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Soil quality — Characterization of soil with respect to human exposure

Qualité du sol — Caractérisation des sols relative à l'exposition des personnes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15800 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Soil and site assessment*.

Introduction

Characterizations of soils and sites relative to human exposure are performed all over the world. They are often planned and conducted by consultancy companies and expert organizations. Data from these characterizations are used in the assessment of human exposure. These characterizations are, furthermore, used for decision-making by companies, individuals and local and national authorities as well as for recommendations and regulations issued by national and international authorities.

The assessment of potential human health effects from exposure may be used for:

- classification of contaminated sites;
- recommendations regarding remediation of sites, soils and soil materials, e.g. priority of remediation;
- decisions regarding the future/planned use of contaminated sites;
- decisions regarding the disposal/treatment/reuse of contaminated or remediated soil and/or soil material.

The data needed for evaluations of human exposure are to some extent dependent on the way in which the exposure is assessed, i.e. calculations may be based on scenarios each requiring different data.

The extent of investigations necessary for the assessment of human exposure may vary depending on the level of contamination and the areal use in question. In some cases the assessment of potential human health exposure may be based solely on information regarding the substances present in the soil and their concentrations and the relevant soil parameters. In other cases more detailed information on the availability of the substance will be necessary. This information will depend on the type and concentration of the substance, the relevant soil parameters and the type of exposure relevant for the areal use in question. Furthermore, the sampling method and strategies may depend on the areal use and the possible exposure patterns.

Due to the large expenditure necessary for both private landowners and public funds set aside for the remediation of contaminated land and the general movement of capital and industry/business corporations, International Standards on the characterization of contaminated soil, especially with regard to human health, are in great demand.

International Standards in this complex field will support the creation of a common scientific basis for the exchange of data, development of knowledge and sound commercial evaluation.

INTERNATIONAL STANDARD **ISO 15800:2003(E)**

Soil quality — Characterization of soil with respect to human exposure

1 Scope

This International Standard gives guidelines on the kind and extent of soil characterization necessary for the evaluation of human exposure to substances that can cause adverse effects.

The possibilities of standardizing the calculations used for the assessment of human exposure are not included in this International Standard.

The information needed for evaluation of human exposure to contaminants leached from soil to surface and/or groundwater or transferred by runoff is not included in this International Standard. Aspects related to radioactivity and pathogens in soil and potential human exposure hereto are also not included in this International Standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10381-1, *Soil quality — Sampling — Part 1: Guidance on the design of sampling programmes*

ISO 10381-5, *Soil quality — Sampling — Part 5: Guidance on investigation of soil contamination of urban and industrial sites*

ISO 11074 (all parts), *Soil quality — Vocabulary*

ISO 15175, *Soil quality — Characterization of soil related to groundwater protection*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 11074 (all parts), ISO 11259:1998 and the following apply.

3.1
bioavailability
degree to which substances present in a soil matrix may be absorbed or metabolized in the human body

NOTE In this context the definition refers to availability in the human body.

3.2
biodegradation
breakdown of a substance or chemical by living organisms, usually bacteria

3.3
contaminant
substance or agent present in the soil as a result of human activity

cf. **pollutant** (3.10)

NOTE There is no assumption in this definition that harm results from the presence of the contaminant.

3.4
data quality objectives
statement of the required detection limits, accuracy, reproducibility and repeatability of the required analytical and other data

NOTE Generic data quality objectives can sometimes be set at national level. Data quality objectives can also embrace an amount of data required for an area of land (or part of a site) to enable sound comparison with generic guidelines or standards or for a site-specific or material-specific estimation of risk.

3.5
exposure
reception of a dose of a substance

3.6
exposure assessment
process of establishing whether, and how much, exposure will occur between a receptor and a contaminated source

3.7
exposure pathway
course a substance takes from a source to a receptor

NOTE Each exposure pathway links a source to a receptor.

3.8
groundwater
any water, except capillary water, beneath the land surface or beneath the bed of any stream, lake reservoir or other body of surface water, whatever may be the geological formation or structure in which such water stands, flows, percolates or otherwise moves

3.9
hazard
inherently dangerous quality of a substance, procedure or event

3.10
pollutant
those substances which due to their properties, amount or concentration cause impacts on (i.e. harm to) the soil functions or soil use

[ISO 11074-1:1996]

3.11
receptor
potentially exposed person

3.12
risk
combination of the probability of occurrence of harm and the severity of that harm

[ISO/IEC Guide 51:1999]

3.13
risk analysis
use of available information to identify hazard and to estimate the risk

3.14
risk assessment
process of risk analysis and risk characterization

3.15
risk characterization
evaluation and conclusion based on the hazard identification and the exposure and effect assessment

3.16
site
defined area, in this context often contaminated by human activities

3.17
site characterization
collection of data providing appropriate information for exposure assessment

3.18
soil
upper layer of the Earth's crust composed of mineral particles, organic matter, water, air and organisms

[ISO 11074-1:1996]

3.19
soil function
function of soil which is significant to man and the environment

[ISO 11074-4:1998]

3.20
source
soil or soil component from which a substance or hazardous agent is released for potential human exposure

3.21
subsoil
material underlying the topsoil and overlying the solid (parent) rock beneath

NOTE All or much of the original rock structure has usually been obliterated by pedogenic processes.

3.22
surface water
lakes, ponds, impounding reservoirs, springs, flowing (streaming) waters, estuaries, wetlands, inlets, canals, oceans within the relevant territorial limits, and all other bodies of water, natural or artificial, inland or coastal, fresh or salt

3.23
topsoil
upper part of a natural soil which is generally dark-coloured and has a higher content of organic substances and nutrient when compared to the subsoil below

[ISO 11074-4:1998]

3.24
trace element
element in low concentration in soil material

NOTE A trace element can be essential at low concentration but harmful at higher concentration.

4 Characterization of soil and sites with respect to human exposure

4.1 Introduction

Characterizations of soils and sites with respect to human exposure are usually performed as a part of a risk assessment.

In this context, a contaminated site is an area defined e.g. by property boundaries and contaminated by past or present human activities. In many countries, contaminated sites are registered publicly as a consequence of specific legislation.

A risk assessment comprises the following elements:

- a hazard identification;
- a dose-response assessment;
- an exposure assessment;
- and, based on the above, a risk characterization.

Risk and exposure assessments are usually performed on the basis of one or more defined scenarios, e.g. in order to obtain general criteria related to the scenario, or on the basis of the data connected with a specific site.

This International Standard includes the element exposure assessment in relation to human exposure.

An exposure assessment is the process by which the intensity, frequency and duration of human exposure to a contaminant are estimated, and it comprises:

- source identification and characterization,
- identification of exposure routes,
- identification of relevant receptors/target groups,
- and based on this: the actual exposure assessment.

Exposure assessments can be carried out in order to assess either the total exposure of a given receptor group (e.g. the population at risk) or the additional exposure from a given source or activity. In this International Standard, only the additional risk from soil contamination is addressed.

For the assessment of possible effects on human health, an analysis of the exposure routes is a prerequisite. For this purpose, the actual and planned use of the site may be included in the assessment, as this may define which exposure routes are of relevance. If a new use is planned, a renewed assessment shall be carried out. Average-, worst- or reasonable-case exposure can be evaluated, and depending on the purpose of the exposure assessment, the data needs can differ for these situations.

If receptors are not directly exposed to a contaminant, exposure assessment needs to consider the various ways by which indirect exposure might occur, and its significance. A contaminant can also undergo transformations through biological, chemical or physical means that might affect its toxicity, availability and mobility. The risk depends on both the concentration of a contaminant and the route of exposure (skin contact, inhalation, ingestion, etc.). For this reason, analysis of the changes that the contaminant undergoes as a result of these transformations and phase transfer processes prior to exposure is an important part of exposure assessment.

Characterization of soil and sites with respect to exposure routes and quantification of the actual exposure is described in 4.2. Characterization of soil and sites with respect to source identification and characterization is described in 5.3, where reference to other relevant International Standards is also made.

4.2 Exposure routes

4.2.1 General

Human exposure from soil contamination may occur through different media.

The following routes of exposure directly from the soil exist:

- soil ingestion;
- dermal contact.

Airborne exposure due to volatilization comprises

- inhalation and ingestion of fugitive dust,
- elevation of outdoor concentrations,
- intrusion of vapours in buildings.

Exposure through the food chain comprises

- consumption of plants, including crops and cultivated plants, wild plants and fungi,
- consumption of animals and animal products, including wild animals.

Exposure routes connected to surface and groundwater are not included in this International Standard. These routes also include exposure due to showering, dishwashing and other domestic use of water, ingestion of fish and of piped water polluted by contaminated soil or groundwater surrounding the pipe. It should be noted that these routes can be very relevant pathways in the overall exposure pattern.

Transfer of contaminants from soil to surface waters is highly site-specific and depends on run-off volume, peak flowrate, soil erodability, slope length and steepness, sorption capacity of the soil, type of vegetation cover, and distance to receiving body. In practice, surface water pollution is usually monitored via direct measurement. With regard to exposure in connection with groundwater, ISO 15175 shall be followed.

The actual exposure routes depend on the site use.

- Playgrounds and private gardens (kitchen and ornamental) can be considered to cause the highest degree of human exposure during use. This use may imply close (skin) contact to the soil, ingestion of soil, ingestion of plants grown in the soil (and of soil on these plants) as well as inhalation of dust and vapours.
- Agricultural zones can be the principal exposure route through the food chain. The size of these areas means that, except when the farmer and his/her family consume part of production, crops are widely distributed to a large population. On the other hand, if the soil is the only source of contamination, the consumption of goods produced in the contaminated area represents only a very small part of those consumed by the population (through dilution with other product sources);
- Parks may be used in ways exposing humans to inhalation of dust and vapours, skin contact with soil/dust and, to a lesser degree than gardens, ingestion of soil;
- Sports facilities mainly give rise to exposure via inhalation of soil/dust and skin contact with soil/dust;
- Consolidated surfaces such as parking lots, roads, etc. give rise to exposure via inhalation of vapours and from accumulation of fine dust;
- Buildings (homes, schools, kindergartens, offices, industry and shops) give rise to exposure via vapours; soil carried into the buildings may cause inhalation and/or ingestion of dust.
- Industry can comprise consolidated and unconsolidated areas, park-like areas and buildings. The information needed for evaluation of human exposure in these types of areas have been listed above.

The actual exposure time can differ between similar site uses, due to differences in climate and actual site use patterns (e.g. number of days per week the site is in use).

An overview of relevant exposure routes for each site use is given in Annex A (informative).

In the following, the characterization of soils with respect to the different exposure routes is described. The uptake patterns and thus the importance of the different exposure routes will vary depending on the properties of the contaminants in question.

4.2.2 Soil ingestion

Soil ingestion by children happens through ingestion of dust, sucking of dirty fingers and by actual eating of soil. Distinction should be made between inadvertent and accidental intake and deliberate long-term persistent behaviour (Pica behaviour). In general Pica behaviour should be regarded as a special case, not necessarily relevant for the actual assessment.

NOTE Some young children go through a short period of exploratory soil ingestion.

Adults mainly ingest soil as dust, e.g. in connection with gardening, and as soil on non-cleaned vegetables and fruit. In the case of the characterization of a specific site, the actual behaviour should be taken into account.

To assess soil ingestion, the contaminant content usually taken into account is that resulting from extraction with strong extractants [this content is known as (pseudo)total for metals]. In addition, the hypothesis of total absorption of the contaminant in the digestive track is often made. A few animal experiments carried out show that this hypothesis is not always relevant, at least for metals. Methods (employing slightly weaker extractants) used for the description of uptake of metals from toys have also been used for this type of assessment. The potential for absorption of a given contaminant can vary with the soil particle size, and information on particle-size distribution may be relevant.

NOTE (Pseudo)total concentration is defined by the actual method of analysis, including the specific extraction method utilized, see 5.5.

4.2.3 Dermal contact

Skin contact with contaminated soil could be caused by dust reaching the skin through atmospheric deposition, by playing or by working with the soil. It should be noted that there is a distinction between skin contact in e.g. a private home and workplace contact, since the latter is usually regulated by health and safety at work. It should be noted that work-related matters are not covered by this International Standard.

For an assessment of this route of exposure, the information needed is the (pseudo)total concentration of each substance in the soil. For calculations of the efficiency of uptake through skin, once the soil particles have reached this surface, the parameters determining the bioavailability may be useful. In evaluation of soil contaminants in connection with skin contact, distinction should be made between contaminants that can be absorbed through the skin and substances potentially causing other effects, such as rashes from hypersensitivity.

4.2.4 Inhalation of dust

The actual importance of dust inhalation (and digestion) as an exposure route is connected to the actual site use [e.g. motorcycle scrambling and soccer fields are site uses where dust inhalation (and digestion) can play a major role]. Climatic conditions and vegetation cover also influence the actual exposure.

Calculations pertaining to uptake via dust can be based on general models for dust in air. For a detailed assessment of the uptake of contaminants from inhaled dust, the parameters determining the bioavailability can be useful. The concentration level usually varies with particle size, the smallest particles usually containing the highest concentrations and having the longest exposure times. This should be taken into account if only measurements of the average concentrations are available.

4.2.5 Inhalation of vapours (outdoors)

Assessment of the inhalation of vapours should primarily be based on measurements of soil air concentrations, preferably by passive sampling methods. If this is not possible or otherwise not relevant (e.g. in the case of planned activities that would alter the distance between the contaminated zone and the receptors, for example by inserting venting systems), calculations of air flux from the contaminated soil volume to surface can be performed. The relevant soil parameters for these calculations would be (together with information on the depth of the vapour dose zone and variations therein):

- concentration;
- porosity;
- water content;
- bulk density;
- organic carbon fraction.

Relevant substance parameters such as water and organic carbon partition coefficients, Henry's constant, and vapour pressure should also be determined. Porosity and water content are also relevant, together with soil type for the characterization of soil air concentrations at depths less than actually measured, and thus of the soil contaminants' contribution to outdoor air concentrations.

4.2.6 Inhalation of vapours (indoors)

Inhalation of vapours indoors can be assessed on the same basis as outdoor vapours, plus data relevant for the estimation of diffusion and advective (crack) transport through the relevant floor construction. These data may include information on pressure differences between the contaminated area in the soil and the target indoor area due to e.g. temperature differences, wind, changes in atmospheric pressure and the ventilation pattern of the building.

4.2.7 Intake via plants

The amount of contaminants taken up and accumulated by plants depends on the physico-chemical characteristics of the contaminant, the type of soil (including soil characteristics), the type and part of the plant that is consumed, and even climate. It should be noted that plants are contaminated by both root uptake and deposition on the leaves, etc. Intake by humans also depends on how a plant is treated before consumption (washing, peeling, cooking, packaging, etc.). Care should be taken in using general models for the assessment of plant uptake in a specific case. Results of experimental studies on accumulation by plants should be used when available, if they have been obtained under conditions similar to those of the assessed site.

It is important to be aware of the total exposure via plant uptake, taking local conditions into account and the influence hereon of possible additional exposure caused by soil contamination.

For the assessment of the exposure of humans to organic compounds via plants, the relevant parameters may include the following: organic carbon fraction, w_{OC}; content (fraction) of clay particles, w_{CM}; cation exchange capacity of the soil, CEC; soil pH; soil bulk density; soil water content; organic carbon partition coefficient, K_{OC}; and redox potential.

Uptake of metals can be evaluated based on e.g. (pseudo)total concentration, clay content, organic carbon content, CEC, distribution coefficients and pH. Plant uptake can also (at least for some metals) be estimated via extraction tests utilizing dilute, non-complexing or organic complexing salts or diluted acids.

The importance of the different parameters mentioned varies not only with the soil, but also with the vegetation and individual species and variety of plants.

4.2.8 Intake via animals

Intake by animals is usually mainly due to direct ingestion of soil from the surface layer or from soil adhering to forage. To a lesser degree, it comes from consumption of fodder after plant uptake and accumulation. The degree of accumulation of the contaminants by animals depends on the properties of the soil, the level of contamination and other components of the diet.

5 Characterization of soil and sites

5.1 Relevant soil processes and parameters

During transport of contaminants in soil, the contaminants are affected by a number of physical or reactive geochemical and biological processes, which may attenuate, concentrate, immobilize, liberate, degrade or otherwise transform the contaminants. Since these transformations affect both contaminant concentration and the route of exposure, information concerning the parameters governing these processes is important for the exposure assessment. It should be noted that the relative importance of the different parameters for the processes is not yet fully understood.

The potential processes involved in fate and transport of the contaminants in the soil depend on type of soil and the type of contaminant, and include

- sorption/desorption,
- binding,
- dispersion,
- solubilization,
- diffusion, including intraparticle diffusion,
- complexation,
- precipitation/dissolution,
- evaporation,
- chemical transformation,
- photodegradation,
- uptake by plants and other organisms,
- biological transformations including microbial, soil animal and plant metabolism.

Fate and transport analysis does not normally include all the above processes, but should at least integrate the key processes. In Table 1 and Table 2 a number of parameters governing the above-mentioned processes and the overall transport processes to different degrees are listed and connected to the exposure route for which they might be relevant.

Table 1 — Matrix of soil properties relevant for different exposure routes

Soil parameter	Soil ingestion	Dermal contact	Inhalation of dust	Inhalation of vapours (outdoors)	Inhalation of vapours (indoors)	Intake via plants	Intake via animals
Porosity		X^{org} [a]		X	X		
Water content		X^{org} [a]		X	X	X	X
Bulk density				X	X	X	X
Particle size distribution	X	X	X	X	X	X	X
Organic carbon fraction		X^{org} [a]		X	X	X	X
Clay content				X	X	X^{inorg} [b]	X^{inorg} [b]
Stratification				X	X		
Depth of vapour dose zone				X	X		
CEC						X	X
pH						X	X
Redox potential						X	X
Temperature			X	X	X		

This table gives examples and is not exhaustive.

NOTE The actual amounts of the different contaminants will vary. Inhalation of vapours usually refers to organic contaminants, for all practical purposes.

[a] X^{org}: relevant only for organic contaminants.

[b] X^{inorg}: relevant only for inorganic contaminants.

Table 2 — Matrix of type of contaminant content relevant for different exposure routes

Contaminant content	Soil ingestion	Dermal contact	Inhalation of dust	Inhalation of vapours (outdoors)	Inhalation of vapours (indoors)	Intake via plants	Intake via animals
Total (pseudo)	X	X	X	X	X	X	X
Acid extractable	X						X
Extractable in organic extractants	X	X					X
Extractable in weak extractants	X					X	X
In small particles	X	X	X				X
In soil air				X	X		
In soil pore water						X	X
Partition coefficient				X	X	X	X
Distribution coefficient						X	
Plant/soil concentration ratio						X	X

This table gives examples and is not exhaustive.

NOTE The concentration ratio (bioaccumulation factor) can vary substantially between the leaves and the roots of the plant, and depends on the actual plant species.

5.2 Sampling

5.2.1 General

The strategies for sampling and analysis should be based on knowledge of actual or planned use of the area/site, together with knowledge of the site history. For more details, ISO 10381-1 shall be considered. Sampling depths relevant for human exposure depend on the exposure route in question, and should be decided carefully based on the actual and/or planned uses for a site. The factors that may be considered for each exposure route include those in 5.2.2 to 5.2.5.

5.2.2 Soil ingestion

Contaminant concentrations relevant with respect to soil ingestion are primarily connected with children playing in and on the soil. Therefore samples should be taken from topsoil in particular. Nevertheless, it should be noted that in gardens, parks and playgrounds occasional activities can bring soil from deeper layers to the surface. For instance, planting and replacement of trees and bushes can imply digging of holes, and some of the soil from the bottom of the hole can, in this way, be brought to the surface.

Earthworms and other soil fauna may also transport soil from deeper layers to the surface.

5.2.3 Inhalation and transport of dust

Dust transport is mainly relevant in areas where the soil in periods is without plant cover (e.g. gardens and cultivated agricultural land) or in areas with intense activity (e.g. gardens, parks and sports facilities). Dust originally comes from the very top layers of the soil, and probably mainly consists of the finer fractions. A separate analysis of the finer soil fraction may be relevant if dust transport and inhalation is considered a major exposure route.

5.2.4 Uptake by plants

Garden and agricultural plants generally have a root depth of less than 30 cm, they can however reach 60 cm but yet rarely exceed 160 cm. Trees may have roots reaching down several metres (they do, however, take up the majority of nutrients in the first 40 cm of the temperate zone).

Garden cultivation and agriculture (hoeing, digging and ploughing) usually affect soil at depths to 30 cm and very rarely reach greater depths (except with subsoiling which can reach 60 cm).

5.2.5 Inhalation of vapours

Based on actual measurements and conservative model calculations, impacts from vapours in outdoor air seldom occur unless the contaminant is very close to the surface and consists of pollutants in free or near-free phase.

Indoor impact due to vaporization of the more volatile organic contaminants can arise if the soil concentration is sufficient and the contaminant is localized in the upper layers of the soil.

5.3 Site characterization

An exposure assessment of contaminated sites as well as soil in general depends on the data available about the characteristics of the site, including contaminant sources, pathways and the potential receptors that may be at risk. Site characterization can thus, for the purpose of this International Standard, be defined as the source identification and characterization element of the exposure assessment.

For practical and economic reasons, investigation of contaminated sites cannot include sampling and analysis for all substances. A phased approach is usually the best way of providing the required data in the most cost-effective and efficient manner. At the initial stage of the assessment, the (types of) substances likely to be found, and their pattern(s) of distribution in the soil, can often be identified by characterization of the possible sources of contamination of the site. This is typically a part of what is often called a “historical survey” of the activities carried out in the site. At this stage it may be relevant to also include a characterization of the general exposure pattern in the area under consideration (e.g. old waste disposal sites, proximity to industries) as well as identification and characterization of possible former activities on the site that could lead to specific contaminations (e.g. gasoline stations, specific industry). It may be relevant to identify different sources (contaminants and location) for the different exposure routes.

The aim of the main site investigation is to define the extent and degree of contamination and to assess the exposures associated with the identified hazards and receptors. It is of major importance to an assessment of human exposure that the extent (concentrations and physical extent) of contamination in all relevant media is determined in the site investigation. As is stated in connection with the soil characterization, an assessment of the availability is just as important.

For a detailed description of the relevant types of investigation, sampling and assessment of a site, ISO 10381-5 shall be considered.

A number of general site characteristics are necessary to assess the possible exposure pattern. Relevant characteristics of the site that might be determined are listed in Table 3.

Table 3 — Parameters useful for site description

Parameters	Description	ISO Standard
Landform and topography	topography, landform, land element, position, slope, microtopography	ISO 11259
Land use and vegetation	land use, human influence, vegetation, buildings, etc.	
Geology	origin of parent material, effective soil depth	ISO 11259
Surface characteristics	rock outcrops, surface coarse fragments, wind and water erosion, surface sealing, surface cracks, other characteristics	ISO 11259
Hydrology	surface water balance, rainfall, evapotranspiration, surface runoff, groundwater recharge, presence and depth of water table, moisture conditions	
Meteorological conditions	wind speed, predominant wind direction, temperature	
Soil type/ Soil horizon description	soil type in regard of the classification system used, sequence and depth of diagnostic horizons, soil colour (matrix, mottling), organic matter, texture, coarse elements, pedofeatures, carbonates, field-pH, structure, fracturing, inhomogeneities, presence of non-soil material, compactness, total estimated porosity, geochemistry, roots, worm channels, biological activity	ISO 11259
NOTE See also [1].		

5.4 Characterization of soil

5.4.1 General

Soil is a mixture of three phases: liquid and gas present in a solid matrix. Soil characteristics depend on the original rock or geological deposit from which it comes, and on other parameters such as the organisms living in and on it and climatological factors. With time, they modify the original material, giving distinct horizons within the profile. This modification results in a wide variety of soils differing in physical and chemical characteristics. Even within one soil type, large variations may occur within a short distance. On a contaminated site, the soil may also contain ash, clinker, bricks, rubble, etc.

Substances present in soil can be bound to the soil matrix by sorptive and binding mechanisms, which can affect availability with respect to uptake and/or metabolization by living organisms, e.g. in the case of inhalation and ingestion. The binding of substances can change with time, due to alteration of the soil or to alteration of the binding mechanism. For the quantification of human exposure to substances present in soil, information regarding the total content of each substance in the soil may therefore not be sufficient. For some substances (e.g. trace elements), the evaluation of human exposure could be based on contents measured by analytical techniques, resulting in data that are expected to be adequate for an evaluation of the (bio)available portion of the substances in soil. Investigators may also take into account available knowledge on resorption and metabolism of the substances in the organism, and the related differences between individuals and population groups (e.g. children versus adults).

As the assessment of possible effects on human health is primarily based on information regarding single substances found in the soil, the possibility of the occurrence of other substances (not investigated) should be evaluated. This evaluation could be based on experience from other site investigations regarding the simultaneous presence of several substances. In general there is a great need for the development of tests that in a broader sense assess a complex soil contamination’s impact on human health. It should also be kept in mind that synergistic or antagonistic-type interactions between substances can affect the actual impact of an exposure.

In the following paragraphs, soil characteristics affecting the sorption and the movement of substances in soils and, consequently, their availability, in context with an assessment of human exposure, are mentioned. The choice of relevant parameters depends on the purpose of the characterization, e.g. a general classification or the characterization of a specific site for a specific site use. Characterization of soil requires the determination of physical, chemical and biological properties, but depending on the specific assessment, not all soil parameters will be relevant in all cases.

5.4.2 Physical characteristics of soils

A number of physical soil parameters are relevant in connection with the assessment of human exposure caused by contamination in soil. Below a number of physical characteristics are listed, together with comments on their relevance in exposure assessments. The actual choice of parameters should be based on the preliminary knowledge of site geology, pedology and contaminant situation.

- **Porosity:** the volume of pore space in the total volume of soil. The pore space can be occupied by air and water (or free chemical phase).
- **Air permeability:** In soil, this is a function of porosity, grain size and water content. Air permeability influences the exposure route for inhalation of vapours.
- **Bulk density:** directly related to the porosity and relevant when estimating phase-partitioning in soil.
- **Dry matter content:** the amount of the total volume (or mass) of soil taken up by soil particles. Chemical analysis often relates the amount of a substance to the dry matter content, so knowledge hereof is important to correctly estimate the partitioning of a substance in the soil.
- **Particle-size distribution:** Four fractions should be distinguished: clay, silt, sand, gravel/stones. The particle-size distribution determines the soil texture and also the surface area of a soil, the finest fraction having the largest specific surface. The surface area influences the actual sorption of substances onto the soil. It should be noted that particles of size $< 0{,}002$ mm, usually defined as clay, may contain other materials which are not clay minerals.
- **Clay:** Clay particles ($< 0{,}002$ mm) affect the reactive properties of soil due to their large surface (for sorption) and the (electrical) properties of the surface. Depending on the type of clay mineral, the charge may be positive, negative or neutral.
- **Water content:** the amount of pore space occupied by water. It influences the binding and the diffusion of substances in the soil matrix.
- **Organic matter content:** This influences biotransformation processes, especially for organic compounds that are difficult to biodegrade and primarily degrade under co-metabolic processes. It also influences adsorption of substances and thus availability.
- **Temperature:** Soil temperature may affect the volatility of organic compounds present and also the possible biotransformation processes in the soil.
- **Particle density:** together with porosity and water content, defines the bulk density and thus relevant in connection with the estimation of phase-partitioning in the soil.

Physical characteristics for which International Standards are available are listed in Table 4. Note that some properties can only be measured *in situ* and some on laboratory samples.

Table 4 — Physical parameters

Parameter	ISO Standard
Particle-size distribution	ISO 11277
Water content	ISO 10573 ISO 11461 ISO 11465
Dry matter content	ISO 11465
Temperature	ISO 11275
Pore-size distribution	ISO 11259
Bulk density	ISO 11272
Particle density	ISO 11508

5.4.3 Biological characteristics of soil

The soil concentration of a contaminant at different depths in the soil will depend not only on physical and chemical processes but also on the microbial influence on the degradable components. To be able to assess this activity in both the present and the future situation, information on the microbial biomass and the microbial activity in the soil in question is important. In addition to microbes, soil animals, their behaviour and metabolism may alter chemical compounds present in the soil.

The contaminant concentration can, on the other hand, influence the conditions for the biota on a specific site. So knowledge of the specific contaminant and concentration level is also relevant in order to evaluate the possible effect of the contamination on the ability of the biota to alter the chemical compounds present in the soil.

Some biological characteristics of soil for which International Standards exist are listed in Table 5. In the table are also listed tests with the purpose of ecotoxicological characterization of the soil, since this may, depending on the intended site use, give appropriate indications of possible constraints on this use caused by toxicity to plants or fauna that cannot be directly interpreted from the chemical characterization. It may also provide additional information on toxicity to humans caused by direct uptake, since tests for estimations of this type of uptake are not yet fully developed and verified.

Table 5 — Biological parameters for ecotoxicological characterization

Parameter	ISO Standard
Microbial activity, e.g.	
Determination of soil microbial mass	ISO 14240-1 ISO 14240-2
Mineralization of organic substances under aerobic conditions	ISO 14239
Nitrogen mineralization and the influence of substances hereon	ISO 14238
Toxicity to plants, e.g.	
Inhibition of root growth	ISO 11269-1
Effects on emergence and growth of higher plants	ISO 11269-2
Toxicity to macrofauna, e.g.	
Acute toxicity to earthworms [a]	ISO 11268-1
Effects on reproduction of earthworms [a]	ISO 11268-2
Effects on earthworms [a] – field testing	ISO 11268-3
Inhibition on reproduction of Collembela	ISO 11267
[a] *Eisenia fetida.*	

5.4.4 Chemical characteristics of soil

A number of basic chemical parameters influence the soil processes that alter the contaminant concentrations, e.g. adsorption, precipitation and complexation. Some are described below.

- **Organic carbon fraction:** Organic matter in soil is present as humic substances (predominantly aromatic polymers with high molecular mass and acidic properties). These molecules can bind organic contaminants as well as trace elements. Bindings may be covalent (strong) or electrostatic (weaker). Due to the described properties, the organic matter in soil also contributes to the CEC and pH of the soil. Organic carbon fraction is typically measured as total organic carbon, TOC.

- **Cation exchange capacity** (CEC)**:** The CEC describes the capacity of the soil to bind positively charged substances and is especially important for the evaluation of metal sorption and thus the availability, e.g. for plant uptake. The CEC essentially reflects the amount and character of the soil organic matter and clay particles.

- **pH:** The acidity of the soil is, as for the CEC, a parameter reflecting several soil characteristics. Among these are the amount and character of organic matter, clay particles and lime. pH affects the availability of positively charged substances and is thus relevant for the assessment of the availability of metals and ionizable organic substances.

- **Redox potential:** The redox potential indicates the degree to which soil conditions are aerobic or anoxic and thus determines the oxidation state of a compound in soil also influencing the availability. The redox potential is of specific importance for the precipitation of certain metal-ions in soil thus reducing their availability.

- **Soil oxygen:** The presence of oxygen in soil is important for the respiration of the soil organisms and thus for the degradation of a number of organic contaminants. Lack of oxygen in the upper-soil layers can be a sign of the presence of contaminants.

- **Soil gases:** The soil gases naturally present in the soil, e.g. soil oxygen, can, on a contaminated site, be supplemented or substituted by volatile (primarily organic) components evaporating from contaminants in the subsoil. The presence of volatile components can affect plant life as well as microbial biomass and can also give rise to the intrusion of volatile contaminants in buildings situated nearby.

Chemical characteristics that it might be desirable to measure and for which International Standards exist are listed in Table 6.

Table 6 — Basic chemical parameters

Parameters	ISO Standards
pH	ISO 10390
Specific electrical conductivity	ISO 11265
Cation exchange capacity (CEC)	ISO 11260 ISO 13536
Redox potential	ISO 11271
Organic carbon	ISO 10694 [a] ISO 14235 (TOC) [b]
Carbonate content	ISO 10693
Exchangeable acidity	ISO 14254

[a] After dry combustion.

[b] Total organic carbon.

5.5 Characterization of contamination

5.5.1 General

Contaminants likely to be present are related to the past use of the site. A suggested list of contaminants related to different types of industry is given in Annex B. It is stressed that this is a non-exhaustive list, and the assessor shall consider the actual situation carefully.

Lists of potential contaminants and methods for their identification and quantification relevant for different types of exposure routes are given in Table 7 and Table 8. Certain parameters require measurement in almost all situations: others only require measurements for certain intended uses of the soil. A judgement shall, however, be made on a case-by-case basis. Inorganic substances are listed in Table 7. Organic substances are listed in Table 8. The range of organic substances that can be present is very wide. Thus, only a few are listed in Table 8, essentially those for which International Standards exist or are in preparation.

Before any laboratory analysis, samples shall be subjected to pre-treatment (e.g. ground, sub-sampled, appropriately dried for pollutant type) compatible with the methods of analysis to be employed. Methods for pre-treatment are specified in ISO 11464. Some methods for extraction or analysis include their own requirements regarding pre-treatment of samples, and these shall always be followed unless there are sound technical reasons not to do so, in which case those reasons should be reported with the analytical result.

It should be noted that it is very difficult to obtain representative samples of soil materials for determination of volatile organic compounds. Various studies have shown that almost all can be lost if samples are not handled correctly. Consequently, concentrations of volatile organic compounds (VOCs) in soil gas are commonly determined directly on site. A variety of techniques are used to make measurements *in situ* or obtain samples of vapour for laboratory analysis (e.g. using adsorption tubes). Reference is made to ISO 10381 (all parts).

Nutrients in the soil are often studied because of their agronomic soil characteristics and capacity to biologically degrade organic substances. As they are seldom of primary importance in connection with direct human exposure, methods for their detection are not included in this International Standard.

5.5.2 Metals and metalloids

Metals and metalloids can be contaminants or natural trace elements that, at higher concentrations, can become hazardous.

In order to evaluate the availability for e.g. direct uptake, plant uptake or leaching, it may be necessary to distinguish between chemical availabilities of the substance in question, e.g. soluble in strong acid, weak extractants or water. Although the extractants may be different, it is often possible to use the same methods to analyse the extract.

Total concentration is the total of the element present in all chemical forms and irrespective of its location in the soil material, including that incorporated into silicate minerals. Determination of these “true” total concentrations requires use of an instrumental technique, such as X-ray fluorescence analysis, or a powerful solvent combination, such as a mixture of hydrofluoric and perchloric acid. The use of such solvent mixtures presents many practical problems, and for many purposes in environmental assessment, pseudo-total concentrations suffice. These are determined using a strong acid or combination of acids, but they typically leave a small insoluble residue with some soil materials. Depending on the element and the matrix, these solvents typically yield 70 % to 90 % of the “true” total concentration (it can be lower for those elements which are present predominately bound to silicate or aluminate lattices). When comparisons are to be made with guideline values for the particular soil uses, it is essential to determine whether “pseudo-total” or “total” concentrations are required.

Concentrations extractable with complexing agents, weak extractants such as salt solutions or with water can be relevant for the assessment of different kinds of bioavailability, including plant uptake, or of exposure routes related to the pore water concentration of the substance. As to water-extractable concentrations, it is important to recognize that when compounds of limited solubility are present, e.g. gypsum, the apparent amount soluble depends on the soil:water ratio employed in the tests. A detailed discussion of soil leaching and extraction tests is provided in ISO 15175.

Guidance on available International Standards for measuring metals and metalloids in soil and their applicability to different extractants is given in Table 7.

Table 7 — Metals and metalloids

Fraction	Extraction method	ISO Standard	Determination method	ISO Standard
“Total”	HF + $HClO_4$ fusion	ISO 14869-1 ISO 14869-2	XRF [a] AAS AAS	ISO 11047 [b] ISO 11047 [b]
“Pseudo total”	aqua regia HNO_3	ISO 11466	AAS AAS	ISO 11047 [b] ISO 11047 [b]
Complexing	EDTA DTPA	ISO 14870	AAS AAS	ISO 11047 [b] ISO 11047 [b]
Weak extractant	$NaNO_3$ NH_4NO_3 $CaCl_2$ KCl		AAS AAS AAS AAS	ISO 11047 [b] ISO 11047 [b] ISO 11047 [b] ISO 11047 [b]
Water soluble	water extracts [c] leaching tests		AAS	ISO 11047 [b]

[a] X-ray fluorescence.

[b] For cadmium, chromium, cobalt, lead, manganese and zinc.

[c] Soluble at specified soil:water ratio using batch tests.

NOTE 1 Methods used to determine (pseudo)total concentrations do not extract all of the component from the soil matrix, however these methods are used in many countries due to tradition and/or to ensure better health and safety in the laboratory.

NOTE 2 There are many different methods for obtaining water extracts based on batch processes, e.g. shaking with a fixed amount of water, sequential extractions or columns. For a detailed discussion of methods, see ISO 15175.

NOTE 3 There is a variety of analytical methods for water specified in International Standards. However, it is important to ensure that they will work with the extracts obtained from a particular (contaminated) soil material.

5.5.3 Organic contaminants

The range of organic substances that might be present is very wide. The listed groups of organic contaminants are some of the more commonly encountered, but the list is not exhaustive. In addition to the groups of organic contaminants mentioned, it is often relevant to look for specific organic contaminants, e.g. individual aromatic hydrocarbons, both volatile and polycyclic, specific solvents, specific chlorophenols. Some of the potentially relevant organic contaminants are mentioned in the list of possible contaminants related to different types of industry in Annex B.

Organic chemical analysis is often interested in looking for any substance which may be present. In practice it takes two forms: determination of what is present (qualitative analysis) and determination of how much of a specific compound or class of compounds is present (quantitative analysis). The detection of adventitious or unexpected substances, particularly when complex mixtures of organic chemical species are present, requires screening methods such as gas chromatography/mass spectrometry. It is also customary to employ analytical methods that purport to give total concentrations of classes of compounds such as phenols, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH) and chlorinated hydrocarbons. Care is required in both the use and the interpretation of the results of such methods. Qualitative analysis is frequently carried out prior to quantitative analysis. Class analysis frequently precedes analysis for a specific compound.

“Total” applied to organic compounds (e.g. phenols) usually means that an analytical technique has been employed that cannot distinguish between similar compounds: for example in the case of the phenols, between monohydric, dihydric or trihydric compounds (i.e. compounds with one, two or three hydroxyl groups attached to the benzene ring). However, the term "total" can be misleading: not all phenols may be detected by the method (e.g. there may be limitations in terms of molecular mass or the number and size of other functional groups present on the benzene ring) and different methods can give different results.

Many organic analyses involve extraction with an organic solvent. The solvent used and the conditions of the extraction can influence the analytical results. For example, more volatile PAHs (generally those with lower molecular masses) can be lost during a hot Soxhlet-style extraction, whereas a cold extraction can be less effective in dissolving higher molecular mass PAHs.

Analysis of soil for volatile organic compounds (e.g. benzene, chlorinated solvents) presents particular analytical difficulties. Research suggests that even under ideal conditions of sampling, transport and sample preparation, etc., substantial losses can occur (one study suggested that 50 % retention was the best that could be achieved). Under less than ideal conditions, almost all can be lost. Thus use of *in situ* methods, such as soil vapour analysis, can give a more reliable indication of distribution and relative concentrations of the substance of concern. In addition, it should be noted that different laboratory methods (e.g. purge-and-trap and head-space analysis) can give substantially different results.

It is important to recognize that organic compounds can be extracted from naturally occurring organic materials (e.g. humus, decaying vegetation, peat, coal) and that non-specific analyses can, therefore, give misleading results.

International Standards relating to analyses of organic compounds in soil are listed in Table 8.

NOTE For the water-soluble part of organic components, there are a variety of methods for obtaining water extracts based on batch processes, e.g. shaking with a fixed amount of water, sequential extractions or columns. For details see ISO 15175.

Table 8 — Organic contaminants

Type of contaminant	Determination method	ISO Standard
Mineral oil content	IR-spectrometry [a] GC [b]	ISO/TR 11046
Petroleum hydrocarbons	GC [b]	
Volatile organic hydrocarbons	Purge-and trap, GC [b]	ISO 15009
Polycyclic aromatic hydrocarbons (sum)	HPLC [d]	ISO 13877
Persistent herbicides		ISO 11264
Organochlorine pesticides	GC [b]	ISO 10382
Chlorinated aliphates		ISO 15009
Chlorobenzenes	GC-ECD [c]	ISO 10382
Chlorophenols	GC [b]	ISO 14154
Polychlorinated biphenyls, PCBs	GC [b]	ISO 10382

[a] Infrared spectrometry.

[b] Gas chromatography.

[c] Gas chromatography with electron-capture detector.

[d] High performance liquid chromatography.

5.5.4 Soil/substance related parameters

A number of parameters relevant for exposure assessment are related to the specific component as well to the soil in question. Description is given below of some of them. Toxicity of a contaminant to micro- and macrofauna can be relevant in specific situations.

- **Organic carbon partition coefficient, K_{oc}:** describes the binding of an organic substance to the organic carbon fraction in the soil.
- **Soil/water partition coefficient, K_{D}:** describes the ratio between the amount of a substance present in solution in the soil water and the amount of substance sorbed to the soil particles.
- **Henry's constant, H:** describes the ratio between the amount of a component present in the soil air and the amount present in solution in the soil water.
- **Bioaccumulation factors for plants:** plant/soil concentration factors vary depending on the specific plant species, the substance, climatic factors, the soil type and the plant component investigated, e.g. roots or leaves, and the age.
- **Degradation rate:** for a specific compound in the soil, the rate is also related to the specific soil conditions, e.g. water content and soil oxygen content. Some compounds can only be degraded under aerobic conditions, while others can only be degraded under anaerobic conditions. Degradation can be biological, chemical, and/or physical. The degradation rate is generally expressed as DT_{50} value and/or DT_{90} value, i.e. the time needed for 50 % and 90 % degradation respectively, see ISO 11266.

6 Data handling, evaluation and quality

The purpose of characterizing soil (or other media) as suggested in this International Standard is usually to enable risk assessment with respect to human exposure. These assessments may be made by reference to published international or national standards that set out physical, chemical or other criteria that shall be met, or against criteria set on a site-specific basis. In many jurisdictions, formal guidance on such assessments has been published and should be considered. Guidance has also been provided by professional organizations and some standardization bodies.

Because soil in itself is heterogeneous, and the spread of contaminants is also heterogeneous, a fairly large uncertainty is connected with a characterization of soils also in relation to human exposure. Before any judgement can be made about risk to humans, the sufficiency of data to be used shall be evaluated. The data shall be sufficient in terms of

- type,
- quantity, and
- analytical/testing quality.

This International Standard provides guidance on the types of data that might be required in an assessment, and indicates for which parameters or procedures International Standards are available. The assessor should choose those parameters that are appropriate to the task at hand. The assessor needs to bear in mind the disproportionate costs and time delays that can result if it is necessary to carry out an additional sampling exercise, if, for example, a particular parameter is not determined when the opportunity is available.

Before investigation of the site is started, it is essential to

- define the objectives of the investigation,
- establish a sampling strategy in terms of types of samples to be obtained, sampling locations, and how samples are to be handled in consistence with these objectives,

- establish an analytical and testing strategy taking into account the guidance in this and other relevant International Standards,
- set data quality objectives consistent with the assessment procedure to be used.

It is essential to have sufficient data. The confidence that can be attached to any judgements made, for example through comparison with the requirements of a published standard (the requirements in such standards regarding sampling shall always be followed) or a site-specific risk assessment, is no greater than the confidence in the representativeness of the data.

Care shall be taken in deciding what statistical expression(s) of the data to use in the characterization, as this can affect the choice of sampling procedures.

The quality of the data to be used can be assured by

- setting formal data quality objectives (e.g. for accuracy, reproducibility),
- using standard analytical and testing methods such as those listed in this International Standard or, where International Standard methods are not available, those published by national standardization or equivalent bodies,
- using accredited laboratories applying standardized methods,
- using laboratories that take part in relevant proficiency testing schemes,
- the commissioning agent employing its own quality assurance procedures.

Often, the reports presenting the results of assessments are scrutinized by regulators and other interested parties, including the general public. It is important, therefore, that such reports are of a high technical standard but also take into account the diverse, and often non-technical, readership. Use should therefore be made of tabular summaries, graphical and other means to present the data in ways that help make the data easy to assimilate and assess.

Annex A
(informative)

Exposure routes depending on actual site use

Site use (receptor)	Exposure route				
	Inhalation		Skin contact	Ingestion	
	Dust	Vapours		Soil	Crops
Playgrounds, etc. (mainly children)	x	x	x	x	x
Domestic vegetable gardens (adults and children)	x	x	x	x	x
Agricultural areas (adults and children)	x	x	x	x	x
Ornamental gardens (adults and children)	x	x	x	x	
Parks (adults and children)	x	x	x	x	
Sports facilities (mainly adults)	x	x	x	(x)	
Industrial/commercial areas, non-sealed (mainly adults)	x	x	(x)	(x)	
Industrial/commercial areas, sealed (mainly adults)	(x)	x		(x)	
Building, indoor climate (adults and children)	(x)	x		(x)	

A parenthesis around the X indicates that this exposure route is of less importance or not always relevant for the specific site use.

NOTE 1 Inhalation and ingestion of dust in indoor areas is related to soil tracked into the buildings by footwear and to a lesser degree from soiled clothes.

NOTE 2 Ingestion of crops in school playgrounds, parks, etc. can be related to growing of crops for educational purposes or the like in such areas, which is not uncommon.

Annex B
(informative)

Industries and related polluting substances

Type of industry	Typical contaminants
Petroleum industry	Volatile aromatics: benzene, toluene, xylenes and ethylbenzene; alkanes C_5 toC_{20}, gasoline lubricants, methyl ethyl ketone, methyl tert-butyl ether, polyaromatic hydrocarbons, acid tars, Pb, As, B, Cr, Cu, Mo, Ni
Petrol stations and other sites for storage, treatment and handling of petrol, oil and gas	Volatile aromatics: benzene, toluene, xylenes and ethylbenzene; alkanes C_5 to C_{20}, methyl ethyl ketone, methyl tert-butyl ether, lead
Gasworks	Phenols and alicylic phenols, polyaromatic hydrocarbons, volatile aromatics, cyanides, thiocyanates, ammonia, sulfur compounds
Asphalt and tar production and products	Volatile aromatics: benzene, toluene, xylenes; phenols, naphthalenes, polyaromatic hydrocarbons and other hydrocarbons
Wood, wood fibre and laminate industries	Toluene, xylene, trichloroethene, methyl methacrylate, other solvents
Impregnation of wood	Phenols, As, B, Cr, Cu, Hg, Sn, Zn, fluorides, polyaromatic hydrocarbons, creosote, chlorophenols, pesticides, dinitrophenol, PCCD/F
Paper and pulp industry	Chlorophenols, organic solvents, metals.
Printing industries	Chlorinated solvents, benzene, toluene, xylenes, acetone, isopropanol, other solvents, Ag, As, Cr, Cu, Hg, Pb, Sb, Zn
Foundries, metal works, etc.	Al, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Sb, Zn, phenols, formaldehyde, acids, cyanates, carbamides, amines, B, Ba, Hg, Se, Sn
Metal industry	Al, B, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Sn, Zn, fluorides, PCBs, PCTs, hydrocarbons, chlorinated hydrocarbons, solvents, glycols, turpentine, paraffins, cyanides, phosphorus, acids, ethers, silicates, polyaromatic hydrocarbons, Sb, As, Co
Galvanizing industry	Solvents, Ag, As, Cd, Cr, Cu, Ni, Pb, Zn, cyanides, hydrocarbons
Manufacturing of paint, lacquer and enamel	Solvents: petrol, turpentine, volatile aromatics, alcohols, ketones, esters, glycol ethers and esters, chlorinated hydrocarbons, acrylamides; As, Cr, Cu, Cd, Pb, Zn, Sb, B, Ba, Co, Mn, Hg, Mo, Ni, Se
Rubber and synthetics industries	Volatile aromatics: benzene, toluene, xylene and ethylbenzene; chlorinated solvents, other solvents, butadiene, Sb, B, Cd, Cr, Hg, Pb, Se, Te, Zn
Textile and tanneries	Sulfides and sulfates, chlorophenols, solvents, cyanides, acids, Al, As, B, Cd, Co, Cr, Pb, alcohols, esters, ketones, xylenes
Chemical laundries and dry cleaners	Trichloroethene, tetrachloroethene, turpentine, carbon tetrachloride
Auto repair	Aliphatic hydrocarbons, volatile aromatics, polyaromatic hydrocarbons, styrene, chlorinated hydrocarbons, other solvents, amines, isocyanates, methyl tert-butyl ether (MTBE), glycols, toluene di-isocyanate (TDI), Al, Cu, Pb
This and any similar list should be used with care. The list of potential contaminants is not necessarily complete — what is present at a specific site depends on the actual processes used. Not all contaminants listed will necessarily be present on a particular site.	

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