SITE INVESTIGATION STRATEGY (SIS) FOR NORISC

Checklist (ver 2.0)

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Pre-Investigation Phase:
Site characterisation and target definition [mainly OFF-SITE]

1. **Collect existing data of the site** [OFF-SITE]

   Possible sources of site data are (cf. with table A2):

   - Local authority records,
   - Register of Companies,
   - The department for labour supervision,
   - Local historical records,
   - Enterprise records on
     - plant,
     - infrastructure,
     - equipment,
     - processes,
   - Background material on production and -techniques
   - Geological and hydrogeological maps/reports, other geotechnical information, and all kind of other maps, incl. aerial photographs,
   - Interviews and investigations.

2. **Organise and analyse existing site data with GIS module.** [OFF-SITE]

   If possible, **identify** and **characterise**:

   - Present and past activities and their duration in chronological order, corresponding contaminants (DSS, table xx),
   - Anthropogenic objects (tanks, pipes etc, i.e., contamination sources and restrictions that may hinder the investigations),
   - All possible contamination sources,
   - Geology and hydrogeology (i.e., prerequisites for spreading contaminants), cf. with table A3,
   - Affected media, usually soil and sediments, groundwater, surface waters, plants and air,
   - Past and present meteorological data,
   - Present and past activities in the surroundings and their possible contribution to pollution of the site,
   - Preliminary risk assessment: Contaminants, polluted areas where concentrations may exceed guideline values, potential migration routes of contaminants, hypothesis of their distribution, exposure pathways, and receptors),
   - Remaining data gaps.

3. Perform **site reconnaissance.** [ON-SITE]
   - Improve site characterisation following the steps above, thereby reducing the remaining data gaps).
   - If necessary, do some preliminary "fingerprint screenings" for testing of potential contaminants.

4. Finalise the **conceptual model**, based on desktop study and site reconnaissance. [OFF-SITE]

5. **Evaluate all data and information available** for the site. [OFF-SITE]
   If the site turns out
   - NOT to be contaminated – STOP HERE [REPORT]
   - Likely or definitively to be contaminated – GO AHEAD.

6. Define **investigation targets** – object- and/or contaminant-related. [OFF-SITE]
   - Estimate site investigation boundaries and data gaps.
   - If necessary, devide the investigation area into sub-areas.

Investigation Phase I: Select strategy and methods [OFF-SITE]

1. Define the **general strategy**, according to the objective of the investigation.
   This may be split into different phases:
   - Exploratory phase,
   - Risk assessment phase,
   - Remediation phase,
   - "Other" (user defined) objective.

2. Use the ***Decision Support System*** **(DSS)**:
   - Select all relevant data and variables,
   - Feed the DSS,
   - Follow the instructions given there.

3. Define the **methods** for the investigation according to the DSS output and this document:
   - Select geological, hydrogeological and geophysical methods from the DSS proposal (based on geophysical and hydro-geological methods, restrictions, and costs), based on data gaps identified when characterising the site and on more general technical recommendations.
   - Select geochemical methods according to the DSS proposal (based on guideline values, contamination profile or site specific guidelines for selected pollutants, geochemical methods and costs)

4. Define the **layout** of investigations according to technical guidelines and rules (e.g., standards like ISO 10381-X (even E DIN ISO), see list of references):
   - Define the layout of geological, hydrogeological and geophysical investigations.
   - Define the layout of geochemical sampling within the area:
     - Target (contaminated area) oriented sampling.
     - Sampling on a regular grid.
     - Sampling by trial and error (random).
     - Other/complementary conditions for sampling, e.g.,
       - Quality assessment (QA) / -control (QC), and/or statistical determination of uncertainty of data,
       - Sampling interval both lateral and vertical,
       - Investigation depth.

Investigation Phase II: Application of selected methods [ON-SITE]

1. **Geological, hydrogeological and geophysical investigations** (based on phase I) including on-site processing of data (GIS), i.e., site characterisation.

2. **Geochemical investigations** (based on phase I and if suitable, either **in combination with the results of or directly in parallel with the geophysical, hydrogeological and geological survey**) including processing of data (GIS), i.e., site characterisation.

3. Verification of results and data refinement – irrespective of the objective of investigations (cf. I.1):
   - The initial plan will be continuously revised during the investigation, depending on the results obtained. Use a GIS module to collect and process data during the investigation, include all historical data.
   - Verify the lateral and vertical extent of the investigation.
   - Verify sampling/investigation points within the area. Different strategies may be applied following either rules given here or national rules of best practice:
     - If any contaminated objects within the area are identified the geochemical investigations may be densified systematically around the objects to survey their extent.
     - Polluted areas of some extent where the contamination exceeds some threshold value may be characterised as being polluted while more efforts are concentrated on investigating the presumably clean sub-areas.
     - On-site geochemical investigations of near surface samples could be used to indicate hot spots that may even extend to deeper levels.
     - On-site geochemical data to be verified by analysing a limited number of samples (5 to 15 % of the total) in the laboratory for quality control.
     - Geochemical data may be further analysed for statistically estimating their uncertainty (cf. Appendix on Statistics).

4. If indicated by the results **further revise the investigation plan** and continue with step 1 or 2 while on-site (e.g., if the geochemical investigations indicate some hot spot) until the objective of the investigation has been accomplished.
   This investigation step is to be understood as an interactive as well as iterative process and most important for optimising the survey and its results.

5. If **risk assessment** (RA) is requested, refine this study and check if you have enough data for RA.

6. **End** of field investigation. [REPORT]

Post-Investigation Phase:
Steps following site investigations [OFF-SITE]

Following the objective of the investigations, perform

1. **Risk assessment** (Human risk assessment HRA) - if not already done on-site, - based on the inherent toxicity of the pollutants and their possible exposure to man and environment. [Use the HRA module of the NORISC shell]

2. A plan for **remediation** including the estimation of costs. [Use the Remediation module of the NORISC shell]

[REPORT]

[END]

Appendices

A1 Overview
A2 Checklist: Collect existing data of the site
A3 Checklist Geology and Hydrogeology
A4 Checklist Stratigraphy

NORISC Site Investigation Strategy (SIS)
Overview

Table SIS – A1
(vers 2.0, Nov 13, 2003)

SITE ASSESSMENT	APPLICATION	ACTION
Collect and analyse all kind of existing site data [OFF-SITE] Desktop study (see A2, A3), based on existing reports, maps, publications, photos	**Site reconnaissance** [ON-SITE] - Improve site characterisation - If adequate, "fingerprint screening" of potential contaminants	**Conceptual site model:** **Evaluate all data and information** [OFF-SITE]: **No Contamination / No Risk** ➜ **Report / END** **Possible Contamination / Risk** ➜ **Define Investigation Targets**
Define General Strategy [OFF-SITE] Estimate investigation boundaries (area, sub-areas) and data gaps.	**Feed the Decission Support System (DSS)** [OFF-SITE] Define methods and layout of the investigation.	
		Site investigation [ON-SITE] Apply the bundle of methods chosen from the DSS: - Geophysical site screening - (Hydro-)geological survey (for risk assessment) - Chemical analysis of contaminants
Evaluation of available investigation results [ON-SITE] Data management and Visualisation, Risk characterisation	**Assessment with exact association** ➜ **Report** **No exact association** ➜ **Re-select specific investigation methods (DSS)**	**Refine the study** [ON-SITE] Verify results / refine data in a dynamic process to optimise the survey.
		Site risk assessment (optional) Determination of parameters for risk assessment
Evaluation of available investigation results [ON-/OFF-SITE] Data management and Visualisation, Risk characterisation	**No Problems** ➜ **Report** **YES, Problems** ➜ **Feed the DSS again / Select specific investigation methods: UP!** [ON-SITE]	**END**

NORISC Site Investigation Strategy (SIS) **Table SIS – A2**
Checklist: Collect existing data of the site (ver 2.0, Nov 13, 2003)

	Sources of Information	Information to be obtained	Importance	Check
1	**Local Authority Records** - Land registry office - Construction authorities - Board of Trade Control - Police and fire services	- Building activities / demolition / sewerage - Underground constructions / infrastructure - Environmental approvals and inspections	Very high	
2	**Register of Companies**	Production activities	Very high	
3	**Local Historical Records**	Historical archives - Old maps - Telephone directories, other booklets - Photographs, newspaper clippings - Details of former accidents, e.g., fires, explosions and their possible consequences in respect to contamination	Very high	
4	**Enterprise Records** Present / Past	Production activities, techniques Substances and products used/produced Construction plans, drawings Photos	High	
5	**Background Material**	Contamination profiles, i.e., General knowledge of equipment, production processes and materials	High	
6	**Interviews and Investigations**	Supplementary information on production plant, infrastructure	Medium/ low	
7	**Meteorological Records**	Local data of precipitation and wind	Medium	
8	**Vegetation**	Characteristics of plant growing indicating possible contamination or underground features	Medium/ low	
9	**Geological, Hydrogeological Maps/Reports, incl. aerial photos**	See table A3	High/ very high	

NORISC - Site Investigation Strategy (SIS) **Table SIS - A3**

Checklist: Geology and Hydrogeology (vers 2.0, Nov 13, 2003)

CATEGORY			SITE CHARACTERISTICS	DESK PRELIMINARY SITE ANALYSIS: SITE HISTORY	TOPOGR MAPS	AERIAL PHOTOS	LITER-ATURE	HYDRO-GEOLOGICAL MAPS AND REPORTS	SITE CHARACTERISTICS: COMPILATION KEYS
GEOLOGICAL-HYDROGEOLOGICAL PROFILE	SURFACE CHARACTERISTICS	TOPOGRAPHY	SLOPE		X				Plain (<2%; 2-6%); Gentle (6-12%; 12-18%); Steep (>18%)
			GEOMORPHOLOGY		X	X		X	plain (alluvial, glacial, eolic), valley, coastal plain, terrace, cone, morraine, dune, hill, mountain (>1000 m a.s.l.)
		OUTCROPPING LITHOLOGY	FILL TYPE					X	Absent; (gravel; sand; silt; clay **)
			FILL THICKNESS					X	Average and maximum (m)
			SOIL TEXTURE					X	Absent; (sandy; silty; clayey; peaty **)
			OUTCROPPING LITHOLOGY			X		X	Unconsolidated: (gravel; sand; silt; clay; peat**). Bedrock: (intrusive; effusive; metamorphic; conglomerate; piroclastites; sandstone; limestone; marl; claystone**)
			SEDIMENTARY STRATA			X		X	No bedrock; Absent; Present
			BEDROCK WEATHERING						No bedrock; Low; Medium; High
			BEDROCK FRACTURING			X		X	No bedrock; Low; Medium; High
			KARST IN BEDROCK					X	No bedrock; karst absent; karst present
	SUBSURFACE CHARACTERISTICS	GEOLOGICAL STRUCTURE	DETAILED POINT STRATIGRAPHY DEPTH TO BEDROCK					X	Profile with thickness (m) according to the following terms: Fill-Soil-Gravel-Sand-Silt-Clay-Bedrock type
			LATERAL EXTENT OF UNITS BEDROCK TOPOGRAPHY					X	No lateral variations; In case of lateral variations, at least 3 georeferenced vertical profilings of the site according the point stratigraphic description
		HYDROGEOLOGY	HYDRO-STRATIGRAPHY					X	Assigning the following terms to stratigraphy:aquifer; aquitard; aquiclude
			WATER TABLE					X	Average or range value (m b.g.l.; m a.s.l.)
			GROUNDWATER FLOW DIRECTION					X	Average azimuth in octants
			SOIL/UNSATURATED ZONE ORGANIC CARBON				X	X	Fraction of organic carbon in soil and in the unsaturated zone (range for each of the two)
			K_{SAT} SOIL				X	X	Saturated hydraulic conductivity of soil and unsaturated zone (range for each of the two)
			HYDRAULIC GRADIENT					X	Average or maximum-minimum range of groundwater hydraulic gradient along the main direction of flow
			GROUNDWATER FLOW RATE					X	Average or maximum-minimum range for actual groundwater flow rate
			AQUIFER ORGANIC CARBON				X	X	Fraction of organic carbon in the aquifer (range)
			HYDRODYNAMIC PARAMETERS				X	X	Hydraulic conductivity (average or range; m/s) and effective porosity of the aquifer
		CONTAMINATION	SPATIAL OCCURRENCE	X		X			Estimation of: thickness, size (m), pattern of occurrence (continuous, spotty)
	TARGETS TO RISK		PRESENCE OF POSSIBLE TARGETS SUBJECTED TO CONTAMINATION VIA GROUNDWATER	X				X	Number of wells and springs, used for human or irrigation purposes, in the surroundings of the area, and of surface water bodies recharged by groundwater (rivers, lakes, wetlands)

** possible also two names, with the first dominant and the second less abundant

RULES FOR CONSIDERING STRATIGRAPHY IN NORISC (ver 2.0)

1. *Is there groundwater at a reasonable depth below the site that can be contaminated?*

   YES: Stratigraphy to be considered down to the bottom of the first aquifer or to the top of the deeper aquifer, depending on the potential hydraulic connection between the two aquifers. **Go to 3**

   NO: **Go to 2**

2. *Is the contamination involving*

   - *the shallow subsoil only?* If YES, do not consider stratigraphy! Stop!
   - *even deeper structures?* If YES, Stratigraphy to be considered down to the bottom of the contaminated layers of the soil. **Go to 3**

3. *STRATIGRAPHY MUST BE CONSIDERED.*

   It is the site manager who decides on investigating vertical stratigraphy only or lateral changes of it as well, according to the preliminary desktop analysis.

   Normally, drillings are used to study stratigraphy. They can be performed by classical drilling techniques or by direct push methods or, eventually, by penetrometric tests. This is decided according to the budget available for the investigation.

   VERTICAL STRATIGRAPHY:

   In this case a soil drilling must be performed at only 1 point per hectare (10.000 m^2) of the site. The stratigraphy must be described lithologically as considered in the DSS. A geologist should locate and describe the collected cores. Eventually, soil samples from different depths could be the subject of granulometric and other types of analysis.

   LATERAL (HORIZONTAL) STRATIGRAPHY:

   In this case at least 3 holes per hectare of the site must be drilled, sampled and analyzed. Preferably, the three drillings should be located at three edges of the area.

   SUPPORT from GEOPHYSICS:

   Especially in the case of assessing lateral stratigraphy, geophysics may help to define it. Use the DSS to look for methods that are capable of detecting lateral changes in stratigraphy under the conditions given. The geophysicist in charge together with the site manager should decide on the application. One or two of the three drillings per hectare (as named above) may be substituted by some geophysical sounding/mapping technique. At least the data of one drilling will help then to calibrate the geophysical data of the subsurface.

   However, for each hectare of the site, at least 1 drilling should be conducted at least.