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B1 Reducing the risk of dispersion

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InfoMil
Juliana van Stolberglaan 3
2595 CA The Hague
The Netherlands
P.O. Box 93144
2509 AC The Hague
Telephone + 31 70 373 55 75
Fax + 31 70 373 56 00
E-mail info@infomil.nl
Website www.infomil.nl

Under the responsibility of
Project Group NRB
ing. P.A. Ruardi (VROM/BWL),
project management
ir. K. de Winkel (Tauw BV), editor

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Conefrey/Koedam BNO, Zeist

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1.1 Risk of dispersion

Even where there is only a negligible soil risk there is a chance of soil pollution. A specific soil investigation is the only way of discovering whether an activity has caused significant soil pollution. Where this soil investigation has to be carried out, and how frequently, depends on the risk of dispersion (see B1.4).

Under the Netherlands Soil Protection Guideline (NRB) the soil risk can be rendered acceptable by monitoring the soil quality to reduce the risk (see B1.5). The monitoring of soil quality to reduce the risk is also governed by the risk of dispersion.
On this point, the NRB provides guidelines that, when the combination of planned and existing measures and facilities leads to a final emission score of '2', for a specific part of the process an acceptable risk of soil contamination (soil risk category A*) sometimes can be achieved by means of intensive monitoring to reduce the risk.

The point of departure of the NRB is that during the renovation or the building of new industrial plants soil risk must be rendered negligible by means of measures and facilities. In that case, monitoring of soil quality to reduce the risk is not necessary.

Exploratory study to determine the risk of dispersion
The dispersion risk is determined on the basis of a thorough exploratory study in which data are collected about:

- the location and form of sources at the industrial site;
- the mobility, solubility and volatility of substances used or stored there;
- the soil profile and geohydrology of the soil.

On the basis of this exploratory study, supplemented where necessary with field research, for each activity it has to be investigated where those substances could appear in the soil and how they would disperse.
In this way a detailed research strategy can then be formulated setting out where (location, depth) and how changes in the soil quality should be monitored to unambiguously establish whether the activity concerned has caused soil pollution.

The outcome of the exploratory study can be used to determine the signalling value, to select the sampling locations for the soil pollution investigation and to devise a measuring system for monitoring to reduce the risk.

1.1.1 Company premises and potential sources

To avoid encountering unexpected problems in a soil pollution investigation information has to be collected about the establishment and history of the company premises. Table 1 summarises the relevant data in this context.

Individual activities on the company premises have to be identified, in particular locations where possible immissions could occur. Existing pavement, feed-through aperture and drains etc., play an important role in deciding on the positioning of sampling locations. The following types of source are distinguished:

1. *Point sources*
   These are sources whose maximum horizontal dimensions are less than 2,5 m, for instance pumps, small machines or storage tanks.
   The mid-point of a point source can be taken as a potential immission location.
2. *Line sources*
   Line sources are linear sources such as pipelines, sewers, gutters, seams or conveyer belts. In designating measuring points for line sources a distinction has to be made between continuous pipes and the point sources in them, such as joints, flanges or transitions. Particularly these 'weak links' can be seen as potential immission locations.
3. *Surface sources*
   Surface sources are sources whose horizontal dimensions are greater than 2.5 m in every direction. An example of a surface source is a floor on which one or more activities take place that *cannot* be regarded as separate point sources. In that case, all joint activities above the pavement may (from the perspective of the soil) lead to unpredictable immission points. In the case of surface sources with an impermeable floor, above all gutters, drains etc. are possible immission points.

Table 1 Basic information about premises and business activities

Level	Necessary	Desirable
Region	local information (monitoring wells, etc.)	
Industrial site	• location of current and historic business activities; • nature and scale of historic soil pollution, the activities involved and the soil protection measures and facilities; • complete list of potential soil contaminants.	• results from previous soil investigations; • local topography, such as elevation and the presence of open water.
Sampling location	• situation of underground infrastructure (pipelines, cables, etc.); • soil profile of excavations (vertical *sand drains,* old foundations, etc.); • situation and type of surface pavements.	

1.1.2 Information concerning employed substances

The specific properties of a substance influence its dispersion behaviour and hence the demonstrability of soil pollution. The information about the substance properties listed in Table 2 must be known, but it is difficult to translate this information into general rules for determining suitable sampling locations.

Table 2 Basic information about compounds

Level	Necessary
General	• Composition of the substance (if the substance consists of several components); • Degradability and degraded products; • Solubility in water (or octanol-water coefficient); • Density; • Vapour pressure (a measure of volatility).

The composition and degradability of a substance influence the way in which pollution can or must be demonstrated. Moreover, the solubility in water and volatility of a substance determine whether it should be monitored in the groundwater and/or the soil air. The best location for establishing possible soil pollution also depends on the density of a substance (density flow) and the interaction of the substance with the soil (mobility).

a Density driven dispersion

If the density of the liquid that is emitted is greater than that of the groundwater there is a possibility of density flow against the movement of the groundwater. Specifically, density flow means that there is an additional (vertical) dispersion component, a component that is very difficult to describe in general terms.
The form in which density flow manifests itself depends on the soil composition, the soil profile and the properties of the substance. Density flow generally occurs only if the density of the liquid differs by more than 2% from the density of groundwater. Table 3 shows when density flow can be expected.

Table 3 Chance of density flow

Density of emitted liquid	Chance of density flow
< 1.02 kg/dm^3	no
> = 1.02 kg/dm^3	yes

Density flow leads to an extra dispersion component in a vertical direction.

b Mobility

The mobility of a pollutant is a measure of the speed of the front in relation to the groundwater flow. The mobility of a contaminant depends on the soil and the properties of the substance. A soil with a high organic substance content, for instance, leads to greater adsorption of (organic) substance and hence to greater deceleration of the dispersion of the pollutant in relation to the groundwater flow.
Table 4 suggests three classes whereby the mobility is derived from the retardation factors as concluded by the RIVM [31].
It should be noted that the factor mobility is not derived directly from the retardation. The retardation is a measure of the average deceleration of the soil pollution. The speed of the front is generally higher than the average speed of dispersion.

Table 4 Mobility classification and retardation factors

	Mobility of the contaminant	Retardation factor
1	Very mobile	1–10
2	Moderately mobile	10–100
3	Immobile	> 100

The retardation factor can be calculated for *organic* compounds using the following formula (see also [31]).

$$R = 1 + 1410 \times \%\,os \times S^{-0.67}$$

where:
• % os: is the organic substance content of the soil as a percentage
• S: is the solubility in water of the contaminant in mg/l

The value for the organic substance content of the soil should in principle be derived from the results of a number of analyses. If there are no data, a provisional value can be derived from the site profile (see section B1.1.3a). Table 5 gives an indication of the organic substance content for each site profile. The solubility of a specific compound can be found in chemistry handbooks.

Table 5 Intervals and values for organic substance contents

Type of location	Organic substance content	
	global interval	value
1 polder	5–20%	10%
2 stream valley	5–10%	7%
3 artificial sand plateau	< 2%	1%
4 sandy soil containing loam/clay/peat	2–5%	3%
5 sandy soil without loam/clay/peat	< 2%	1%
6 sandy region, unsaturated zone > 8 m	< 2%	1%

The mobility of *inorganic* compounds depends heavily on the redox potential, pH and CEC value of the soil. Consequently, there is no uniform relationship between the mobility of inorganic compounds and a particular type of soil. The retardation of inorganic compounds must be considered separately from case to case.

The RIVM has calculated a retardation factor for a number of *heavy metals* [31]. All heavy metals considered are regarded as immobile.
Only cadmium and lead are moderately mobile under certain conditions, in an acidic environment and with a low organic substance content respectively. However, it should be noted that the margin for error in the values calculated is large. The 'Circular on the entry into force of the Soil Protection Act cleanup regulations' gives equivalent numerical values for heavy metals in the appendix. In the appendix all heavy metals, except molybdenum (moderately mobile), are also regarded as immobile. Molybdenum does not appear in the RIVM report.

The only other inorganic compounds for which target and intervention values are fixed in the context of soil remediation are cyanide and cyanide compounds. These are mobile. With respect to the inorganic compounds (non-metals) that are not mentioned, such as chloride, ammonia and sulphate, it is assumed that they are mobile unless otherwise demonstrated.

1.1.3 Soil profile and geohydrology

The dispersion of the substances in the soil is heavily influenced by the *heterogeneity* of the soil. There may be 'hydrological highways' (preferred pathways) in the soil. It is known that preferred pathways occur in distinctly layered systems; however, even in apparently homogeneous sandy layers one needs to beware of preferred pathways.
Table 6 lists the basic information required about the soil profile and geohydrology.

During the exploratory study an effort should be made to gain an insight into possible preferred pathways. Since the state of the art is not yet advanced enough to map heterogeneity, it is at least as important to take this uncertainty into account in determining the locations for measurements. The constructional facilities needed for the intended industrial activity can have a major influence on the existing geohydrology. Possible changes in the groundwater flow must be anticipated as far as possible in designating sampling points for the soil pollution investigation.
In general the study should be based on the possible dispersion route of substances after pollution of the soil. These are generally the soil layers with the coarsest granulated structure.

The exploratory study must in any case lead to identification of the soil layers with the highest permeability and provide insight into the most likely dispersion route of the contamination.

a Site profile

The dispersion risk at a site depends directly on the groundwater flow speed (volume of flow / porosity). Flow speed can be established with regular measurements of the level of ascent of the average local groundwater. This is the preferred method.

Table 6 Basic information on soil profile and geohydrology

Level	Necessary	Desirable
Region	infiltration or seepage	influence of future spatial changes (autonomous developments) on the groundwater or surface water.
Industrial site		level, depth and location of nearby surface water and the drainage and/or infiltration flowing from it.
Sampling location	• detailed description of soil profile; – distinct soil layers up to at least 0.5 m below the underground infrastructure – organic substance (humus) and clay content (sieve fraction < 2μm) • geohydrology – average highest and lowest groundwater level – direction(s) and speed of groundwater flow.	• natural variations in hydrological variables (seasonal effects).

If there are practical objections to this approach, the dispersion risk can easily be related to the geohydrological situation by making a sub-classification into types of sites. The division into site profiles is a simple way of showing differences in the dynamics of soil. Each site profile has a characteristic pattern and speed of groundwater flow and soil composition.

The following site profiles are distinguished:

1 polder area, this area is characterised by artificial drainage and predominantly upward seepage. The groundwater flow in the non-raised covering layer moves at between 0 m/year and 5 m/year;
2 stream valley area, because of the proximity of natural drainage there is a natural seepage situation. The groundwater flow is generally between 3 and 8 m/year;
3 artificial sand plateau several metres high on a sealing layer formed by the former ground level dedicated for industrial activities. The groundwater moves downwards and horizontally at 5 to 10 m/year;
4 sandy soil, consisting of a sandy covering layer originally containing clay and/or loam. The groundwater infiltrates and moves horizontally at 5–15 m/year;
5 sandy soil, with a very thin or no covering layer, infiltration and a high groundwater flow of 15–50 m/year;
6 sandy region with a large unsaturated zone (> 8 m), such that the dispersion in this zone is the benchmark.

If a location does not automatically fit into one of these profiles the study should be based on the groundwater flow speed and the vertical flux (percolation or infiltration). A site profile can be chosen from the following table on the basis of situation and flow speed, although measured values for the groundwater flow speeds are preferable.

Table 7 Site profiles and indicative groundwater flow speeds in m/year

Site profile	Indication of speed
1 polder (artificial seepage)	0–5
2 stream valley (natural seepage)	3–8
3 artificial sand plateau (infiltration)	5–10
4 sandy soil containing loam/clay/peat	5–15
5 sandy soil without lime/clay/peat	15–50
6 sandy region, unsaturated zone > 8 m	n.a.*

* the benchmark is dispersion in the unsaturated zone.

The size of the *unsaturated zone* influences dispersion in all site profiles.

1.1.4 Determination of signalling value

The signalling value is the reference value against which a measured value has to be compared. The objective is to determine whether the soil quality has been affected. The signalling values must be as low as possible so that any change in the soil quality can be observed as soon as possible. On the other hand, the signalling value must be clearly distinct from the background values.

Three factors determine the signalling value:

- *The detection limit*
  The signalling value will only be based on the detection limit if the background value is lower than the detection limit of the analyses;
- *Sampling and analysis variability*
  Despite standardised procedures there may be some variability in laboratory analyses and sampling. This must be taken into account in establishing the signalling value and decisions towards further action;
- *Background values*

a Signalling values of soil and groundwater

The background values for soil and groundwater are derived from soil samples and observations in measuring pipes respectively.
If samples are taken at *fewer* than 30 locations the signalling value is equal to the mathematical average of the measured values for the relevant substances multiplied by a factor of 1.3. If *more* locations are sampled the signalling value is equal to the 98th percentile of the measured values.

b Signalling values of soil air

Soil air monitoring only takes place for volatile contaminants. Volatile contaminants do not occur naturally and the background value for soil air measurements is zero.
This means that both the signalling value and the choice of parameters are clear. The signalling value is equal to the detection limit.

In exceptional cases there is an increased background level. An investigation is needed into the cause of the increased background level and the signalling values which are to be used in that case. Such a situation is however so specific that no general guidelines can be given for it.

Table 8 Basic information for establishing signalling value

Level	Necessary	Desirable
Region		Regional background concentration.
Industrial site		Background concentration at industrial site.
Sampling location	for the substances used in the business process the chemical quality of • permanent soil phase up to at least 0,5 m beneath the underground infrastructure • groundwater (in so far as this is not impossible in practice due to deep groundwater level) • soil air (only useful in the case of historical soil pollution with volatile compounds).	Background concentration at sampling location (e.g., NEN package for soil and groundwater contaminants: PACs, heavy metals, EOX, mineral oil, volatile aromatics, etc.).

1.2 Soil sampling

The purpose of a soil sampling programme is the timely detection of new soil pollution on the basis of increases compared with a predetermined signalling value.
The competent authority ensures that a sampling programme complies with an approved design and with the following principles with respect to the measuring methods. In principle measurements can start without intervention by or consultation with the competent authority.

1.2.1 Selecting sampling and analysis parameters

From the perspective of efficiency the choice of parameters must be geared to the contaminants that are used. If several substances are used *separately* these must be included in the range of substances to be analysed. If the substances appear in a cocktail at least two of the most mobile and persistent compounds with the greatest distinctiveness in relation to the background value must be selected. Special attention should be given to degradable compounds of which the breakdown products are more mobile than the original compound. Both the original compounds and the breakdown products must be included in the substances to be analysed. An example of this is cisdichloroethene and vinyl chloride (breakdown products of trichloroethene and tetrachloroethene).

1.2.2 Selecting the soil compartment to sample

A soil investigation can in principle take place in any soil compartment (solid soil phase, groundwater, soil air). Groundwater is regarded as a reliable sampling medium. Confidence in measurements in the soil air is also increasing rapidly. The main advantage of soil air sampling is that detection is possible at an early stage. The disadvantage of soil air sampling is that measurements are only possible for volatile substances. In addition the dynamics in the soil air, the potentially high degree of biological breakdown and evaporation make it necessary to impose higher standards for measurements in the soil air.

Although measurements in the solid soil give a clear picture they are poorly reproducible, destructive and expensive. Because they are not very reliable with respect to monitoring the soil quality, sampling in solid soil is not practical in the context of monitoring of soil quality to reduce the risk.

However, *maximum reliability (or 100% chance of success) is not felt to be attainable* with any soil medium. Mathematical descriptions may be based on a success rate of 100% but in particular (micro)heterogeneities in the soil will always lead to a difference between the description of the actual situation and practice in the field.
Groundwater and soil air are mobile soil phases. This implies that soil pollutants spread through convection, diffusion and dispersion. Consequently, the chance of quickly identifying pollution is relatively greater by sampling these soil phases. Heterogeneity plays a far greater role when the solid soil is being sampled. Even if distances between measuring points are short there can be large differences in concentration between measuring points in the solid soil.
By contrast with groundwater sampling the frequency of measurement has a substantial effect on the reliability of soil air systems. The reasons for this are biological breakdown and evaporation.

The selection of the soil compartment in which the sampling should take place depends on:
- the location of the sampling point in relation to the potential source;
- the average lowest groundwater level;
- the volatility of the substance. A compound is regarded as volatile if the evaporation pressure at 273 K is at least 0,1 x 10^3 N/m^2. If the evaporation pressure is more than 100 x 10^3 N/m^2 one refers to a high degree of volatility.

The following considerations also play a role:

A If the unsaturated zone between the potential source and the average level of groundwater is less than 1 m, monitoring of the soil air alone is unreliable. As a result of capillary rise the actual unsaturated zone is even smaller and the chance of short circuit flow (attraction of clean air from above ground level) is very high. For this reason sampling of the groundwater is primarily recommended. If something still needs to be measured more quickly, depending on the local soil profile one option is to also consider sampling soil air. If the contamination is not volatile the soil air sampling will not be an option.

B If the unsaturated zone between source and the average lowest groundwater level is greater than 8 m, groundwater sampling is no longer permitted in view of the maximum extent of spread. A volatile contaminant can be monitored through the soil air.

C When the thickness of the unsaturated zone is between 1 and 8 m the selection of the compartment depends on the degree of volatility of the contaminant. If the vapour pressure is lower than 0.1 x 10^3 N/m² the groundwater will be sampled. If the vapour pressure is between 100 and 100 x 10^3 N/m² (at 273 K) the appropriate compartment is soil air. If the volatility is higher soil air sampling alone is not sufficient and the groundwater must also be sampled.

1.2.3 Sampling and analysis methodology

Sampling must be carried out by a company in possession of a valid certificate according to BRL SIKB2000. This certificate must have been issued by a certification body which is a member of the SIKB.
The treatment and analysis of samples must be carried out by a laboratory accredited by STERLAB.
Note: SIKB is currently working on a certification scheme for the treatment and analysis of samples. As soon as a laboratory is certified for these activities it can be regarded as equivalent.

The preparation and analysis of samples depend on the substances to be investigated. There are a large number of standards for these activities. It is beyond the scope of the NRB to provide a list of the standards that apply to the generation and analysis of a particular sample for a specific substance.

1.2.4 Site of the sampling

Sampling for the purposes of monitoring soil quality to reduce risk or a soil pollution investigation must be geared to the form of the potential source and preferably take place as close as possible to that source, generally downstream:

- At each *point source* at least one sampling point must be installed;
- For *line and surface sources* sampling points are placed primarily at components that determine the risk such as filling points, draining points or sampling points, flanges, pumps, transitions in the pipelines/gutters, etc.

Subject to these preconditions measuring points can be clustered so that the soil investigation can take place for different business activities with the same measuring points.

a Groundwater

If the preliminary investigation has shown that there are likely to be *artificial or natural preferred pathways,* dispersion along these pathways must be anticipated. This would include not only former ditches, cable ducts or gullies, but also more vertical subsidence (anisotropy) or other natural disturbances. In these cases the preferential pathways must be monitored.

a.1 Sampling line

A sampling line is the line along which the sampling points are installed. In general the position (the distance to the source) of the sampling line is geared to the existing infrastructure, for instance immediately alongside a pavement or between two buildings. In this case, the point of departure remains that the sampling line is situated as close as possible to the source. The sampling line must be projected on the downstream side(s) of the source, while the length of the sampling line is equal to the dimensions of the source. Depending on the groundwater flow direction this means that the sampling line must be installed on one or more sides of the source. The following situations are distinguished:

- *Unequivocal groundwater flow direction*
  The sampling line is projected on the downstream side(s) of the source;
- *Multi-directional flow*
  If there is an unequivocal multi-directional flow the sampling line must be projected on all sides on which the flow occurs;
- *Alternating groundwater flow*
  The sampling line must be installed at least at those places where flow may occur one or more times a year.

a.2 Distance between sampling points

The distance between the sampling points themselves depends on the distance between the sampling points and the source. In principle, the greater the distance to the source, the wider the contamination plume and hence the greater the distance between the sampling points or monitoring wells. As a guideline, the distance between the sampling points is equal to the distance between the source and the sampling points. There are two exceptions to this rule:

- *Close to or beneath the source*
  Close to or beneath the source (< 5 m) the distance between the sampling points is kept at 5 m. Shorter distances are not felt to be useful for the following reasons:

– in the unsaturated zone there is always some horizontal and vertical dispersion of contamination;
– the chance that an immission will occur precisely between two monitoring wells is small;
– if the distance is too small the costs will be unnecessarily high.

• *Further than 10 m from the source*
In the case of distances greater than 10 m the distances between monitoring wells are proportionately shorter. The maximum must never be greater than 20 m because the risk of flow along preferred pathways as a result of heterogeneities in the soil increases steadily with distance.

b Soil air

Soil air pollution generally only occurs close to the source and spreads via diffusion. There are scarcely any pressure gradients. As a result of evaporation and biological breakdown, moreover, dilution will quickly occur on the edges of the soil air contamination The monitoring points are therefore positioned primarily beneath the point sources or horizontally at less than 1 m from the point source.

1.2.5 Interpretation and evaluation of results of the soil investigation

When a series of measurements for the purposes of a soil investigation have been completed it is important that the results are correctly interpreted and evaluated. It must be clear whether action needs to be taken, and if so what action. This is important for both the company and the competent authority.

a Reporting sampling results

Precise what a soil investigation report has to contain will be determined in consultation between the company and the competent authority. An indication of the minimum requirements for such a report are given below:

• an outline of the sampling network and monitoring programme;
• the results of the measurements;
• a summary of any departures from signalling values that were observed, with an indication of whether or not they have been reported to the competent authority;
• an overview of the curative actions taken;
• a list of proposed changes as well as an overview of changes made to optimise the monitoring system.

The frequency with which evaluation reports appear will be agreed upon with the competent authority and will depend on the frequency of the sampling. Obviously if curative actions are required in the interim it will be necessary to contact the competent authority sooner.

b The evaluation by the competent authority

The results of an analysis will be assessed against the signalling values. If a measured value exceeds the signalling value, the measurement must be repeated within a month at the latest. If the signalling value is still exceeded the competent authority will be notified and the measurement repeated for a third time.
In the event of continuing infringement of the signalling value the source of the contamination will be traced, the cause of the contamination remedied and further agreements made with the competent authority for soil remediation. If an Action Plan for soil remediation is agreed in advance between the competent authority and the company, the actions included in it will be implemented.

1.3 p.m.

1.4 Soil pollution investigation

1.4.1 Introduction

a Purpose of the soil pollution investigation

The purpose of the soil pollution investigation in the context of preventive soil protection is described in sections A2.2.2a and A4.4.4.d of the NRB. This chapter describes this investigation in more detail.

b Basic principles of soil pollution investigation

The soil pollution investigation must show whether there has been pollution of the soil despite the measures and facilities adopted. For this purpose, the baseline situation of the soil quality must be established. The baseline situation is the actual quality of the soil prior to the business situation for which the permit is sought. Ideally the findings of a baseline situation soil investigation will be enclosed with the application for a permit.

This baseline situation serves as a reference for the soil quality when an identical investigation is carried out to establish whether after a period of time soil pollution has been caused by the relevant source.
The soil investigation designed to establish the soil quality will be repeated in any case on termination of the activity.
Whether (in the case of a negligible soil risk) this investigation also has to be conducted in the interim depends on the acceptability of the costs of soil remediation; in other words, the scale of any soil pollution and hence the mobility of any substances that might be released. The time needed to reach a plume length of 10 m in a given situation, together with an estimate that the costs of remediation will exceed € 22,500, determine the required frequency of interim soil pollution investigations. The maximum permissible remediation costs follow from the 'Draft Decree on Financial Guarantee' [Government Gazette, 17 July 2001, 134].

1.4.2 Establishing a system for soil pollution investigation

a Baseline soil pollution investigation

All information needed to establish a system for the soil pollution investigation is set out in section B1.1.1. The baseline soil pollution investigation should be regarded as the field study designed to establish the signalling values.

a.1 Establishing sampling locations

The soil pollution investigation for individual business activities can often be clustered. The presence of pavements and/or drains on the site will generally mean that possible soil pollution – as a result of individual activities – will still have common immission points. An extensive sampling network for soil pollution investigations is therefore generally unnecessary for surface sources.

The actual design of the sampling network also depends on the findings of the exploratory study described in section B1.1. The selection of the sampling and analysis parameters, the appropriate soil compartment for carrying out soil pollution investigations and the sampling sites are determined on the basis of the considerations outlined in section B1.2.

Sampling sites are preferably between 5 m (for highly mobile (R < 10) and immobile (R > 100) substances) and 10 m (for mobile substances) downstream from potential emission points. In designating sampling sites account has to be taken of the form and nature of the potential sources. The considerations in section B1.2.5 play an important role in this respect.

b Final and interim soil pollution investigations

b1 Establishing sampling methodology and sampling locations

The field research for the final and interim situation soil pollution investigations must in theory take place in the same way and at the same locations as the baseline investigation. The results of the analyses are assessed against the signalling value. On this point, see section B1.2.7.

For practical reasons it is sometimes necessary to select another sampling location. In some cases – for example because a pavement or impermeable floors have been constructed on a site – it may not be possible to take samples from the solid soil phase. In that case groundwater samples must of necessity suffice, possibly supplemented by soil air samples. In that case, existing monitoring wells /filters will preferably be used. Existing monitoring wells which have not been sampled for some time may have become unusable.
As a result of building activities at the industrial site and/or (temporary) groundwater withdrawal the physical soil profile and/or geohydrology may have changed compared with the situation established in the exploratory study.
If – as recommended in section 1.1.3a – the groundwater level has been monitored in the meantime using installed monitoring wells, in designating sampling locations account can be taken of changes in relation to the assumed direction of movement.
Sometimes new sampling points will have to be installed in light of the changed situation.

c Frequency of interim soil pollution investigation

The need for interim soil pollution investigations is dictated by the scale of the consequences of possible soil pollution and the ensuing costs of soil remediation (see section 1.4.1b). Interim soil pollution investigations are generally confined to sampling of groundwater and/or soil air via the monitoring wells /filters which were installed for the baseline investigation.

Table 9 shows whether, and if so how often, an interim soil pollution investigation has to be carried out. The frequency of the interim soil pollution investigation follows from the mobility of the substance and the site profile. The mobility of the substance is established on the basis of section B1.1.2b, the site profile on the basis of section B1.1.3.a.

Table 9 Sampling frequency for interim soil pollution investigation

Site profile	Mobility class		
	1 **)	2	3
1 polder	1/10 years	*	*
2 stream valley	1/10 years	*	*
3 artificial sand plateu	1/10 years	1/10 years	*
4 sandy soil with loam/clay/peat	1/3 years	1/7 years	*
5 sandy soil without loam/clay/peat	1/1 year	1/2 years	*
6 sandy region, unsaturated zone > 8 m	1/1 year	1/2 years	*

* Only final soil pollution investigation needed.

**Relatively low soil remediation costs mean that for highly mobile substances in soil profiles 1, 2 and 3 there is no requirement for frequent interim soil pollution investigations.
In soil profiles 5 and 6 the required frequency of investigations has been fixed at once a year for pragmatic reasons; however it is conceivable that in light of the local (geohydrological) situation a frequency of once a year is not enough to detect pollution that has occurred.

1.5 Monitoring of soil quality to reduce the risk

1.5.1 Introduction

a Purpose of monitoring of soil quality to reduce the risk

The NRB defines 'monitoring of soil quality to reduce the risk' as 'monitoring the soil close to a source with specific techniques and effective frequency in order to identify soil pollution early'. The aim of soil monitoring to reduce the risk is to limit the volume of any soil pollution that occurs, and hence the costs of soil remediation, to acceptable proportions.

Monitoring of soil quality to reduce the risk is a management measure whereby under certain conditions the soil risk can be rendered acceptable (soil risk category A*) (see also sections A2.2.3 and 2.3). Soil monitoring to reduce the risk can also be used as an instrument to safeguard the quality of soil under the 'Above-Ground Atmospheric Storage Tank (Soil Protection) Guideline' and subject to a guaranteed 'quality assured management system for soil polluting incidents'(see section A4.2.4). The actual soil monitoring to reduce the risk to be carried out in that case is based on a practical implementation of the directions given in this chapter.
The method by which soil monitoring to reduce the risk should be implemented to reduce an 'increased soil risk (soil risk category B)' to an acceptable soil risk are set out in the 'Monitoring of Soil Quality in Business Activities Guideline'; this guideline lays down the state-of-the-art for targeted soil investigations and forms the basis of this chapter. [1]

[1] The intensity of the monitoring required, the soil profile and/or the impracticality of soil remediation prevent the application of this soil protection strategy.

The decision to bring about an acceptable soil risk for particular units of a company requires permission from the competent authorities; close coordination between the permiting authority and the applicant on the basic principles and preconditions for the monitoring system is essential.

Monitoring of soil quality to reduce the risk is not necessary for business activities with a negligible soil risk (soil risk category A).

Monitoring of soil quality to reduce the risk is expressly ***not*** intended for monitoring existing soil pollution over time.
Automatic systems which safeguard the impermeability of each installation outside the soil – such as leak detection systems – are not regarded as monitoring systems in the NRB, since such systems reduce the chance of emissions and are consequently preventive measures (see A5.1.2a).

b Basic principles of the Monitoring Guideline

The 'Monitoring Guideline' is designed to issue clear instructions concerning:

- the design, set up and operation of sampling systems for soil monitoring to reduce the risk;
- milestones and criteria for the decision-making process intended to lead to effective monitoring of the soil quality; and
- procedures for putting the sampling system into operation and actions to be taken on the basis of the results of the monitoring.

It was consciously decided to only include operational sampling systems about which a lot is known and with which a lot of experience has already been acquired in practice in the Monitoring Guideline. Soil air sampling also received greater prominence because of the policy preference for monitoring as close as possible to the source.

Application of the Monitoring Guideline results in a sufficiently reliable and efficient design, structure and management of the sampling systems.

Where possible the Monitoring Guideline leaves scope for advances in the state-of-the-art of monitoring. For ease of use a number of criteria have been defined numerically. In practice there are generally no firm limits. This means that the use of the decision-making criteria must be employed with a certain discretion. In the guideline each situation is schematised as far as possible to a standard situation. Application of the Guideline therefore leads to standard monitoring systems, even though the geohydrology and the use of each location is unique. The permit authority and applicant must then reach agreement on the selection of any such standard solution. Draft rules will be produced for each solution with a certain margin intended to gear the design to the specific situation. The Guideline also outlines the procedures to be followed.

1.5.2 Design of a monitoring system to reduce the risk

In the consultations prior to submitting an application for a permit or a notification, the feasibility of soil remediation and the soil investigation to reduce the risk will be discussed by the company and competent authority on the basis of the exploratory study carried out by the company (see B1.1).

When discussing the design and implementation of a sampling system the company and the competent authority must also consider the practical and organisational consequences if the established signalling values are exceeded. The possible consequences (in other words soil remediation) of opting for soil monitoring to reduce the risk must be clear.

For the purposes of adequate assessment the design must be supported with:

- A design for the sampling network.
  - an inventory of the sources and where necessary further specification of them. The specification focuses on the weak or critical points of a source with respect to leaks etc.;
  - an account of the positions of the sampling points chosen for groundwater or soil air measurements;
  - the draft specifications of the sampling network.
- An outline of the monitoring programme.
  - an inventory of the substances used or intended to use at relevant sources especially substances hazardous to the soil. The inventory covers purchased substances, substances formed during the production process as well as breakdown products from them;
  - an account of the analysis parameters chosen, especially for the use of indicators for a group of substances hazardous to the soil;
  - an account of the selected sampling method and where relevant the composition of mixed samples;
  - an account of the frequency of sampling.
- An action plan for soil remediation.

If the competent authority agrees to the proposal to bring about an acceptable risk by means of monitoring to reduce the risk on the basis of the suggested plan and the underlying arguments, the company can proceed to design the sampling system. An approved system for monitoring to reduce the risk is the result of consultation between the company and the competent authority.

a Determination of soil compartment to monitor

The choice of compartment for sampling in soil monitoring to reduce the risk depends on the soil profile, the volatility of the potential pollutant, and the physical possibility of sampling in the immediate vicinity of the source. Such a choice can only be made if it is assumed that the relevant measurements will be performed optimally, that is to say the influence of the sampling frequency, for example, on the reliability is kept to an absolute minimum during the design phase.

a.1 Relation between soil compartment and sampling distance

If soil monitoring to reduce the risk is to be effective as a method of achieving an acceptable soil risk, the system will have to be designed in such a way that the chance of success is as high as possible. In practice this is not always possible and this basic principle generally has to be translated to: ‘as close as possible’. The distance between the actual monitoring and the potential source, remote or close, is important for the choice of the soil compartment to be monitored.

If the distance between source and necessary sampling points is less than 5 m, it is referred to as *sampling at the source.*
In exceptional cases *sampling further from the source* can take place. In this case it always has to be remembered that a pollutant must never spread beyond the boundaries of the site.
Sampling further from the source is only possible *in the groundwater,* because horizontal dispersion of substances takes place principally via the groundwater and not via the solid soil or soil air. In general substances seldom if ever disperse horizontally in the soil air (low pressure gradients), and must therefore be measured directly at the source. If this doesn’t happen there is a good chance that pollution will not be observed.
Sampling further from the source is only permissible if the specific circumstances at the site justify it, such as:

1 *Existing floor for storage and transshipment*
In the case of an existing liquid retaining floor on which storage or transshipment activities take place,

access to the desired sampling locations may be physically prevented or it may be impossible to install or reach sampling points.

2 *Drilling in impermeable floor is not allowed*
It may not be possible or allowed to drill in a containment facility, which could sometimes be a reason for sampling at a greater distance. In general, however, an impermeable floor can be drilled in to install sampling facilities. There are now adequate technical solutions available for the sealing of bore holes.
An impermeable pavement may be a reason not to place sampling points close to the source placed on them but to move them to the drainage area and/or the edges of that pavement.

3 *Dense network of cables and pipelines*
A very dense network of infrastructure facilities such as cables and pipelines which makes it unsafe to perform drilling or excavation work.

Sampling at distances further than 5 m from the source *is not permitted under any circumstances* if the following conditions are not met:

1 *The thickness of the unsaturated zone is less than 8 m*
The distance between the average lowest water table and the relevant source must not be more than 8 m. If this distance is greater, with monitoring further from the source both the signalling time and the extent of the pollution will become too great and sampling far from the source is not permitted.

2 *The density of the pollutant is lower than or similar to water*
Sampling at a greater distance from the source is only permitted in the case of substances with a density lower than or equal to water. If the density of the liquid is more than 2% greater than that of water ($\geq$ 1,020 x 10^3 kg/m^3), the risk of density flow (vertical transport of substances at a relatively high rate) is too great.

a.2 Selection of soil compartment

The preferred compartment for soil monitoring to reduce the risk can – partly in light of the above – be determined on the basis of the considerations outlined in section B1.2.1.

Soil monitoring to reduce the risk at distances greater than 5 m from the source is only possible with groundwater sampling (on this point, see the criteria in the previous section). With an average lowest groundwater level greater than 8 m groundwater monitoring is no longer permitted because of the maximum extent of dispersion. This all implies that soil monitoring to reduce the risk is not possible for non-volatile compounds in elevated sandy areas (location type 6, often also type 5)!

For other soil profiles there are four remaining types of sampling:

1 Groundwater sampling further from the source, because sampling at the source is not really possible;
2 Soil air sampling at the source;
3 Sampling of both groundwater and soil air at the source, prescribed for very thin unsaturated zones or very volatile substances. The measurements can take place in combined filters for soil air and groundwater;
4 Groundwater sampling at the source.

a.3 Determination of signalling values

The method by which signalling values for assessing measurements for the purposes of soil monitoring to reduce the risk are established is described in B1.1.4.

b Design of sampling network for soil monitoring to reduce the risk

The information needed for the design of an effective sampling network is derived from the exploratory study as described in section B1.1.

The design of a sampling network close to the source must be geared to the form of the source: point, line or surface source.
In principle samples must be taken within 5 m of the source. It is important to note that sampling further than 10 m from the source is only permitted in highly exceptional circumstances and if supported by sound arguments. Detection of an immission during sampling at a distance further than 10 m from the source signifies the presence of substantial pollution with excessive costs for soil remediation.

Table 10 Minimum required sampling frequency

Type of location	Mobility class					
	1	2	3	1	2	3
	1 < R < 10	10 < R < 100	R > 100	1 < R < 10	10 < R < 100	R > 100
	no density flow			with density flow		
1 polder	1 / 1 year	1 / 3 year	1 / 10 year	2 / 1 year (c)	1 / 1 year	1 / 3 year
2 stream valley	1 / 1 year	1 / 3 year	1 / 10 year	2 / 1 year (c)	1 / 1 year	1 / 3 year
3 artificial sand plateu	2 / 1 year (c)	1 / 1 year	1 / 3 year	2 / 1 year (c)	2 / 1 year (c)	1 / 1 year
4 sandy soil containing loam/clay/peat	2 / 1 year (c)	1 / 1 year	1 / 3 year	2 / 1 year (c)	2 / 1 year (c)	1 / 1 year
5 sandy soil without loam/clay/peat	2 / 1 year (c)	2 / 1 year (c)	1 / 1 year	2 / 1 year (c)	2 / 1 year (c)	2 / 1 year (c)
6 sandy region, unsaturated zone > 8 m	2 / 1 year (c)	2 / 1 year (c)	1 / 1 year	2 / 1 year (c)	2 / 1 year (c)	2 / 1 year (c)

(c) = continuous

c Sampling frequency in soil monitoring to reduce the risk

The required frequency of sampling depends on the geohydrology and properties of the substance (see B1). Table 10 shows the minimum sampling frequency required for soil monitoring to reduce the risk for different types of location as a function of the mobility (see B1.1.2a and b) of different substances.

In drawing up the Monitoring Guideline, however, it was found that sampling frequencies of once every three years or less are too limited for their signalling function. The low sampling frequency implies that monitoring wells that are not used for very long deteriorate in quality or are even 'lost'.

c.1 Sampling of groundwater

In order to guarantee the operational capability of a network for groundwater sampling the maximum recommended period between two samplings (with maintenance inspections) is two years.
If the operational capability of the network can be guaranteed, for instance through regular cleaning of the monitoring wells, the sampling frequency in table 10 can be adopted.

Time of first sampling

If the sampling is further than 5 m from the source, it is possible that (new) pollution will not migrate from the source to the sampling line within the sampling periods referred to. Depending on the mobility of the substance and the geohydrology (see B1.1) the contamination will be moving for some time before the sampling points are reached. In consultation with the competent authority it may be decided to delay the timing of the first sampling in accordance with the expected transport time in the case of business activities that have still to start.

c.2 Sampling of soil air

Soil air sampling is only regarded as reliable enough if the measurements are carried out frequently. This frequency must be geared to the degradability and volatility of the substances. The degradability can differ greatly from case to case. Assuming the soil is clean at commencement only in exceptional cases will there be breakdown of pollution within six months. In those cases however the risk of substantial pollution is small. On the other hand, the transport in the case pollution of the soil air depends on diffusion, which is generally a slow process.

Based on these two aspects (degradation and diffusion) the frequency to be adopted for an effective soil air sampling system is twice a year. From case to case the company should consider whether to install (online) measuring equipment: equipment consisting of a measuring sensor linked to a switch system that links different sampling points alternately to the measuring sensor. Although this equipment requires a large investment, with an extensive sampling network the equipment can quickly pay for itself.

Juliana van Stolberglaan 3
P.O. Box 93144
2509 AC The Hague
The Netherlands
Telephone +31 70 373 55 75
Fax +31 70 373 56 00
E-mail info@infomil.nl
Website www.infomil.nl

infoMil