Commentary Article: Regulatory Advances

Guide Values for Contaminated Sites

in Baden-Württemberg*

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Abstract

The treatment of hazardous sites in Baden-Württemberg is based on three legal documents: the state waste disposal act (LAbfG, 1990), the assessment committee directive (KommissionsVO, 1990), and the guide values directive (UM &SM B-W, 1993). The guide values directive was commonly issued by the Ministry of Labor, Health and Social Affairs and the Ministry of the Environment of the state of Baden-Württemberg (UM & SM B-W, 1993) and contains a three-level hierarchy of numerical criteria and rules which serve as both screening levels during the investigation and as remediation objectives. The decision for the appropriate level of remediation is based on feasibility and environmental balance considerations. The levels are ordered as follows:

- Level 1 (Background-Values)

On principle, all remediations have to be based first on background levels. In the case of lack of feasibility or negative environmental balance for level-1 objectives use-specific requirements are considered next.

- Level 2 (Assessment-Values for Worst Case Exposure Conditions)

The generic requirements underlying level 2 afford appropriate protection for humans regarding the most sensitive uses of the environment. At least four resources are considered on this level: Groundwater as such and its use, the health of humans on contaminated sites, and soil with respect to growth and quality of plants. Barriers against migration of the contaminants, the effect of dilution, and abandonment of certain uses, etc., are not taken into consideration on level 2.

- Level 3 (Site-Specific Requirements)

Lack of feasibility or a negative environmental balance of level-2 objectives lead to consideration of site-specific circumstances which may alleviate the requirements. With respect to groundwater, the distinction is again necessary between groundwater as a resource and the use of groundwater. On level 3 the guideline gives rules of how to derive site-specific remediation objectives for groundwater in the form of concentrations and fluxes of contaminants after taking into account barriers, dilution, and the abandonment of uses.

The guideline is the only directive of its kind in the world that regulates both concentrations and fluxes of contaminants into groundwater.

1 Introduction

The treatment of hazardous sites in Baden-Württemberg is based on three legal documents: the state waste disposal act (LAbfG, 1990), the assessment committee directive (KommissionsVO, 1990), and the guide values directive (UM & SM B-W, 1993). This article is concerned with part three of the state waste disposal act which applies to the registration, investigation and remediation of hazardous sites. For the purposes of this act, suspected hazardous sites are divided into abandoned hazardous **waste disposal** sites and abandoned hazardous **industrial** sites. As long as no details about the quality, quantity and location of hazardous materials at any given site are known, the term "suspected hazardous site" is used. In accordance with the federal waste disposal act (AbfG, 1986) the state act defines a site as hazardous if it impairs the public welfare (in the authorized English translation of the law the term "common weal" was coined). Therefore, we speak of a "hazardous site" from the moment it is proved that the site interferes with the common weal.

The state act further determines the clean-up goal as the restoration of the common weal, and for industrial hazardous sites the law in addition requires to make sure that the **concern** of water contamination is eliminated.

In the early phase of dealing with contaminated sites, the state of BadenWürttemberg conducted quantitative surveys in selected communities to obtain the approximate number of these sites. A figure of around 35,000 publicly owned sites statewide can be inferred from these surveys. The multitude of contaminated sites necessitated the setting up of guide values and a standardized procedure to deal with these sites in an effective and uniform manner. Preliminary drafts (v.d. TRENCK & FUHRMANN, 1990 and 1991; HAHN, 1991; RUF & v.d. TRENCK, 1992; LfU, 1992) were tested by the state administration, and the resulting guideline was subsequently issued on September 16th, 1993, as a joint directive by the Ministry of Labor, Health and Social Affairs and the Ministry of the Environment of the state of Baden Württemberg (UM & SM B-W, 1993).

* Abbreviations carrying an asterisk (*) are explained in the "List of Abbreviations" (→ *section 7*).

The guideline contains a three-level hierarchy of numerical screening criteria and remediation objectives (→ *section 3* "Remediation Objectives"). Originally the guideline was merely intended to aid in setting remediation goals. In the present form the same values also serve to trigger technical investigations of a site if they are exceeded (screening levels).

2 Screening Levels

The state administration follows a systematic procedure of five steps in dealing with public contaminated sites (UM B-W, 1988; HILLMERT, 1990). In the early investigative stages of this procedure, the guide values are used as screening levels to determine whether a site is to be moved to the next stage of the assessment procedure where specific actions are to be taken.

2.1 Background Levels (H-Values)

The ubiquitous presence of contaminants, whether it is due to the natural soil composition or caused by human activity, is indicated by background levels for soil in mg/kg dry matter (**H-B***) or groundwater in μg/L (**H-W***). The H-W-values can also be used to characterize a leachate obtained from soil or other solid materials through sampling in situ or via model experiments in vitro. In cases of samples taken downstream of the contamination, the dilution has to be taken into account for calculating the original concentration in the leachate at source.

Since background levels may differ vastly throughout the state, either the range or the 90. percentile or a similar value was entered into the table (→ *Appendix, p. 260)* in the case of naturally occurring substances. The table entries can be regarded as default values and replaced where appropriate regional values are known. For anthropogenic chemicals, the practical quantitation level or the analytical detection limit is given instead of the theoretical background of zero.

Resulting action: The spatial distribution and representative concentrations of all relevant contaminants are to be investigated if the H-values are clearly exceeded by single samples.

2.2 Assessment Levels (P-Values)

Groundwater and Soil Leachate

The assessment levels for aqueous samples (**P-W* in μg/L** for groundwater or leachate obtained from soil or other solid materials) were derived according to the principles underlying the German drinking water directive (AURAND et al., 1991). These comprise both the exclusion of health effects according to toxicological criteria and the maintaining of the water quality by minimizing all unfavorable components.

Soil

Assessment levels for soil (**P-M*in mg/kg**) were toxicologically derived from tolerable daily intake (TDI*)- or equivalent values to exclude any risk to human health by contact with contaminated soil (the TDI* is used in this context as defined in WHO, 1993). **P-M1* values** are based on the playground scenario, – the most sensitive case, – with children of 15 kg body weight and 0.5 g soil ingestion per day as an exposure standard (SM BW, 1992; UM & SM B-W, 1993). For accumulating contaminants only 10 % of the TDI was attributed to this pathway, since for these substances the major portion of the body burden is to be expected via food intake. With arsenic and the metals nickel and thallium, the resulting value fell in the background range. For these contaminants, the upper limit of the background level was rounded off and used as P-M1-value instead.

Residential and industrial areas are other standard scenarios on which assessment levels were based. Since residential areas are partially covered or overgrown, a five-fold lower soil ingestion rate of 0.1 g/day was assumed. This assumption yielded tolerable levels in residential soil (**PM2***; UM & SM B-W, 1993) that are generally five-fold higher than in the playground scenario (P-M1).

The frequent access of children to industrial areas can be excluded. Therefore, a four-fold higher body weight of 60 kg and an overall intake rate of 0.1 g soil and dust per day for the oral, dermal and inhalative routes combined were assumed for the industrial scenario (**PM3***; UM & SM B-W, 1993) with soil levels four-fold above P-M2 as a general rule.

For volatile organic compounds, the inhalative route is more significant than soil ingestion. Here the worst case is defined as a situation with little air exchange and unhindered access to the contaminated soil (e.g. indoors with leaky walls through faulty pipe connections). In such a scenario, the vapor concentration of a volatile contaminant can reach equilibrium. For this scenario, SELENKA (1990) derived a transfer coefficient of 1 mg/m^3 in the air per 10 mg/kg soil from measurements with benzene at a particular site in a finely porous non-compacted marly soil. This relationship can be expected to hold true for other sites under similar conditions such as pore volume, moisture content, temperature, etc. The only relevant physico-chemical property which was not considered here is water solubility. Therefore, the P-M-values derived are safe for dry soil and overly conservative for moist soil. Moisture content may vastly change with weather, and it is sufficient for the purpose of the P-values to take the worst case into account. The most relevant soil parameter is its porosity. But even extreme variations in soil porosity will not change the volatilization of benzene by more than a factor of 2 as was shown by detailed environmental modelling (BERENDT & BRÜGGEMANN, 1994). Therefore, SELENKA's transfer coefficient was used as a first approximation to derive assessment levels (P-M) for soil concentrations of volatile compounds making adjustments solely for substantial differences in vapor pressure.

The lower the equilibrium air concentration, the higher is the permissible soil concentration. Thus, based on their equilibrium air concentration at 20 °C, some organic solvents that are typically found as soil contaminants were classified in three groups:

- **Group 1** from 10 to 90 mg/L with ethylbenzene and xylene as examples

- **Group 2** from 91 to 900 mg/L with toluene, benzene, perchloroethylene, 1,2-dichloroethane, trichloroethylene, carbon tetrachloride and 1,1,1-trichloroethane
- **Group 3** above 900 mg/L with cis- and trans-1,2-dichloroethane, chloroform, vinyl chloride and 1,1-dichloroethylene

The P-M-values for volatile soil contaminants were calculated by combining a 24-hour inhalation exposure with either the TDI or, in the case of carcinogens, the virtually safe dose (VSD*, KLAASSEN, 1986). There is no difference between P-M1-, P-M2- and P-M3-values for volatiles since the increased uptake by adults with a respiratory volume of 20 L/d (as opposed to children with 5 L/d) is counterbalanced by a fourfold body weight (60 kg versus 15 kg). For group 2 with an equilibrium air concentration similar to benzene, the resulting soil concentration according to SELENKA (1990) was adopted as P-M-value for the three standard scenarios (transfer coefficient: 10 mg/kg soil/1 mg/m^3 air). For the less volatile group-1-compounds, a 10-fold higher soil concentration was permitted as P-M-value (transfer coefficient: 100 mg/kg soil/1 mg/m^3 air). For the more volatile group-3-compounds, the P-M-value was lowered by a factor of 10 to account for the higher exposure rate (transfer coefficient: 1 mg/kg soil/1 mg/m^3 air).

The calculation of the tolerable soil concentration (TSC) for benzene is given as an example:

$$TSC = VSD \times bw \times tc/di = 0.000\,0625 \times 60 \times 10/20 = 0.0019 \text{ mg/kg.}$$

bw = body weight (60 kg)
di = daily intake of the contaminated medium (20 m^3 air/d)
tc = transfer coefficient (for benzene: 10 mg/kg soil/1 mg/m^3 air)
VSD = virtually safe dose (for benzene: 0.0625 μg/kg $\times$ d at a risk of 10^{-6}; SELENKA, 1990)

Since a soil concentration of 0.002 mg/kg is not measurable by routine analytical methods, the practical quantitation level of 0.01 mg/kg is used as P-M-value instead. It is associated with a 5.3×10^{-6} lifetime risk under the conditions of the standard scenario.

Another set of screening values was designed to protect the growth and quality of plants (**P-P* in mg/kg**). These values take into account the phytotoxicity of soil contaminants and their transfer into the human food chain via plant products. For inorganic substances, they were taken from the 3rd directive (UM B-W, 1993) pertaining to the state soil protection law (BodSchG, 1991), and for organic substances they were derived in a similar way.

Resulting action: A remedial investigation including the setting up of the appropriate remediation objectives is to be initiated if representative concentrations of contaminants exceed the assessment levels (P*-values). The remedial investigation is conducted with the aim of yielding all data needed to make the decision whether or not a specific site should be remediated and to what extent.

If the representative contaminant concentrations fall below the assessment levels, no remediation is necessary.

The decisions concerning the necessity of further investigation or remediation of a particular publicly owned contaminated site is made by the assessment committee of the respective state (→ *section 4* "Necessity of Remediation").

3 Remediation Objectives

The remediation objectives are ordered in a hierarchy of three levels:

- Level-1 objectives (background- or H-values)
- Level-2 objectives (generic requirements = P-values)
- Level-3 objectives (site-specific requirements and rules to derive maximal tolerable fluxes of contaminants into the groundwater)

Comprehensive Protection

Level-1 criteria describe the natural composition of the uncontaminated environmental media soil and groundwater. Use is not considered at this background level, and therefore no health effects have to be taken into account. It turns out that the corresponding contaminant concentrations are generally very low and permit all uses. Thus, level-1 criteria are the most protective of the resources soil and water. (This level is described in more detail in sections 2.1 and 3.1).

Protection of the Most Sensitive Human Use

Level two introduces toxicological effect data combined with conservative exposure assumptions. It was designed to protect the most sensitive but still plausible human uses of a site. The corresponding set of numerical criteria constitutes general requirements, which are use-specific but not site-specific. (This level is described in more detail in sections 2.2 and 3.2).

Protection of Site-Specific Modes of Use

Level three objectives protect a specified use of soil or water at a particular site by taking into account all site-specific conditions. These objectives cannot be prefabricated numbers from a list. The guideline, rather, gives rules indicating how to derive these values. (This level is described in sections 3.3 and 3.4).

Choice of Cleanup Level

The level of protection applicable at each particular site is the result of a **process of balancing** the economical and technical feasibility with the degree of environmental quality on one hand, and on the other hand weighing the gains at the site under consideration against the losses elsewhere, e.g. through energy consumption and CO_2 emission, through toxic residues emitted by the incineration of excavated waste, or through space used up in landfills, etc. As a result, only level-3 objectives will be appropriate in most cases. But level-3 objectives cannot be adopted without demonstrating the lack of feasibility and/or an unfavorable environmental balance for the more demanding levels 1 and 2. Actual examples show that level-2 and even level-1 remediations have been viable alternatives.

3.1 Level-1 Objectives (H-Values)

On principle, all remediative actions have to first aim for background levels. In case of a lack of feasibility or a negative environmental balance for level-1 objectives, use-specific requirements are considered next.

3.2 Level-2 Objectives (P-Values)

The generic requirements underlying level 2 afford appropriate protection for humans regarding the most important and most sensitive, but still plausible uses of the environment. At least the following resources have to be considered on this level:

(1) Groundwater as a resource
(2) The use of groundwater
(3) The health of humans on contaminated sites
(4) Soil with respect to the growth and quality of plants.

The P-values have two different meanings [(1) "protection" and (2) "repair"] with respect to groundwater:

(1) For the **protection** of groundwater against further contamination by substances eluted from the contaminated zone, the **P-W** values serve to limit the **effluent concentration**. The term effluent refers to all water after its passage – either horizontally or by vertical seepage – through the contaminated zone without any dilution. On level 2, protection of groundwater as a resource does not permit making use of the aquifer's capacity to dilute the effluent concentration in order to prevent the groundwater from gradually reaching the P-level ceiling, as there may be several contaminated sites discharging into the same aquifer.

(2) For remediation in the sense of **repair** of **groundwater** which has **already** been **contaminated**, the **P-W** values serve as clean-up goals. Thus, the safe use of this water for human consumption is guaranteed.

(3), (4) All activities of humans on contaminated land are protected by the **P-M1** values, and the plants by the **P-P** values for the soil. Therefore, these values serve as level-2 clean-up goals if unrestricted use is in concordance with feasibility and environmental balance considerations.

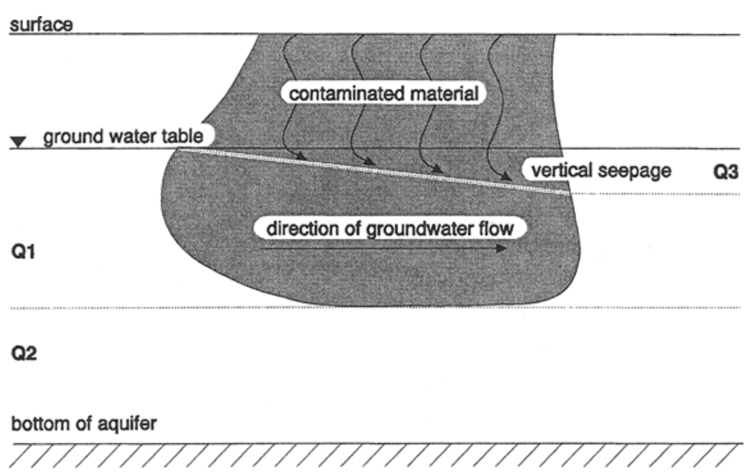
The complete coverage of these resources, (1) – (4) on level 2, also generally prevents severe damage to the ecosystem.

3.3 Level-3 Objectives (Site-Specific Requirements)

Lack of feasibility or a negative environmental balance for level-2 objectives lead to consideration of site-specific circumstances which may alleviate the requirements. With respect to groundwater, the above distinction is again necessary on level 3 between groundwater as a resource (1) and the use of groundwater (2).

(1) Groundwater as a Resource

Both of the following requirements are to be met (1.1) and (1.2); → *Fig. 1):*



Q1 = flux of contaminated groundwater [L/sec]
Q2 = flux of uncontaminated groundwater [L/sec]
Q3 = vertical flux of contaminated seepage [L/sec]
C_0 = contaminant concentration upstream [μg/L]
P – W = level-2 objective to protect groundwater [μg/L], *(→ Appendix)*
E_{max} = effluent flux limit [g/d], *(→ Appendix)*
C_{eM} = tolerable concentration limit on level 3

(1.1) Effluent Flux Limit:

$C_{eM} \times (Q1 + Q3) \leq Emax\ (= P-W \times 25\ L/sec)$

(1.2) Concentration Limit for Groundwater Affected by the Site:

$C_{eM} \times (Q1 + Q3) + C_0 \times Q2 \leq P-W \times (Q1 + Q2 + Q3)$

Fig. 1: Calculation of tolerable concentration limits (CeM) to protect groundwater on level 3

(1.1) **Limit of Effluent Discharged from the Site (E_{max})**

The daily **effluent** (E^*) of contaminants emitted by the contaminated zone into the groundwater must not exceed the E^*_{max} values [g/d] tabulated in the appendix. This requirement is site-specific since the flux of contaminants depends on the fluxes of water through the site, on the mobility of the contaminants and their accessibility to the water as well as on the adsorptive capability of the underground. The E_{max} values were designed as amounts of substance sufficient to contaminate 25 L of clean water per second ($= 2.16 \times 10^6$ L/d) up to the P-value concentration. They limit the extent to which the diluting capacity of the groundwater present at the site may be used.

(1.2) **Limit Concentration of Groundwater Affected by the Site**

In usable groundwater, no contamination (averaged over the depth of the directly involved aquifer) is admitted above the **P-W** values. Thus on level 3 the P-values limit the **final groundwater concentration** instead of the effluent concentration which is regulated by the P-values on level 2.

This latter requirement (1.2) protects all usable groundwater against manmade loading with contaminants above a level that is safe for human consumption. Whether groundwater is usable depends on its quantity and its geogenic quality. The former requirement (1.1) prevents the exhaustion of the diluting capacity of large aquifers by polluted effluents in an unacceptable manner.

(2) **The Use of Groundwater**

The use of groundwater may be abandoned on level 3, or the water may be decontaminated before its distribution as drinking water to the consumers.

(3), (4) **Human Health & Growth and Quality of Plants**

The guideline provides residential (**P-M2**) and industrial (**P-M3**) assessment levels, based on two standard scenarios, to protect human activities on contaminated sites. These levels serve as benchmarks enabling the State Health Administration to define site-specific remediation objectives. In cases where the situation is the same as the standard scenario of this guideline, these values can be used directly as remediation objectives. Otherwise, further investigations are necessary to explore the site-specific scenario and/or specifically restrict the use of the site.

The same applies to soil with respect to plant production: If the P-P values cannot be adopted as goals, further studies and/or exclusion of certain crops are necessary.

3.4 Restriction of Uses

P-values are only binding as remediation objectives, if the respective uses are desired in future. On level 3, the use of already contaminated groundwater (2) may be abandoned, the access of humans to a site (3) may be blocked, or the consumption of plants (4) from a contaminated site may be restricted. In these cases, the respective P-values can be disregarded.

However, the pertinent law (§ 25 LAbfG, 1990) requires that usable groundwater be protected against polluting effluents without exception. The maximal alleviation possible concerning groundwater as a resource (1) has been formulated above (→ *section 3.3 (1.), (2.)*) as a combination of the effluent limit (E_{max}) and the limit concentration (P-W).

Partial restriction of the other uses (2), (3), (4) requires the administration to issue site-specific remediation objectives. In all cases with use restrictions, the uses possible in the future are to be legally defined and recorded.

4 Necessity of Remediation

The decision concerning the remediation objectives is made by the assessment committee of each state (KommissionsVO, 1990). The committee consists of specialists of the relevant branches of the public administration including one representative of the state environmental protection agency. It is headed by an officer of the state magistrate.

Remediation of a contaminated site is necessary, if the concentration of at least one contaminant surpasses the remediation objective set by the committee. Therefore, the remediation objectives have to be set first and compared with the actual state of the site.

5 Miscellaneous Regulations

5.1 Site Demarcation

In the case of level-2 remediations (P-W values as objectives), a contour line of a slightly higher concentration can function as the "practical" boundary of the area that is to be remedied. This possibility exists for the resource groundwater (case 3.2. (1)) only, and the demarcation of the zone to be remedied can be done with the aid of the $P_{max}W$ values. The $P_{max}W$ values are based on the same scenario as the P-W values, but pose a slightly increased toxicological risk.

The $P_{max}W$ values were derived by combining toxicological criteria (such as acute toxicity without a safety factor and the tolerable daily intake [TDI] which does contain a margin of safety large enough to allow lifetime exposure under worst case conditions) with the risk index system that is used for ranking sites and for deriving the resulting need of action (Hillmert, 1990; UM B-W, 1988). The procedure is explained in detail in a previous publication (v.d. Trenck et al., 1993). The decision about the extent of the use of the P_{max}margin is based on a qualitative appreciation of the relevant case-specific details.

For instance, in case of a sharply confined contamination, nothing is gained by making use of the P_{max}margin. In such a case, the amount of material that has to be treated will not decrease significantly by using $P_{max}W$ instead of P-W as the boundary of the area that is to be remedied. However, with a more diffuse contamination that is slowly tapering off into the surrounding area, it may make a great difference in cost to tolerate a ring of slightly contaminated material around the center that is to be cleaned up.

5.2 Redeposition of Material Treated ex-situ

No material from contaminated sites may be redeposited within the inner zone of water protection areas. If the site that receives treated material is situated within the wider zone of a water protection area, the P-values have to be halved or the H-values observed. Outside water protection areas, redepositing of treated material is admitted if the material emits no contaminants in excess of the P-values.

5.3 Discharge of Treated Groundwater

Recirculation of groundwater treated from a contaminated site should be attempted. Alternatively, discharge into sewers or a body of surface water has to be provided.

The following requirements apply for discharge into surface water:

- The quality of groundwater discharged must not be inferior to the surface water.
- The contaminant concentrations in the groundwater discharged must not be higher than twice the P-W values, in the case of zinc not higher than 500 μg/L.

If the discharge into a sewer or a body of surface water is impossible or not desirable, discharge into the groundwater close to the site of drawing can be permitted under the following conditions:

- The procedure must improve the protection of groundwater.
- Outside water protection areas, the contaminant concentrations in the groundwater discharged must not be higher than the P-values.
- Inside the wider zone of water protection areas, the contaminant concentrations in the groundwater discharged must not be higher than half the P-W values or the H-values.

Discharge of treated water into groundwater is neither allowed in the direct proximity of a well nor within the inner zone of a water conservation area.

6 Concluding Remarks

Due to the high cost-intensiveness of remedial actions involving groundwater, a major portion of the costs for contaminated sites will have to be spent on groundwater remediation and protection. With regard to this resource, the guideline presented here (UM & SM B-W, 1993) is the only directive of its kind that regulates not only concentrations of contaminants, but fluxes as well.

It was issued at a time when increasing numbers of contaminated sites had been sufficiently investigated, and clean-up objectives needed to be established for these sites. From July 1992 through December 1993 a total of 1554 contaminated sites were assessed by the 44 assessment committees in the state of Baden-Württemberg; some of them more than once, so that 1793 site assessments are recorded overall during this period. In 103 of these cases, the investigation has proceeded to a level of evidence that allowed the definition of remediation objectives and remedial actions are under way at 19 sites. From these 18 months of experience with a statewide application of the directive, we can say that it has withstood its first test.

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7 List of Abbreviations

E	= effluent flux
E_{max}	= effluent flux limit
H-B	(Hintergrundwert für Boden) = background level in soil
H-W	(Hintergrundwert für Grundwasser und Bodeneluate) = background level in groundwater or leachate
P	(Prüfwert) = assessment value
P-M	(Prüfwert für den Aufenthalt von Menschen auf kontaminierten Flächen) = soil assessment level for humans
P-M1	(Prüfwert für Kinderspielplätze) = soil assessment level based on the playground scenario
P-M2	(Prüfwert für Wohngebiete) = soil assessment level based on the residential area scenario
P-M3	(Prüfwert für Industrie- und Gewerbeflächen) = soil assessment level based on the industrial area scenario
P-P	(Bodenprüfwert im Hinblick auf Wachstum und Qualität von Pflanzen) = soil assessment level for plants
P-W	(Prüfwert für Grundwasser und Bodeneluate) = assessment level for groundwater and leachate
$P_{max}W$	(Toleranzgrenze des P-W-Wertes für die Abgenzung des zu sanierenden Bereiches auf Stufe 2) = maximal leachate concentration for site demarcation on level 2
TDI	= tolerable daily intake as defined by WHO (1993)
VSD	= virtually safe dose of initiating carcinogens (Klaassen, 1986)

8 Literature

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Addendum: Concentration-Based Ranking of Sites

The guide values H (negligible risk) and P (tolerable risk) are markers of environmental hygiene that characterize any given substance. Combined with a third marker for extreme risk, the concentration that would exert a lethal effect in the worst scenario (LC), they form a characteristic triple that may serve to rank sites on the basis of representative contaminant concentrations.

The three markers H, P, and LC can be regarded as equivalent over the whole spectrum of contaminants (v.d. TRENCK et al., 1993; v.d. TRENCK & RUF, 1994). For the purpose of ranking, the marker concentrations were assigned to the risk indices $r'_c = 0$, $r'_c = 4$, and $r'_c = 16$, and thus span a characteristic curve: the evaluative function $[r'_c = f(c)]$. This function integrates the criteria for the necessity and the objective of a remediation into the ranking system which determines the priority and the need of action (UM B-W, 1988, HILLMERT, 1990).

The effect-related markers (P and LC) are based on the worst-case scenario without consideration of possible site-specific alleviations. Often the actual risk is lower because of restricted site use and limited spreading of the contaminants. On level 3 the actual conditions determine the remediation goal. Therefore, the residual contamination (c_{eM}) will be higher than the P-values in most cases.

The restricted use and reduced exposure of the actual case are expressed by the ratio of the site-specific clean-up goal and the assessment value (c_{eM}/P). The measured concentration (c) is, therefore, divided by this ratio resulting in a reduced concentration ($C = c \cdot P/c_{eM}$) for the purpose of ranking. Entered into the evaluative function, the reduced concentration yields the relevant concentration-based risk index R_C [$R_C = f(C)$].

This procedure allows a realistic incorporation in the relevant risk index of all results of the site investigation and of all decisions of the assessment committee.

Literature

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Appendix 1

Substance		Guide Values (UM & SM B-W, 1993)							
		Leachate/Groundwater			Soil				Maximal Flux of Effluents
		H-W µg/l	P-W µg/l	P_{max}-W µg/l	H-B mg/kg	P-P mg/kg	P-M mg/kg		E_{max}-W g/d
Al	aluminum	100	150	750	- [6]	- [6]	P-M1	- [6, 10]	320
							P-M2	- [6, 10]	
							P-M3	- [6, 10]	
As	arsenic	3	10	25	6 - 17 [1]	20 (pH≥5, T1 [1])	P-M1	20 [11]	22
						40 (pH≥5, T2-T6[1])	P-M2	30	
							P-M3	130	
Cd	cadmium	1	3	8	0.2-1.0 [1]	1 (T1 [1])	P-M1	3	6.5
						1 (5≤pH≤6)	P-M2	15	
						1.5 (pH≥6, T2-T6[1])	P-M3	60	
Cr	chromium (total)	2	40	200	20 - 90 [1]	100 (pH≥5)	P-M1	100	90
							P-M2	500	
							P-M3	- [4]	
Cr(VI)	chromium (hexavalent)	0.4	8	30	1	- [7]	P-M1	- [4]	18
							P-M2	- [4]	
							P-M3	- [4]	
Cu	copper	5	100	250	10 - 60 [1]	60 (pH≥5)	P-M1	- [3, 10]	220
							P-M2	- [3, 10]	
							P-M3	- [3, 10]	
Hg	mercury	0.05	0.7	2	0.05 - 0.2 [1]	1 (pH≥5)	P-M1	2	1.5
							P-M2	10	
							P-M3	40	
Ni	nickel	3	20	75	15 - 100 [1]	50 (pH≥5)	P-M1	100 [11]	45
							P-M2	100 [11]	
							P-M3	300	
Pb	lead	4	10	40	25 - 55 [1]	100 (pH≥5)	P-M1	100	20
							P-M2	500	
							P-M3	4000	
Se	selenium	4	8	25	1	- [7]	P-M1	- [7]	17.5
							P-M2	- [7]	
							P-M3	- [7]	
Sn	tin	2	10	50	4 - 20 [1]	50	P-M1	- [3, 10]	20
							P-M2	- [3, 10]	
							P-M3	- [3, 10]	
Tl	thallium	3	8	25	0.2 - 0.7 [1]	0.5 (pH≥5; T1 [1])	P-M1	1 [11]	17.5
						1.0 (pH≥5; T2-T6[1])	P-M2	4	
							P-M3	15	
Zn	zinc	150	1500	3400	35 - 150 [1]	150 (T1 [1])	P-M1	- [3, 10]	3200
						150 (5≤pH<6;T1-T6[1])	P-M2	- [3, 10]	
						200 (pH≥6;T2-T6[1])	P-M3	- [3, 10]	
CN^-	cyanide (total)	0.2 or n.d.	40	80	n.d.	- [7]	P-M1	50 [16]	85
							P-M2	150 [16]	
							P-M3	150 [16]	
F^-	fluoride	250	750	1750	150	250	P-M1	750	1600
							P-M2	3750	
							P-M3	15000	
NH_4^+	ammonium	100	500	1600	- [6]	- [6]	P-M1	- [6]	1100
							P-M2		
							P-M3		
Total AH [9]	usually benzene, toluene, xylene, ethylbenzene	n.d.	10	50	0.01	- [7]	P-M1	60 [15]	20
							P-M2	60 [15]	
							P-M3	60 [15]	
Benzene [9]		n.d.	1	5	0.01		P-M1	0.01 [13]	2
							P-M2	0.01 [13]	
							P-M3	0.01 [13]	

Appendix 2

Substance		Guide Values (UM & SM B-W, 1993)						
		Leachate/Groundwater			Soil			Maximal Flux of Effluents
		H-W µg/l	P-W µg/l	P_{max}-W µg/l	H-B mg/kg	P-P mg/kg	P-M mg/kg	E_{max}-W g/d
toluene[9]					0.01	-[7]	P-M1 9 P-M2 9 P-M3 9	
VCH [9]	volatile chlorinated hydrocarbons	0.1 or n.d.	10	50	0.001	-[7]	P-M1 0.2 P-M2 0.2 P-M3 0.2	20
VCH (carc.) [9]	CCl_4; 1,2-dichloro-ethane, vinyl chloride (sum)	0.1 or n.d.	3	10	0.001 or n.d.	-[7]	P-M1 0.001 [14] P-M2 0.001 [14] P-M3 0.001 [14]	6.5
CHCl etc. [A1) 5) 9)]	chloroform etc., boiling below 65°C	0.1 or n.d.	10	40	0.005 or n.d.	-[7]	P-M1 0.02 [17] P-M2 0.02 [17] P-M3 0.02 [17]	
HCH (total)	hexachlorocyclohexane	n.d.	0.1	1	0.004	0.1	1 15 (betaHCH: 2) 2 -[3] 3 -[3]	0.2
HC (IR)	hydrocarbons, mineral oil	10 [A2]	50 [A2]	300	50/100 [12]	400	P-M1 - P-M2 - P-M3 -	100
Naph.	naphthalene	0.05	2 [A2]	10	0.05	-[7]	P-M1 -[7] P-M2 -[7] P-M3 -[7]	4.5
PAH	EPA-PAH without naphthalene [A3]	0.05	0.15	0.8	1.0	10	P-M1 5 (BaP: 0.5) P-M2 25 (BaP: 2.5) P-M3 100 (BaP: 10)	0.32
PCB (LAGA)	polychlor.biphenyls (sum or LAGA = DIN x 5)	n.d.	0.05	0.5	0.05	1.5	P-M1 3 P-M2 -[3] P-M3 -[3]	0.1
PCDD/F	dioxins and furans as 10^{-6} ITE	n.d.	5	15	2	5	P-M1 cf. P-M2 dioxine P-M3 directive	10
PCP	pentachlorophenol	n.d	0.1	0.5	0.004	0.2	P-M1 9 P-M2 -[3] P-M3 -[3]	0.2
Pesticides	without PCP and HCH	n.d.	0.1	1	0.03	0.2	P-M1 -[7] P-M2 -[7] P-M3 -[7]	0.2
Phenols (volatile with water vapor)		10	30 [A2]	100	0.02	-[7]	P-M1 -[7] P-M2 -[7] P-M3 -[7]	65

A1) Abbreviation designates chloroform, dichloromethane, 1,1-dichloroethene as well as cis- and trans-dichloroethene.

A2) The assessment level is considered to be exceeded as soon as the substance is sensually perceptible.

A3) In leachates obtained in vitro from soil or other material contaminated with PAH, part of the contamination may absorb onto lab ware and escape the determination. Therefore, such results should be confirmed by backcalculating groundwater samples or by comparison with leachates formed in situ.

1) According to the clay content (T1-T6) or the indigenous mineral (cf. directive referring to § 19 chpt. 3 BodSchG, 1991).

2) pH: pH-value according to DIN 19684, Part 1.

3) Case by case decision; in spite of the low toxic potential for humans, higher levels cannot generally be tolerated because of ecotoxicological relevance.

4) Case by case decision; consider possible exposure to dust containing carcinogenic Cr(VI)!

5) This parameter comprises chloroform, dichloromethane, 1,1-dichloroethene as well as cis- and trans-1,2-dichloroethene.

6) The total soil concentration is not relevant in contaminated sites; the H-W- and P-W-values have to be observed.

7) Case by case decision.

8) For anthropogenic substances, the practical quantitation level is given as H-B-value.

9) For volatile contaminants (e.g. aromatic or chlorinated hydrocarbons), the guide values are valid for the total depth of the contamination. Mixing of material for combined analysis is allowable only within maximal steps of one meter of the depth profile (UM & SM B-W, 1993, Appendix 3.3).

10) Toxic for humans only in concentrations of g/kg.

11) The theoretical value [mg/kg] for As = 6.4, Ni = 15 or 75, respectively, Tl = 0.75 is within the geogenic background of soils in Baden-Württemberg. The table contains the upper rounded background concentration as P-value. According to current knowledge, these soil concentrations have not led to elevated burdens in humans.

12) In upper soil layers with > 1% organic carbon content.

13) The practical quantitation level is given as P-value.

14) The value corresponds to the practical quantitation level for CCl_4. It is not attainable for the other substances. In case of suspected soil contaminations with these substances a special investigation (e.g. soil air content) is advisable.

15) All the guide values for benzene and toluene and the total AH-value have to be observed.

16) The acute toxicity dominates the assessment level for cyanide; pica behavior with 10 g single soil ingestion is considered. The P-M1 value is based on 10% of the LOEL of 0.5 mg/kg and 10 kg body weight. The P-M2 and P-M3 values are based on 10% of the LD50 of 1 mg/kg and 15 kg body weight.

17) The values for the total VCH and VCH (carc.) have to be observed in addition to the tabulated value.