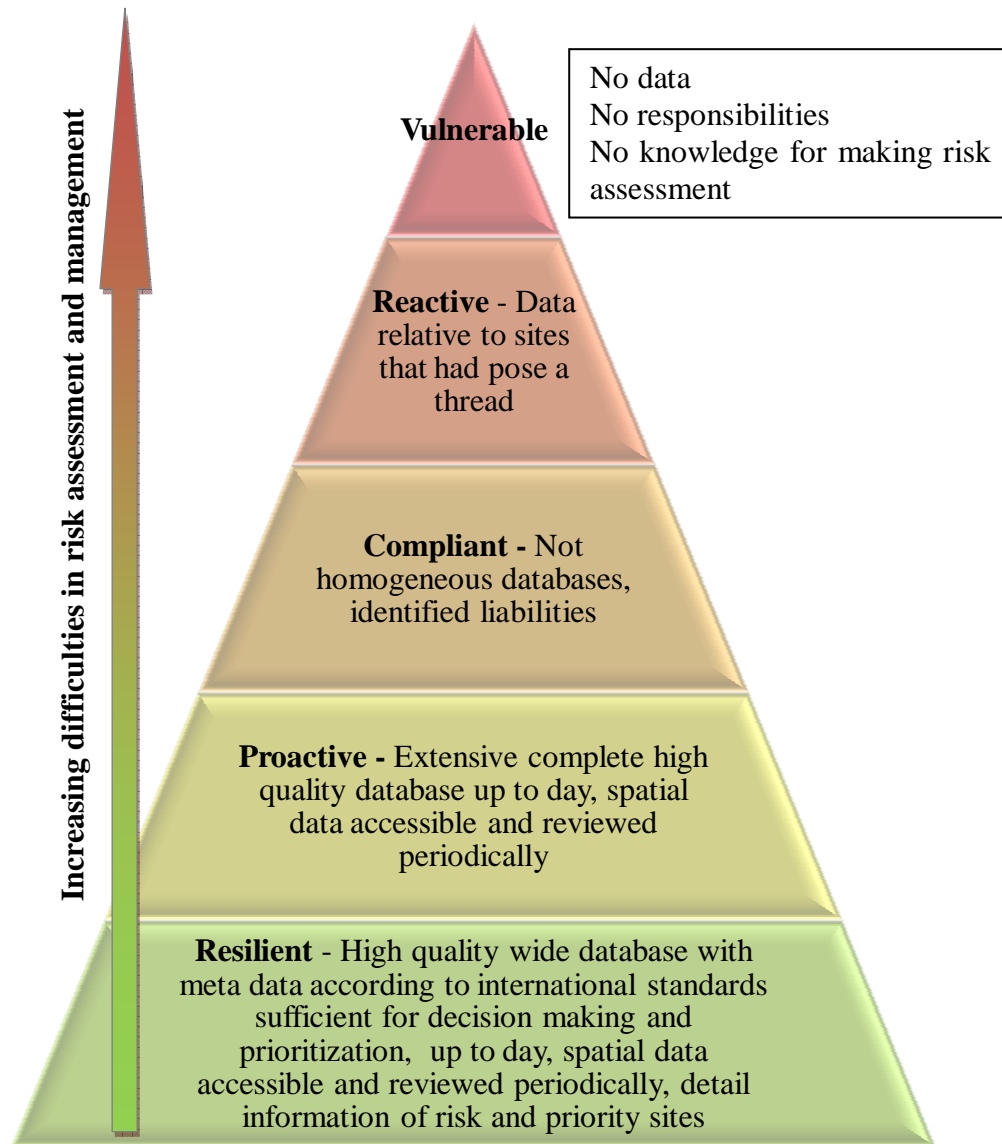


FIGURE 11. Scheme of different data availability configurations and their impacts on risk assessment and risk management /6/

Implementing a risk inventory methodology to a developing country would then comprehend the methodology itself included in a system where responsibilities are allocated and possibly a financial program is established for continuing the assessment. Concerning the methodology, the risk has been evaluated using the source-pathway-receptor model practically in all the countries, while the ranking and assessment method differed. A risk based inventorying methodology in different data availability situation should take anyway into consideration the country for which it will be done, its specific environment, the “available” data and accessibility to the areas.

7.2 Steps for creating an inventory

The fact that an authority of the country would be active in starting and implementing a risk based inventory represent a valid starting point, since it means that there is a financial program and responsible persons allocated to the matter. Several methodologies have been seen and some have been applied to low data availability countries, as those created for Chile, Latin America and Namibia. Possible steps to perform an inventory in developing countries and low data availability countries are hereby described based on the experiences analyzed. A scheme proposed is visible in Figure 12, where the main steps are schematized to be described in detail in the following paragraphs.

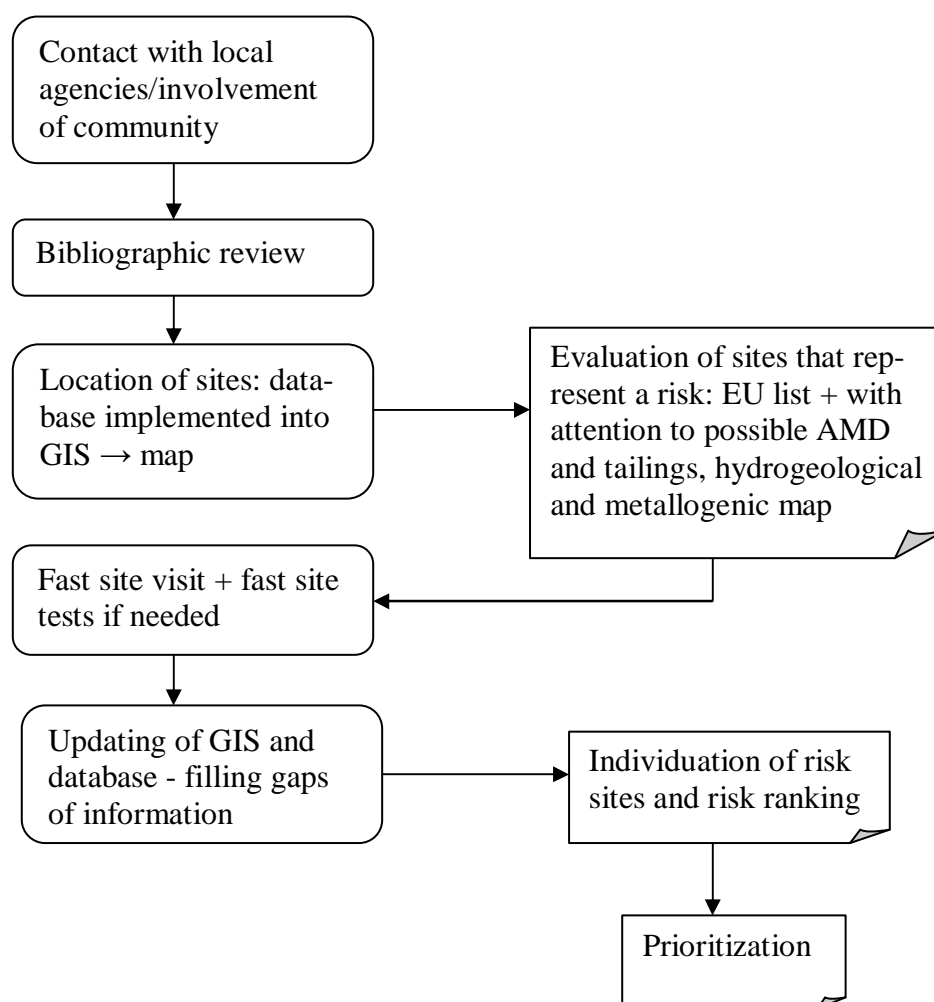


FIGURE 12. Steps for performing an inventory

It is encouraged to perform an inventory considering the whole mining site since impacts could be generated by the whole complex. The inventory should follow the source-pathways- receptor model on the mining site highlighting those sites that could

pose serious threat to human health and the environment, that means death or severe illness, and in which the contamination is persistent, cause a long lasting damage and cannot be restored with minor actions, as also considered within European countries.

In ranking the risk a weight is given to different factors, meaning that some aspects are more important than others in defining a risk. Each site will have then to be analyzed on its own, but one problem compared to the other countries studied could be that African countries present dispersed population with scarce water resources. Even a small mine site could pose high risks if it has contaminated water and it might be difficult to be pointed out, unless through close contacts with the communities.

7.2.1 Engage local agencies and community

One of the most important steps would be to cooperate with regional offices. This would provide the dual benefit of improving building their capacity by the beneficiary country and increase efficiency of the actions undertaken in the projects. Local agencies, in fact, gain knowledge and increase their ability to manage the risks while they represent the main source of information, being expert of their environment, culture and working frame.

Engaging the community and the stakeholders in the processes is as well important, as visible from the Australian experience, understanding the closed or abandoned mine site not only as threat but also as an opportunity for future development. Community can be a source of information to characterize the risks posed by the mine site but they can also promote new economical or cultural exploitation. Therefore the community might be the driving force not only for rehabilitating the environment but also for strengthening local economy and social and cultural aspects.

7.2.2 Bibliographic review - Alternative sources of information

The first important factor that characterizes all the methodologies is to collect bibliographic material. Local authorities or geological survey of the country can have the full picture of the situation, having first hand information and knowledge of the area, of the history and of the processes. Local offices can have information on the geology, mineralogy, geochemistry, even environmental problems that can support the work.

An example is shown by the Southern African Institute for Environmental Assessment (SAIEA) that has been cooperating with other African countries, over international projects and produced educational materials.

Developing countries witnessed high mining activity in the past might not have anyway complete mine documentation deposited to an authority, but some information from international bulletin or publications might still be found. Moreover, from local cooperation it might be possible to contact persons that have been working in the field and that hold oral knowledge of the mining activity not to be underestimated in situations where there are difficulties in finding written material.

Some information could be then collected from alternative sources, as for example, relative to environmental conditions. One can refer to **statistics**, as done in the study by S. Strode et al /51/, where the effects of mercury caused by gold rush in North America has been evaluated worldwide upon data of sediment and glaciers previously collected. Sites, grouping links to statistics, as the library of Princeton /52/, facilitate the research, even though the analysis of the statistics themselves are time consuming and the results might not be as successful as hoped.

No profit organization active in health, pollution and environmental issues might have also taken some actions in risk areas in developing countries, as for example the Blacksmith Institute that had started a global inventory of polluted sites in which risk areas have been identified upon bibliographic data and site inspections /53/. Other small projects have already been working on specific sites to remediate the impact given by closed facilities as in Zambia in the lead contaminated city of Kabwe /53/.

The United Nations and its Environmental Program (UNEP) might have also been researching development countries' areas, generally not for abandoned mine sites, but for other social and health matters and these data could also constitute a base for risk evaluation. A good collection of databases is available from their site /54/ even though access might be slow or under maintenance. Another source of information are reports, as for example the report about "Inventory of National Coordination Mechanisms, Legal Frameworks and National Plans for Disaster Risk Reduction in Africa" that contains for each African country information on the platform built to control the

risk, including earthquakes, landslides and floods, and contact information or reference to competent authority. /55/

International projects have also been carrying research in developing countries and some data, characteristics and base information can also be found from those. An example is the 7th Frame Program (7thFP) project “EO Miners” on remote sensing techniques to evaluate environmental impacts of mining activity that studies also an area from South Africa /56/. In these cases project deliverables represent only a small part of the knowledge gained running the projects, that instead is hold by the organizations that participated in the activities. Those that acted as experts and cooperated with developing countries, as well as those that operate in the beneficiary countries gain relevant quantity and quality of data and increase their expertise.

For example BRGM, Bureau de Recherches Géologiques et Minières, participated in several projects for African development that generated for example the establishment of GIS platform with main element association, Au-Fe-Mn, Cu-Pb-Zn, Ni-Cr-Sn-W for Gondwana as visible from the site “The Gondwana Metal-Potential GIS” /57/. In a future inventorying perspective it would be useful for pre-assessing risk on the base of the ores exploited.

Also SIGAfrique project has been managed by BRGM where updated metallogenic and hydrogeological maps have been digitalized and are available by all African partners relative to African continent scale and regional scale (1:10.000.000 and 1:2.000.000) /58/. Performing an inventory the maps in this case would serve as a base for further analysis.

Another 7th FP project, African-European Georesources Observation System - AEGOS, coordinated by BRGM, in which the Geological Survey of Finland (GTK) has been involved, created the bases for future implementation of GIS as a working tool. Therefore AEGOS deliverables form an important information source listing, besides other things, local entities that can provide geological and mining data.

Another possible source of information is given by those companies that operated within aid programs in support of developing countries. For example the consulting company Geomin, that assessed the risk caused by mining activity in Kyrgystan with-

in a program of aid by Czech Republic towards the region, around the year 2002. It performed a site assessment and site rehabilitation analyzing the impacts given by a tailing dam failure happened in 1964./59/.

Finally, in case of lack of information, it should be evaluated if there are possibilities to understand from successive photographic maps or satellite maps if there have been changes on the use of the land. From comparison of images from different years it may be possible to evaluate if there has been activities and if those have encountered problems. This method has been used for example in South Africa from photographic map comparison /47/ but also in the EU entering countries comparing in these cases the maps with different corrected wave lengths to individuate mineral anomalies /24/.

7.2.3 Identification of the sites

The information gathered from bibliographic research, including image analysis, should be collected in a database and excel form would facilitate the successive uploading into a GIS handling format when precise coordinated would have been made available. Even lacking geographic references, it can be preceded since polygons could be traced in ArcGIS from image analysis to identify the site, while corrections could be added in a successive time when more precise information are gathered. For Africa the available platform of GIS built in SIG-Afrique contains already information on metals, geology and waters besides topographic maps.

ArcGIS or other GIS handling platform would be able to coordinate also the information relative to future site inspection and testing. Site identification can comprise:

- geology, hydrology, chemical, geochemical or metallogenic data of mine sites (attention to presence of Ag, As, Cu, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Sn, Te, Tl, U, V, Zn, asbestos)
- topography and river networks, properties of stream waters and of sediments
- owner, name of mine site, location, kind of mine and kind of activities undertaken on the site, mining technique and waste facilities, processes, ore composition and mineral extracted, chemicals used, ...
- past performances and problems encountered

- position of inhabited buildings, road infrastructures as tunnels and roads, agricultural and forest areas, natural areas and important ecosystems to be protected as well as cultural heritages
- precipitations (average yearly rain fall, maximum rainfall within 24h in 10 years reminding that according to Namibian guideline in Africa the minimum legislative freeboard in tailing dam has to be assured during 72h storm within 100 year), climate and bioclimate
- seismic and geothermal characteristics
- aerial photographs from different periods and satellite images (Landsat or Google Earth plate 3.1) that can be used on specific wave lengths to identify FeOx and OH bearing minerals or to monitor tailing characteristics and evaluate possible movements

Information about risks associated to specific minerals could be already pre-identified from map analysis. In Namibia's methodology there is no specific or particular attention to the possibility to characterize in advance, from maps or bibliographic information, the risks relative to the minerals, so site evaluation has been performed. On the other hand, the methodology applied by Germany, to characterize with relative precision the waste content from mining prospecting boreholes, might not be feasible for African countries, since those information might be in possess of the mining company that owned the place. But the interpretation of the available geochemical, metallogenic maps and of the information, if found, about the metals extracted and processes applied might help in evaluating the risks.

Supporting data could also come from research projects as visible from IGCP/SIDA Project 594 /47/ where Africa had been subject to local or district researches as those performed in the gold area of Mali and Katanga (DRC) and in the copperbelt province of Zambia, or in Zimbabwe and South Africa. Sampling of soils, surface water and groundwater has been performed over several years. These tests, even if performed on active mining, can help in understanding the anomalies seen in further analysis.

7.2.4 Risk evaluation- Field visits or GIS

The next step would require understanding and managing the available data. Use of GIS as an independent tool, without field visits, performing the all risk characteriza-

tion on image analysis might be possible. It has been performed for the European entering countries, for UK and for South Africa. AMD and dust risks from mine residue deposits have been defined in Eastern Witwatersrand in South Africa using GIS through geological and hydrological maps, land use information, geotechnical characteristics and information of minerals besides historical photographs from 1938, 1964 and 2003 as described in the report of IGCP/SIDA Project 594. /47/.

Probably it is the fastest tool for those agencies that have already implemented it as a normal procedure, but might be more time consuming and might be leaving more uncertainties for those organizations that have to put it up for the first time. In Namibia it has not been used on its own, also because it requires expertise to provide confidence in the results. As seen from previous studies, errors could occur in evaluating the parameters of input, in the creation of the model and in misunderstanding the natural anomalies against the anthropogenic ones. Therefore it is recommended to use GIS as a coordination tool, a base or support for performing the risk evaluation. The map observation could help to locate risk areas, also according to bibliographic information, and if possible to historical maps.

It is recommended to move with a map of scale 1:50.000 in hand when performing a field visit since it is an essential support for orienteering and localizing the different elements of the mining site, while helping in understanding the hazards. From all the low data availability countries analyzed, field visits have constituted an important initial step for the inventory probably because of lack of other supports and in order to give more precise information on the risks posed by the site. The site visits performed during inventorying have not been carried out to produce a higher risk assessment of the site than that required in a Tier 1 approach. Most of the low data availability countries in fact presented so high amount of mine sites that could not be judged on bibliographic references and from which a fast visit helped in gaining basic information, constituting a base for further studies.

Importance of site inspections has been also recognized in the Namibian inventorying methodology and in Latin America. Field visits thought present problems relative to difficulties in reaching the site and to the time spent for performing the visits, even the fast ones, therefore the analysis to be performed on site have to be evaluated. The strategy adopted in Namibia has been to simplify the site inspection so that local au-

thorities without the expertise of the sector could manage it regionally or locally, to fill the bibliographic gaps and give a ranking of the imminent visible risks. As a downside it is to be recognized that the results can be affected by a bias given by personal perceptions. On the base of the material obtained, expert teams could perform a more detailed site assessment. /14/.

Site assessment could comprise visual examinations and field tests, and if needed also sampling for further laboratory analysis. Visual evaluations to be performed during a field visit are shown in Figure 13.

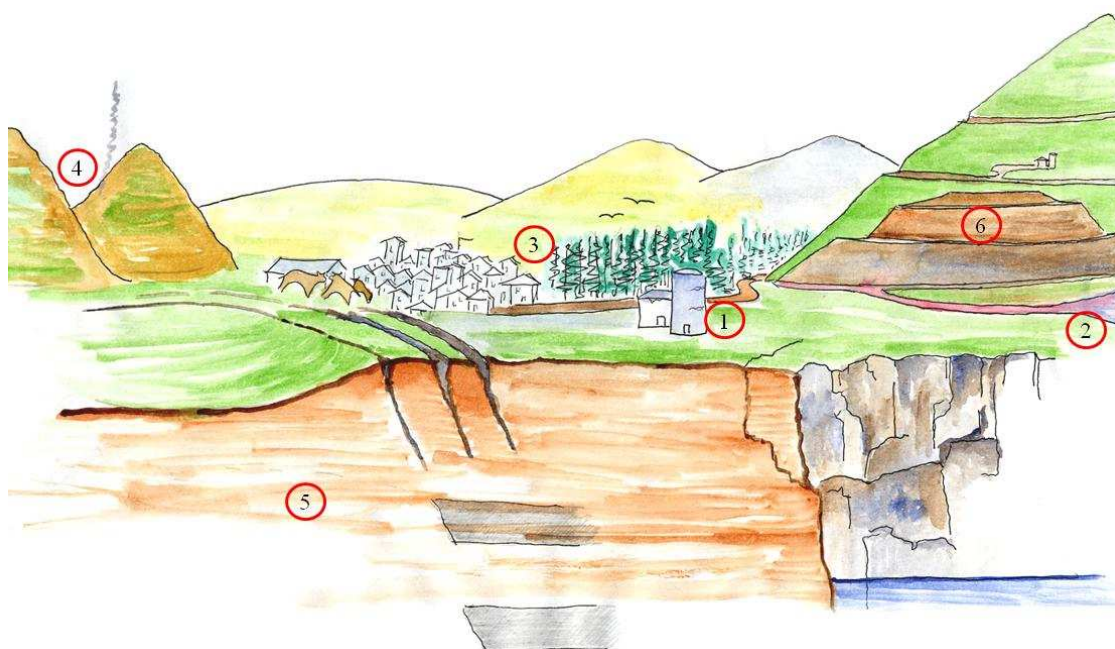


FIGURE 13. Field visual evaluation

- 1) Evaluate mining commodities organization on the land and their status, individuation on the map of the parts of the mine
- 2) Localization and mapping of the water streams: proximity of mining site and waste facilities to water streams and understanding of the use of water. Depth of water table. Visible release of pollutants. Risk of pollution for water stream could be ranked for vicinity. The European approach has been applying a precautionary principle, so the vicinity of water courses at risk has been pointed for being at 1km from the waste facility. In a frame where the mine is assessed in detail and a ranking is given, the Irish methodology for example ranked as highest risk the water streams nearer than 10 m and lowest those at distances higher than 30 m. The risk distance is also affected by geographic and topo-

graphic configuration, considering that a tailing dam failure could affect distances higher than 1 km if located in a steep valley.

- 3) Individuation of human settlements (people, aquaculture, farming, forestry, fishing, tourism, livestock), natural receptor (fauna, flora, aquatic life, protected area), artistic receptors - (on site and off site). The European methodology consider the receptors within 1 km, but others had ranked them depending on the distance, giving highest scores to those nearest to the facility. Ecological simple screening is also possible if a Tier 1 ecological risk assessment is wanted to perform. It is needed to note changes in plant cover and existence or deficiency of specific trees, plants, scrubs or lichens that can be indicative of pollution.
- 4) Heaps: method of construction, stability, accessibility, possibility of fallings, fires, presence of water, visible leaching, erosion risk evaluating if the surface is uncovered and exposed to winds, the vegetation and possible accumulation of dusts in the surroundings. All the parameters could be scored according to their extent and risk level posed. For example from visual evaluation could be scored the dust generation risk according to the percentage of coverage, giving highest risk to low coverage, and lowest risk to higher coverage.
- 5) Mine: if it is filled with water, quality of water, stability (walls, tunnels) and risk of collapsing (sinkholes), cave-in, sliding- failures- crack. Also in this case a risk ranking can be attributed to each parameter, one can use also threshold value, or a yes/no approach depending on the parameter. For example if there is a visible subsidence a score 1 can be given, a score 0 if there is none.
- 6) Tailings: can be noted the conditions of the structure and the slope's structural geometrical characteristics, the slope angle, the material used, the erosion risk, the coarse-fine separation within the tailing, the presence of water in the tailings and the freatic surface, the pond coverage, the drainage system and rain-water collection systems, possible cracks, presence of vegetation, presence of leached water and seepage water and finally the foundation slope.

Soil, surface water, air, vegetation, fauna and landscape could be assessed on site. The field visit should also be documented with a photographic report and the data could be introduced on GIS. This would allow to reassess the risks more in detail, since probably the interaction with other characteristics (geographical position, geological, metallogenic and hydrogeological assets) can be evaluated more easily and it will also al-

low to manage the database and publish the results. Simple basic field tests to define better the risks are also possible to be performed already during the visit and in Table 7 are shown some together with possible laboratory tests.

TABLE 7. Field tests and laboratory tests

	Column A	Column B
	Basic evaluation- field	Deeper evaluation-laboratory
Size of facility	Surface and height with GPS, walking trough	Tacheometric method
Slope	Brunton compass or inclinometer	
Tailings	Measurement of the freeboard (from the embankment crest to the tailing level), granulometric measurements, pore water pressure	Leachate tests, static and/or kinetic tests
Solid waste		field-portable x-ray fluorescence (FP-XRF) analyzer, leachate tests, thermal scanning, static tests (ABA)
Mine water, mine water discharges and water quality upstream and downstream up to 500 metres, pore water and seepage waters	pH, redox, conductivity, oxygen multimeasure a kit for evaluation of water quality, color and turbidity, salinity	Total nitrogen content and total phosphorus content, Biological Oxygen Demand, Chemical Oxygen Demand, Total Dissolved Solids and Total Suspended Solids, total metals, dissolved metals, heavy metals, total and dissolved mercury, major cations: Ca, Mg, Na, K, anions: NO ₃ , NO ₂ , Cl, PO ₄ and SO ₄ .
Soil	Colour, field-portable x-ray fluorescence (FP-XRF) analyzer	Chemistry-toxicology-ecology tools for Tier 1 simple screening

Portable XRF could be utilized, but for the cost of the instruments might not be worth compared to perform laboratory tests reinforcing local expertise. Thermal scanning had been used to evaluate presence of fires in waste heaps and it might be a possibility to be evaluated in each situation.

In some cases when there is already good knowledge of the site leaching test could be performed while basic tests on water allow to define its ecological quality and its metal content to understand possible contamination derived by the mine site. Detailed testing and sediment analysis would be done on a Tier 2 level while further evaluation

would then reach a Tier 3 level including toxicological and ecological assessment and sensibility tests.

For soils a Tier 1 approach of ecological risk assessment for contaminated lands can also be carried out. It would need knowledge of the metals extracted and chemicals used to assess their toxicity and the fraction of species potentially affected. It is a similar approach as the one done in Italy, based on toxicological data. As a laboratory measurement one can perform on pore water or leachate the luminescence test of *Vibrio fischeri* bacteria that produces light as a result of its metabolic activity. Ostracod inhibition and mortality test, putting the organism in contact with contaminated soil, is also a possible method that has been considered suitable also for sediments. Another fast and cheap test could be done using invertebrate tests kits based on acute or chronic toxicity on one of the following organisms: *Ceriodaphnia dubia*, *Thamnocephalus platyurus*, *Brachionus calyciflorus* or *Tetrahymena thermophila*. /60/

One of the main uncertainties, even within European countries, has usually been the dam stability. The European countries' approach has been different. Besides the main information on slope angle, dimension, height, Italy for example did not account for it for risk ranking, since the structures of the facilities were not known. On the contrary, UK has considered to monitor it in response to accidents previously happened. As a safety action, Hungary has applied a maximum risk score to tailings, not performing a field visit and not having perfect knowledge of the structures. Field visits, visual inspections and field tests would probably help in filling also this gap also considering that a dam could fail also in those situations not considered by the EU guideline.

7.2.5 Risk ranking and site prioritization

Risk ranking helps to identify the sites that represent a higher risk compared to others. Not all the countries have performed it in fact Finland has not given scores but has characterized the risk posing areas. But in this country, that has high availability data, all the risk posing sites can be assessed by the competent authority that can determine the actual risks. Other countries have adopted different approaches, some had lower availability data and lower field expertise and had to handle hundreds times higher amount of sites defining through scoring those to be undertaken first.

The approach adopted in Hungary even being very simple because based mainly on the pre-selection guideline require anyway some level of expertise to give a score. The method adopted in Italy and UK had been run by professionals, but the one adopted in Namibia had been built up by professionals to be used by non expert persons.

The approach adopted in Latin America and in Namibia, in fact, of giving a score depending on the probability of incidence and the magnitude of consequences seems the easiest way to create a list. The one used in Latin America requires that the person making the assessment would understand which accidents could happen and the magnitude of consequences that they would generate on the environment and the population. The one used in Namibia is the easiest, since it allows to give a single score to each of the factors observed. Proper tables with questions addressing hazards should be created in order to cover pollution potential and safety hazards (mineralogy of the ore extracted, hazardous materials, risk of AMD and stability, stability, coverage, vicinity inhabitants, effects on ecosystem,...). The partial scores are later introduced in the risk matrix and combined generating risk level of the site and its ranking. The weight to single factors can be different. In an inventorying purpose the highest risk could be attributed to presence of hazardous materials and possibility to pollute, secondly presence and accessibility to pathways, and reachability of receptors, then stability and dimension of the sites.

Site prioritization had been seen to be mainly driven by health and safety issues but also by governmental priorities, social and community needs and other diplomatic agreements, therefore it will have to be done by the local authority themselves. Anyhow it will be important to cooperate with the community and to take into consideration also the benefits that could be gained by the abandoned site.

8 CONCLUSIONS

The European preinventory list allows to identify the mining waste facilities that might represent a severe risk for the human being and the environment, in which, for example, waste facilities containing hazardous waste or sulfide minerals are assessed for the ability to reach receptors independently from their containing structure and their quantity. The methodology is restricted to waste facilities and lack the important impacts generated by the all mining site.

The methodology does not allow defining the risks of the specific areas and it is configured as a Tier 0 or Tier 1 approach, based on fast screening of the sites and focusing more on water pathways. Those sites that after the inventory are listed have then to be assessed anyhow. Several countries have been assessing the validity of the method adopted, assessing some waste facilities or mining sites, others have applied a methodology comprehensive of field and laboratory testing for all the sites. The approaches have been different, more addressed on toxicological aspects or more to metal content and AMD potentials, probably depending on the data available, confidence and expertise of the body that carried on the activities. The results obtained from different countries are not easy to compare since the specific mining sites are not known in detail.

During this research the validity of GIS for handling the data has been seen, coordinating the information from metal, geological, hydrological, ecological and geographical layers and presenting it to the public in a logical format. On the other hand, field visits have been essential for filling the gaps of bibliographic knowledge in low data availability countries but problems in finding and accessing the site have been reported worldwide. Field visits based on qualitative evaluation, based on a “walking through” approach, could help in understanding the site, while field assessments have been essential for defining the real risks. Probably a qualitative visit would be suggested also to decide the testing and sampling strategy for performing the site assessment. Therefore the approach pictured in Figure 14 is proposed. Change of color from darker red to lighter red means lowering of uncertainties, happening when is moved from a lower to a higher knowledge of the site. Darker red in a tiered approach would represent Tier 1, lighter Tier2 and lightest Tier 3.

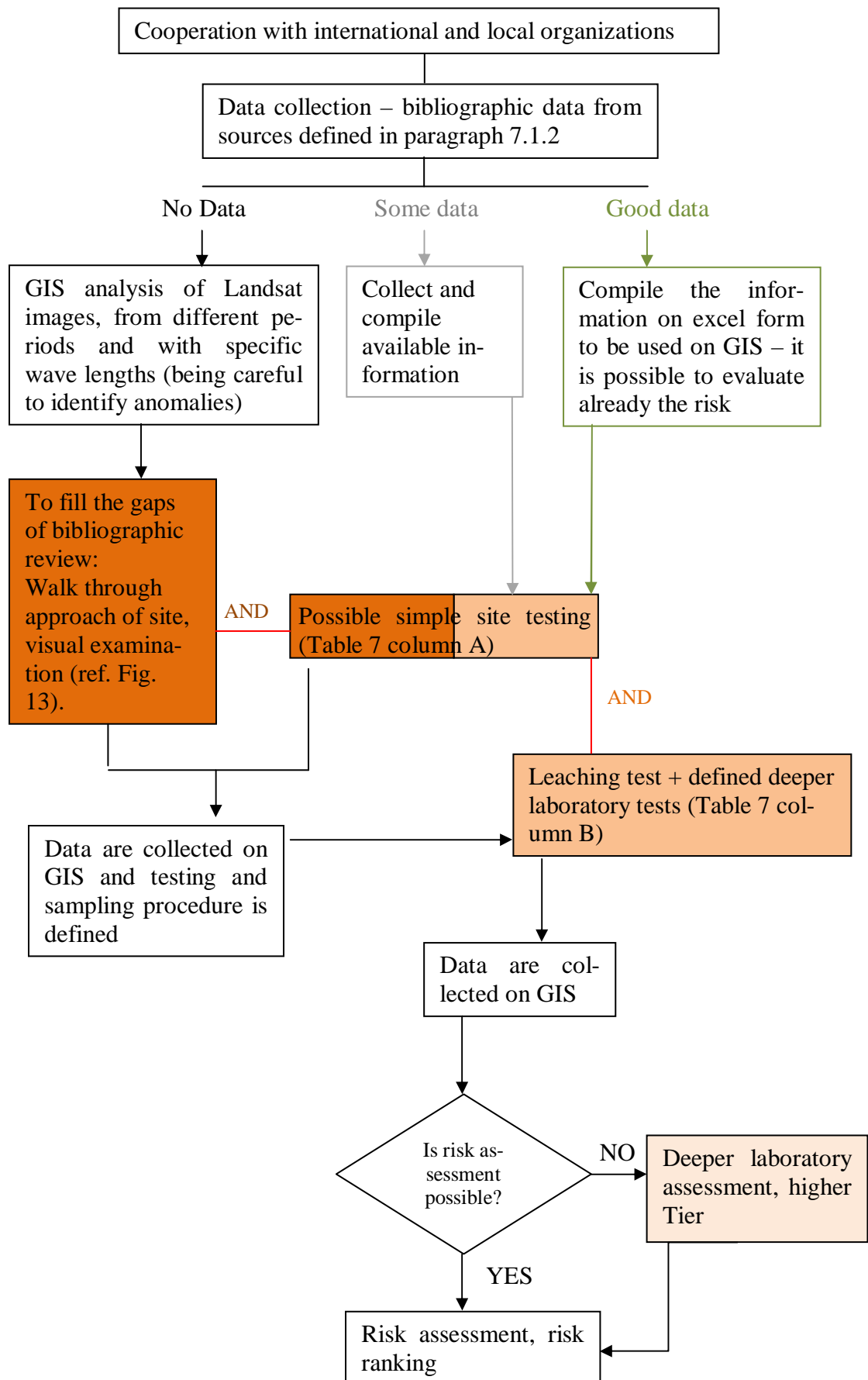


FIGURE 14. Inventorying risk assessment approach

The list of field tests proposed for fast visits does not allow to make detailed assessment but allows to point out those sites that have to be assessed more or less urgently. A detailed risk assessment allows instead defining the remediation actions needed that can be then implemented into a program and assessed. Ranking can help in the prioritization process for managing the allocation of finances but sites that have not been included on the list of priorities cannot be anyway ignored, since the risk is based on a source-pathway-reception model, pathways and receptors might change during time.

During this research the importance of cooperation between countries has been seen. Several methodologies have been implemented thanks to national and international cooperation, and numerous projects have already been going on in several developing countries, therefore it is important to cooperate to exchange information and improve methodologies supporting the capacity building of the receiving countries. Also communication with the community and the consideration of the mine site not only as a threat but as an opportunity can bring higher benefits than the sole management by local authorities, therefore it is suggested to discuss and involve the community about future economical and social aspects related to the closed/abandoned mine sites and disclose the results obtained in an open and transparent way. The use of an international language helps also in building up new cooperation and possibly in finding new opportunities.

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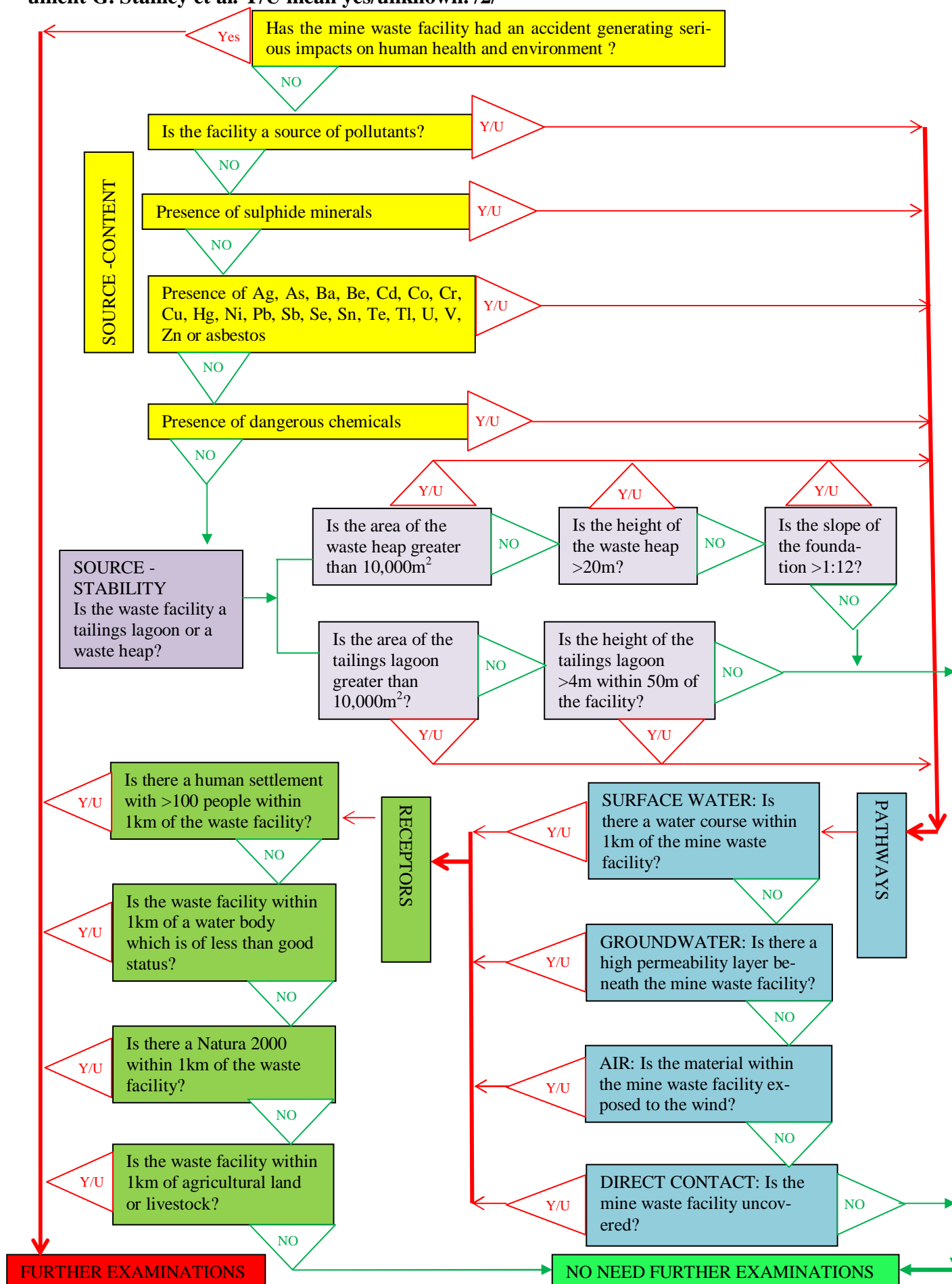
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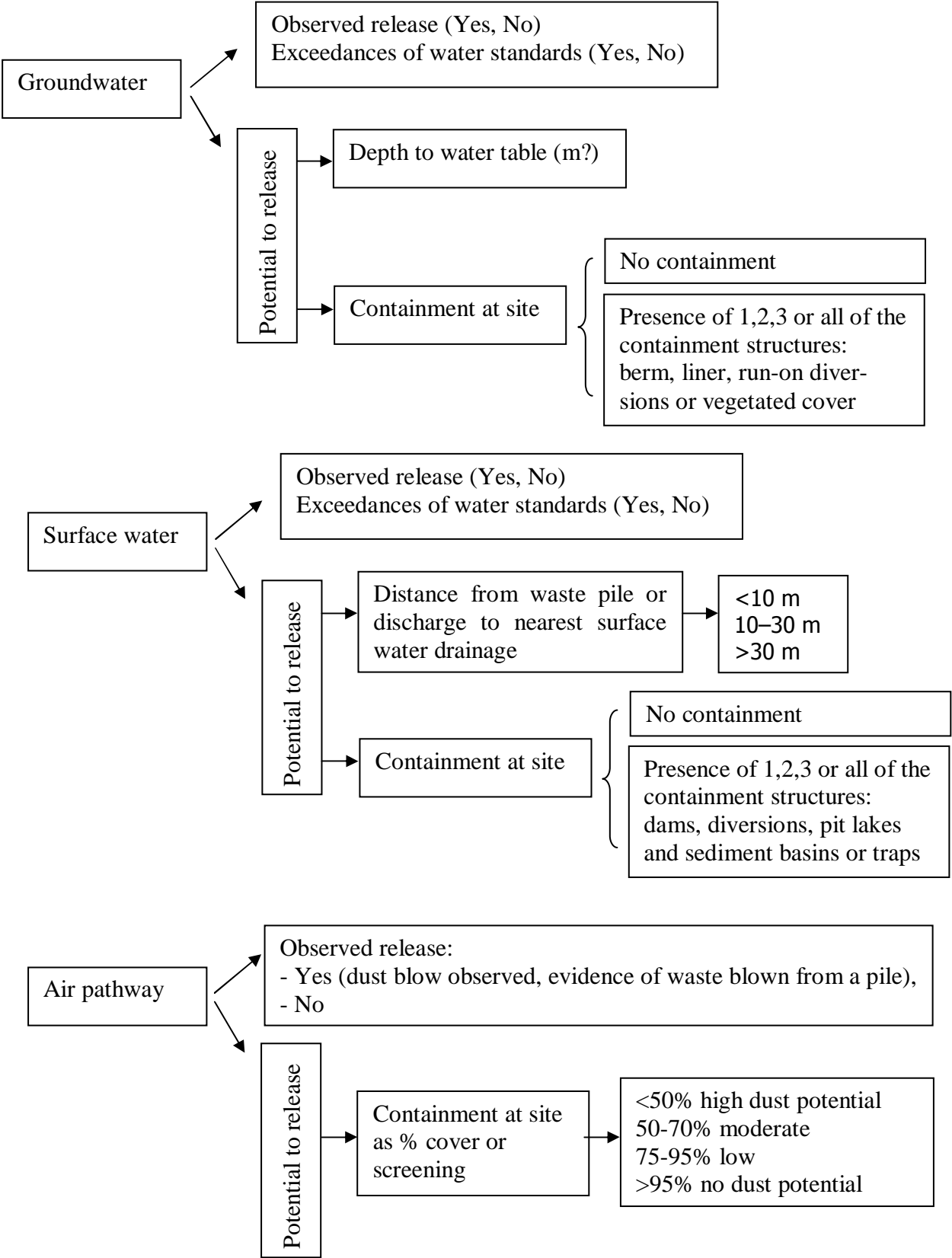
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Flowchart relative to pre-inventory methodology in EU countries extracted from the Guidance document G. Stanley et al. Y/U mean yes/unknown. /2/



Parameters of likelihood of release in the Irish inventorying methodology/4/



APPENDIX 2 (2).

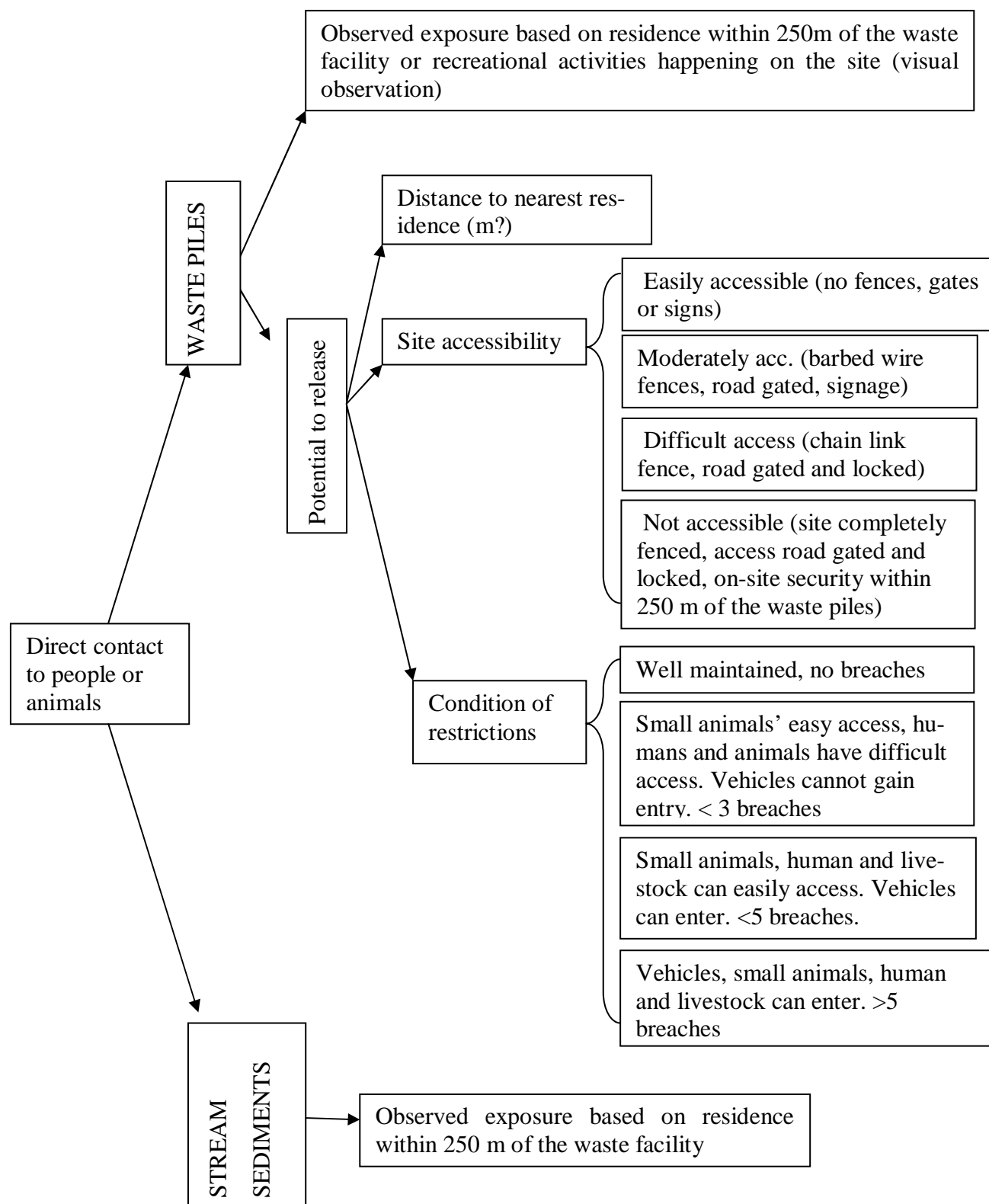


Table of comparison of different European risk inventory methodologies and correspondent risks scoring systems

Receptors comprised human, ecology, buildings, services, crops, livestock, pets and wild animals

Country	Risk evaluation	Risk scoring	Site visits
UK	<p>Different for coal and no-coal mine</p> <p>Risks focused on surface water pollution + particulate and suspended solids, soil pollution, instability and on fire</p> <p>Based on:</p> <p>Kind, location and size of the mine, chemical - geochemical data, proximity to surface waters</p> <p>River networks, properties of stream waters and of sediments</p> <p>Flows and concentration</p>	<p>Vicinity to surface water</p> <p>Slope</p> <p>Area</p>	<p>Presence of mining wastes, proximity to streams, potential impacts on water quality, potential instability and/or erosion of wastes,</p> <p>Sample water quality upstream and downstream of wastes (up to 500 metres downstream)</p> <p>Sample mine water discharges, short written record of site visit + photographs</p>
EU entering countries	<p>Content and size of waste area, geological and terrain features, seismic activity, hydrological configuration and vulnerability, climate effects and evaluation of stability (also impacts by underground mining activities and explosions). Climate change</p>	<p>Based on water pollution potential, highest risk scores to vicinity of houses and social buildings, second scoring to vicinity of industrial buildings, transport axis and big rivers</p> <p>lower scoring risk to low traffic transport axis, lowest risk associated to areas without construction and rare person circulation.</p>	
Ireland	<p>Similar to site risk assessment, based on USA methodology, some points from EU pre-inventory methodology, based on a risk ranking done in 1996. Sources: adit discharges, seeps, waste piles, tailings impoundments, stream sediments. Pathways: air, surface water, direct contact, groundwater, stream sediments. Receptors human beings and farm animals</p>	<p>Individuation of the source, measurements on it, risk scoring for each source and each mine, ending with the combination of the scores : hazard score x likelihood x receptor score. Summing up those from different pathways.</p> <p>Evaluated chemical composition of the sources and the relative toxicities, volume or area of the sources and likelihood of release</p>	<p>FP-XRF, XRF, ICP-AES. Water analyses: total metals, dissolved metals, total and dissolved mercury, major cations, anions, BOD, COD, TDS and TSS, upstream and downstream</p>
Spain	<p>Based on site evaluation, comprehensive of the whole mining site, including safety</p> <p>Evaluating impacts on the environment and the risks of the mining sites on the province.</p>	<p>Ranking in function of risks and impacts. Risk for safety and Risk for environment. Sum of: (Intensity or magnitude of the processes x Territorial impact or extension) considering also the intrinsic value of the element affected</p>	<p>Precise localization, environmental description, photographic report, evaluation of security related to vicinity of inhabitants, infrastructures and ecosystem</p>

Continuation of the previous table.

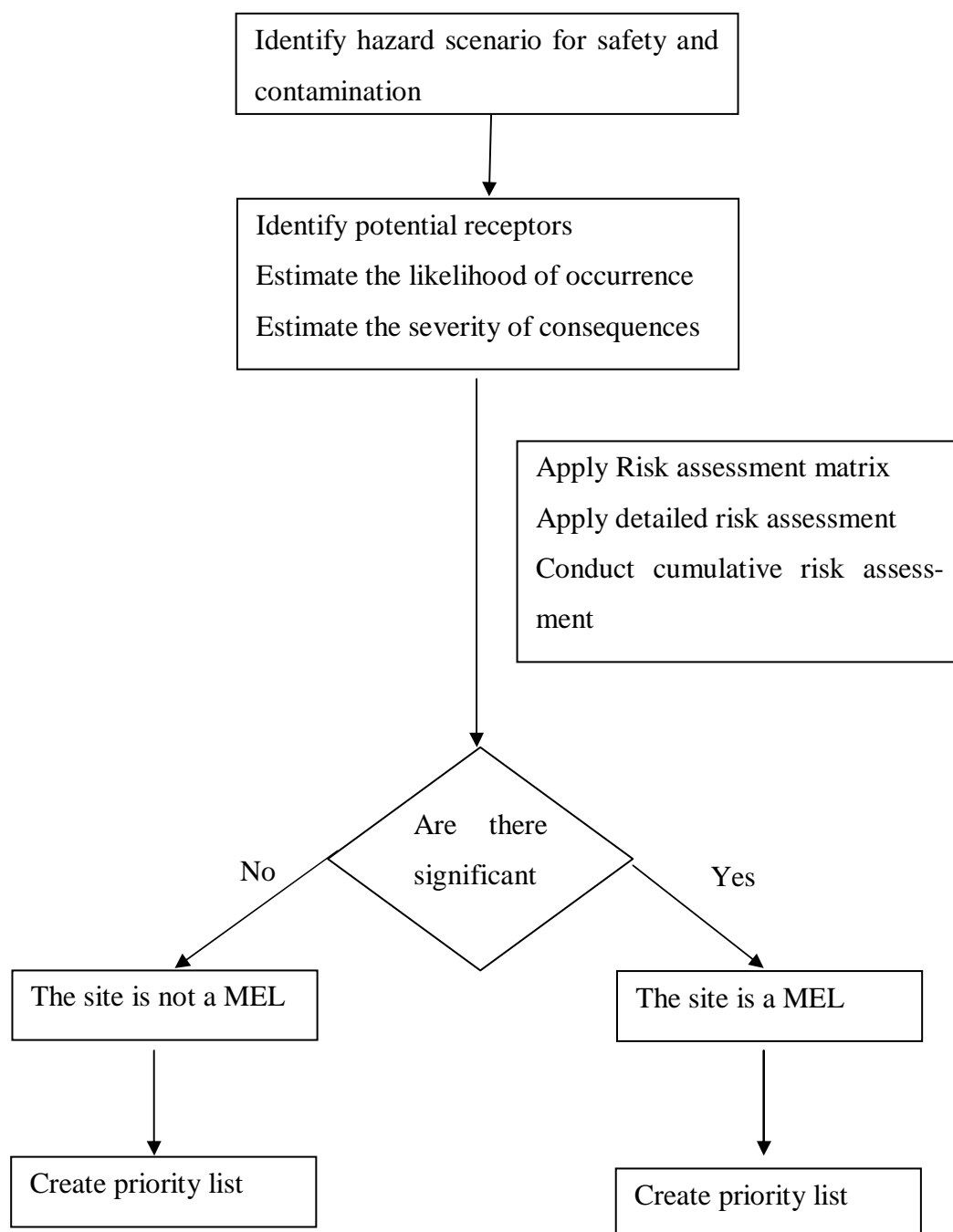
APPENDIX 3 (2).

Country	Risk evaluation	Risk scoring	Site visits
Italy	<p>Sources: polluted soils and waters Transportation paths (contact, ingestion, inhalation, under-ground and surface water, indoor outdoor air), Receptors: human and natural/artistic</p> <p>Risk= magnitude x probability and the probability = probability that an event occur x probability that will affect the targets Contaminants identified in carcinogenic and non carcinogenic based on toxicological information, risk evaluated also based on dimension of the source during time</p>	<p>Health ecological risk, no stability evaluations. Based on toxicological analysis and modeling. 5 classes of risks produced (low mean-low, mean, mean- high, high risk),</p>	-
Hungary	<p>Preinventory guideline implemented. Screening parameters as dimensions, topographic characteristics, type of waste facility, contaminant sources, number and characteristics</p>	<p>Ranking on pre-inventory guideline based on number of YES answers + Ranking on remediation actions</p> <p>Tailing ponds and waste heap considered to represent a risk, evaluated according to dimensional and topographic characteristics</p>	-
Finland	<p>Preinventory list + own list, metal composition of waste essential to forecast AMD. Ground and surface water, groundwater extraction areas, distances, inhabitants and inhabited buildings, ecological condition of the waters, vicinity of Natura 2000 areas or other areas as bird water areas, Ramsar areas, international important water flow areas IBA, presence and kind of animal shelters</p>	<p>No ranking: risk or no risk areas identified: screening based on size, presence of sulphide minerals and the potential of AMD generation, dangerous materials and radioactivity.</p>	-

Inventorying methodology of Chile /39/

	Probability	Life & health	Infrastructure	Natural receptors	Comments
Contamination					
Contamination of water					
Generation of dust					
Others					
Massive Collapses of mineral wastes or discharges					
Breaking of the dam					
Massive collapse of other waste					
Others					
Security problems					
Falling of rocks					
Accidents in open gallery					
Collapse of a wall or slope					
Falling from high wall					
Accident from an equipment of remaining building					
Accident from abandoned material					
Accident in a water body					
Others					
Use of land					
Subsidence					
others					

Inventory methodology implemented in Namibia extracted from the Risk Assessment Handbook for Shut Down and Abandoned Mine Sites in Namibia /14/



MEL: mining environmental liability