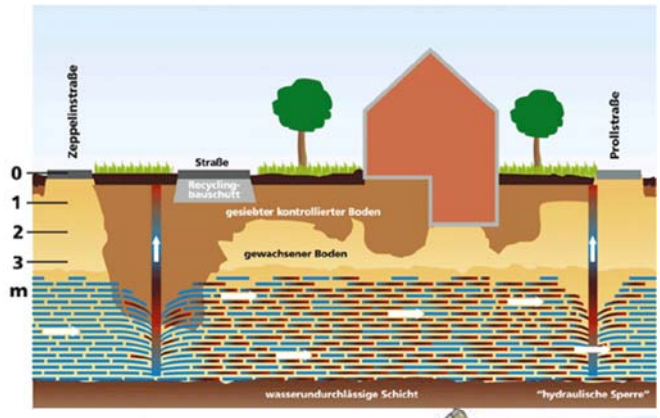
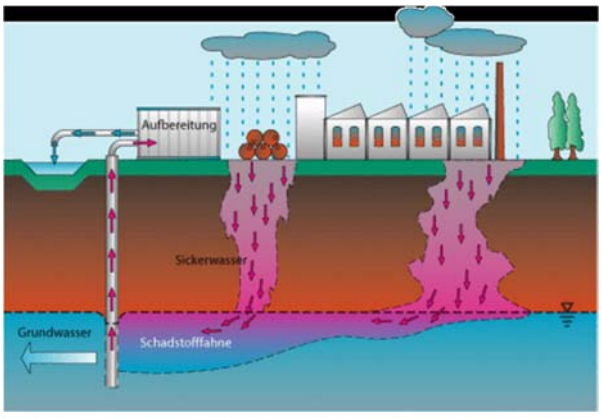
12 Contaminated sites and polluted areas





Solid Waste Management
Dr.-Ing. Dirk Weichgrebe
Leibniz Universität Hannover

Contaminated sites/ Brownfields / Polluted areas - Definitions

- **Harmful changes of the soil:**
  Impairments of the soil functions which **are capable of producing** hazards, considerable disadvantages or heavy annoyances

- **Potentially contaminated areas/abandoned polluted areas:**
  Areas where hazardous changes of the soil are **suspected**

- **Contaminated sites:**
  - Abandoned waste disposal plants and other premises where waste has been treated, stored, or deposited (= **old deposits**),
  - Premises of closed plants and other premises where environmentally-polluting substances have been handled (= **abandoned industrial sites**, such as gas works, ammunition factories, military sites, areas with high air emissions, pesticides, leakages, asbestos production),

  which may **cause** hazards for individuals or society as a whole through dangerous changes of the soil.

Register of contaminated sites in Germany 2005

Characteristic [1]	State	Site suspected to be brownfields	Old deposits (OD)	Abandoned Industrial sites (AS)	Abandoned polluted areas	Sanitation completed	Hazard Assessment completed	Abandoned polluted areas being sanitised	Monitoring
Baden-Württemberg	12/2003	10,118	2,644	7,474	758	878	6,278	562	71
Bavaria	03/2003	13,930	10,193	3,737	1,449	727	3,042	1,427	22
Berlin	02/2004	2,711	857	2,322	439	49	n.d.	69	54
Brandenburg	12/2003	20,080	6,703	13,377	959	2,24	n.d.	59	309
Bremen	06/2003	2,965	55	2,910	101	307	499	56	62
Hamburg	01/2004	2,317	420	1,933	236	347	3,070	54	34
Hesse	03/2004	666	316	350	444	228	582	659	125
Mecklenburg–West. Pom	12/2003	8,546	3,648	4,898	642	742	596	256	355
Lower Saxony	02/2004	39,876	8,976	30,900	884	582	965	222	80
North Rhine-Westphalia	12/2001	42,868	18,337	24,642	1,917	2,90	8,915	1,843	1,58
Rhineland Palatinate	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Saarland	03/2004	1,807	1,671	136	412	26	588	28	139
Saxony	04/2003	30,073	7,655	22,418	1,63	2,84	7,828	1,15	1,54
Saxony-Anhalt	11/2003	19,443	5,985	13,958	104	617	1,470	44	4
Schleswig-Holstein	12/2002	18,508	2,412	16,096	162	624	1,726	86	n.d.
Thuringia	11/2003	16,650	5,556	11,094	458	489	1,612	109	9
Germany		**230,558**	**75,428**	**156,245**	**10,60**	**13,60**	**37,171**	**6,63**	**4,38**

Register of contaminated sites in Germany 2011

Characteristic [1]	State	Site suspected to be brownfields	Old deposits (OD)	Abandoned Industrial sites (AS)	Abandoned polluted areas	Sanitation completed	Hazard Assessment completed	Abandoned polluted areas being sanitised	Monitoring
Baden-Württemberg	12/2009	14.472	1.968	12.504	2.124	2.445	14.312	635	413
Bavaria	03/2010	16.545	11.450	5.095	1.084	1.490	4.590	1.006	78
Berlin	07/2010	4.978	1.142	4.468	911	187	n.d.	68	75
Brandenburg	06/2010	19.885	7.140	12.745	1.545	3.997	4.327	124	214
Bremen	06/2010	3.560	27	3.533	432	596	898	43	170
Hamburg	07/2010	1.876	272	1.623	519	429	3.024	135	139
Hesse	07/2010	1.044	554	490	424	812	1.624	181	40
Mecklenburg–West. Pom	12/2009	5.907	26.978	3.229	1.049	1.222	284	341	429
Lower Saxony	06/2010	99.783	9.399	90.384	2.948	1.478	4.095	360	325
North Rhine-Westphalia	01/2010	75.370	30.493	44.877	n.d.	6.158	17.969	n.d.	n.d.
Rhineland Palatinate	07/2010	12.408	11.947	461	294	127	6.305	167	57
Saarland	05/2010	1.977	1.650	323	456	156	379	35	64
Saxony	04/2010	20.018	6.799	13.219	667	2.836	6.474	468	1.393
Saxony-Anhalt	05/2010	17.210	5.248	11.962	173	1.436	3.271	74	27
Schleswig-Holstein	12/2009	13.682	2.092	11.590	311	951	2.585	69	42
Thuringia	03/2010	13.583	4.072	9.511	814	739	4.241	234	70
Germany	**02/2011**	**322.298**	**121.231**	**226.014**	**13.751**	**25.059**	**74.378**	**3.940**	**3.536**

Brownfields – Legal Basis

- Federal Soil Protection Act - **BBodSchG**, 1998 and Federal Soil Protection Act - **BBodSchV** of 12.07.1999
- According to the **polluter-pays-principle**, the following parties are obliged to precaution (§7 BBodSchG), liable and cost-responsible, and obliged to sanitation
  - **first the disturber (liability for actions) being that natural or legal person which has caused the hazard**
  - then the interrupter **(liability for conditions) being the owner and proprietor of the actual command over an entity** from which a hazard originates, as well as the former owner in case of selling after 01.03.1999, if they were aware or had to be aware hazardous pollutions (§ 4 BBodSchG)
  - thus, **liability** of: former operators, (former)/current owner of the property, perhaps the waste conveyors, waste producers
- If the originator cannot be held liable (bankrupt; not existent anymore) or in case of sovereign responsibility (present permission; lacking control):
  → **Principle of common burden**
- According to § 9 BBodSchG, the responsible bodies are generally the federal Lands;
  the owners are obliged to participation and sufferance

Responsiblities for Abandoned Polluted Areas

Responsibility for brownfields

Penal Law

particularly
- § 324 a StGB (soil pollution)
- § 324 StGB (water pollution)
- § 326 StGB (environment-polluting waste disposal)

Administrative Environment Law

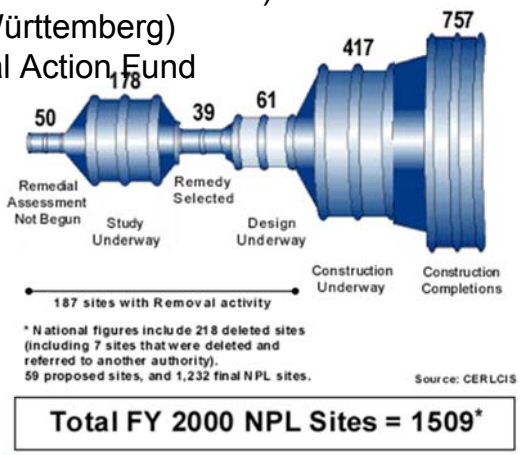
- Federal Soil Protection Act
- Federal State Law on Abandoned Polluted Areas
- General Police and Administrative Law of the Lands

Civil Environment Law

- Omission of disposal claims §§ 906, 1004 German Civil Code
- Contractual Liability § 459 ff. German Civil Code
- Environment liability
  - Liability for injustice debt § 823 German Civel Code
  - self-abandonment requirements §§ 906 II 2 German Civil Code 14 BImSchG
  - absolute liability § 22 Water Resources Act §§ 1,3 Environment Liability Act

Funding

- Polluter-pays-principle (see Legal Basis)
- Alternatively: principle of common burden or group charges (responsible branches)
- Licensing fees (NRW) or special waste fees (Lower Saxony) are unconstitutional;
- Taxes conceivable
- Cooperation models
  - Federal state and industry (Bavaria; Hesse);
  - Federal state and special waste union (Rhineland Palatinate)
  - Federal state and municipalities (Baden-Württemberg)
- USA: State Superfund* / Urban Sites Remedial Action Fund
  - Cooperation financing
  - National Priority List 2000 (1509 Sites) →
  - National Priority List 2011 (1288 Sites)



*A controlling company is under certain conditions „directly" qualified as owner of the plants of its subsidiaries. Through control over and influence on the subsidiary, the controlling company immediately fulfils the legal liability standards, even if the (tighter) preconditions of the classical *piercing the corporate veil* are not fulfilled.

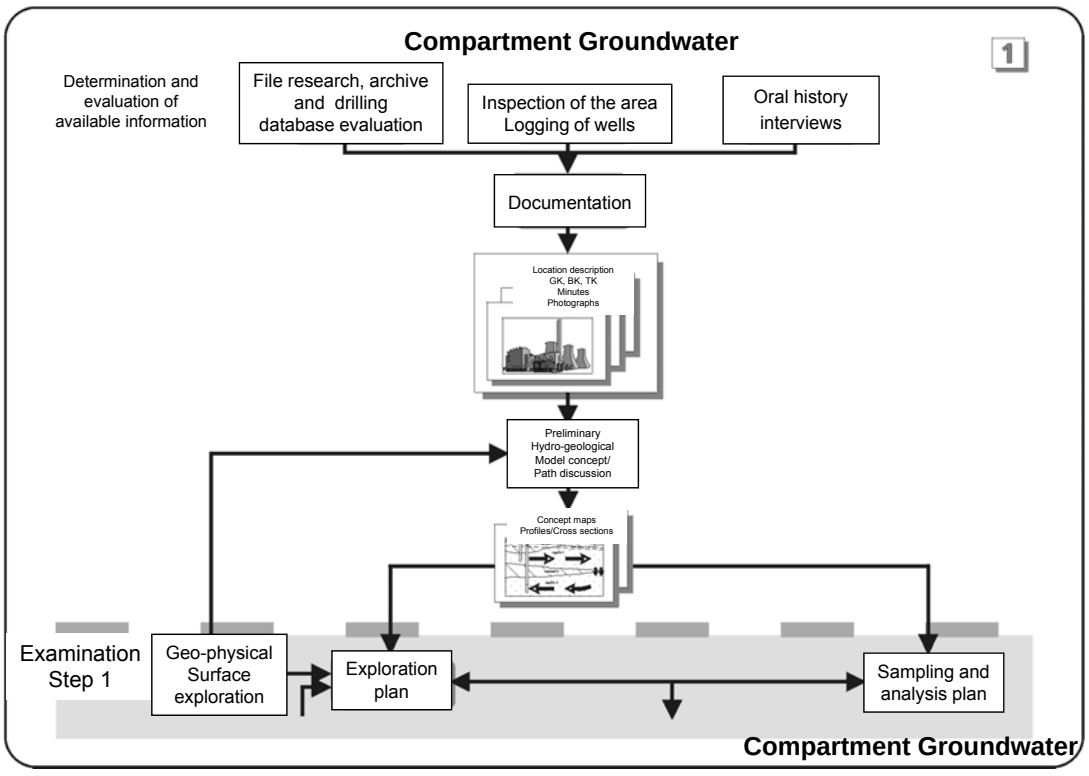
Affected compartments

- groundwater
- surface waters
- soil

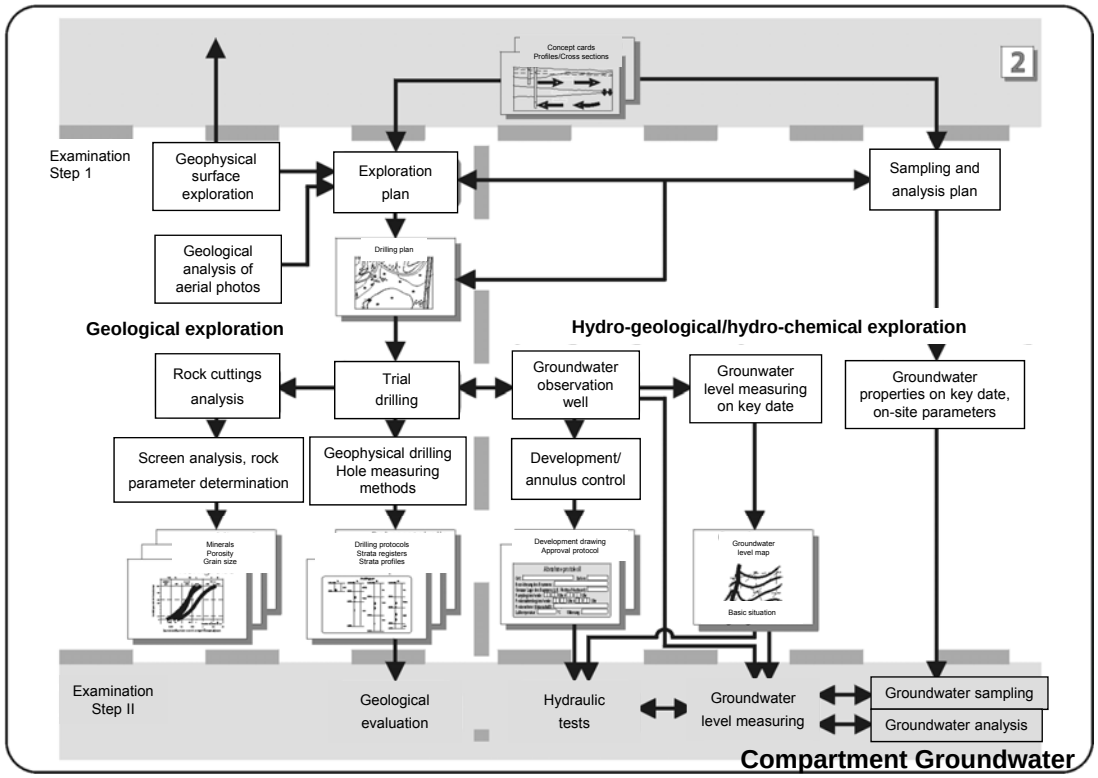
The compartment “air” is affected in only a very few cases of brownfields processing.

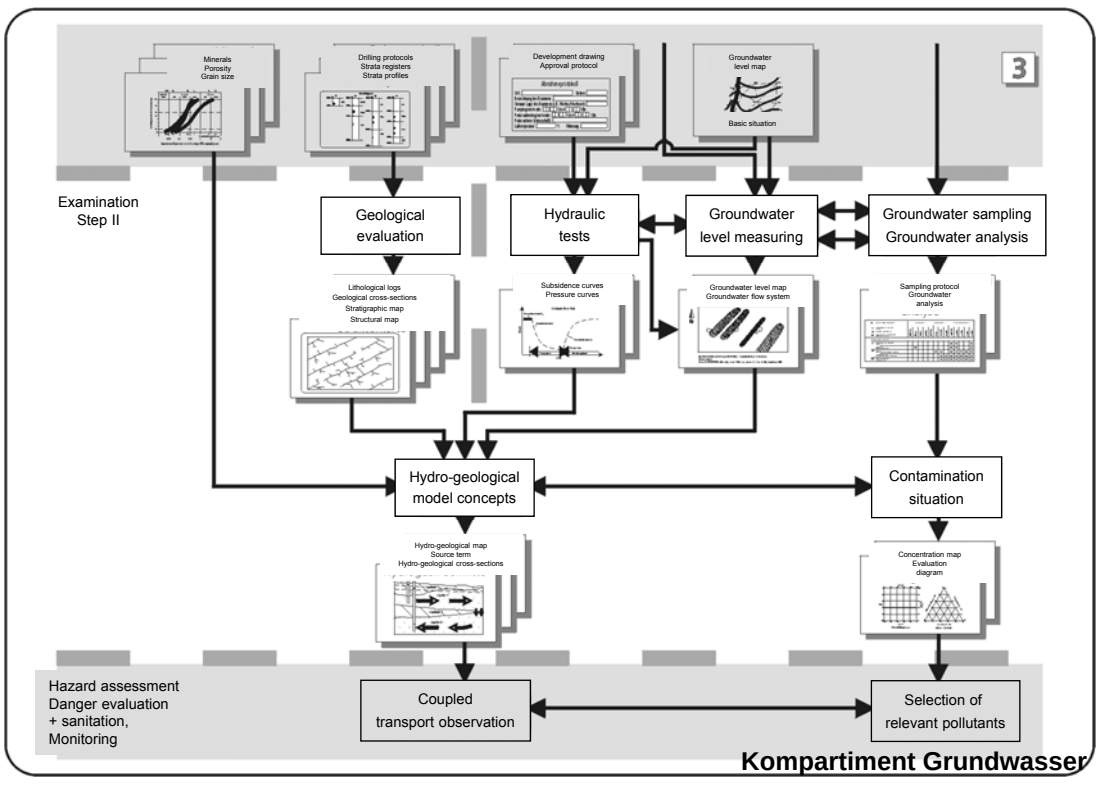
Sewage sludge ponds

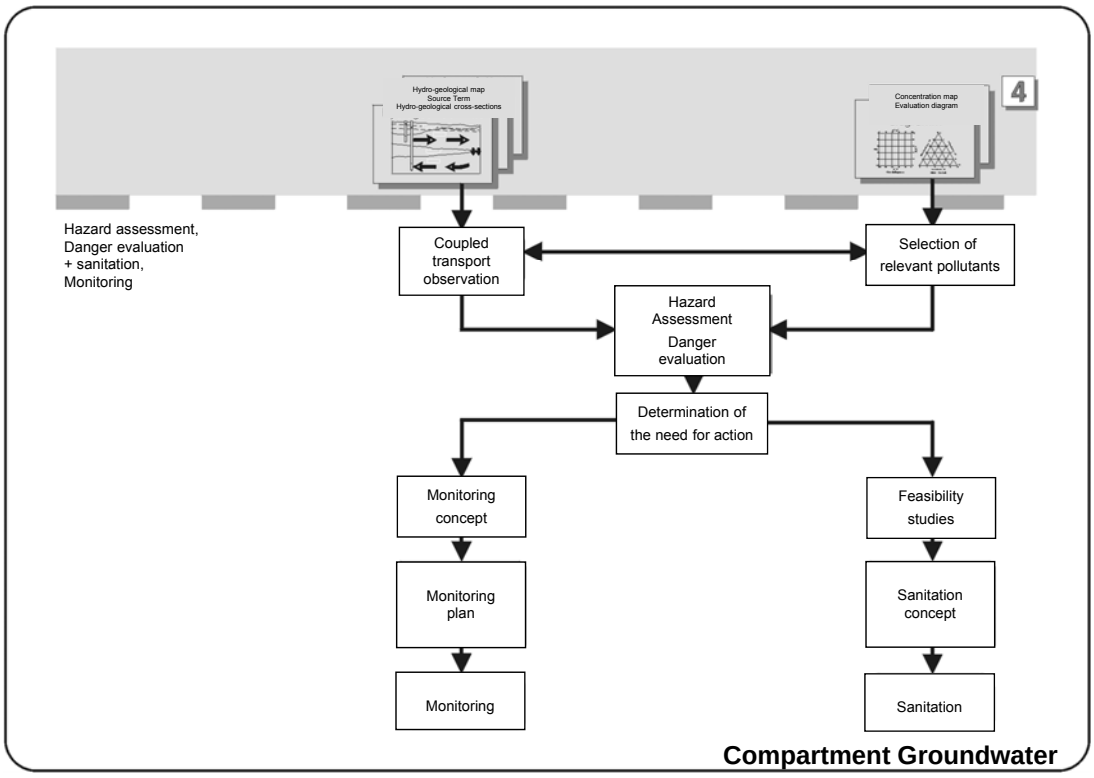
Open construction waste dump site

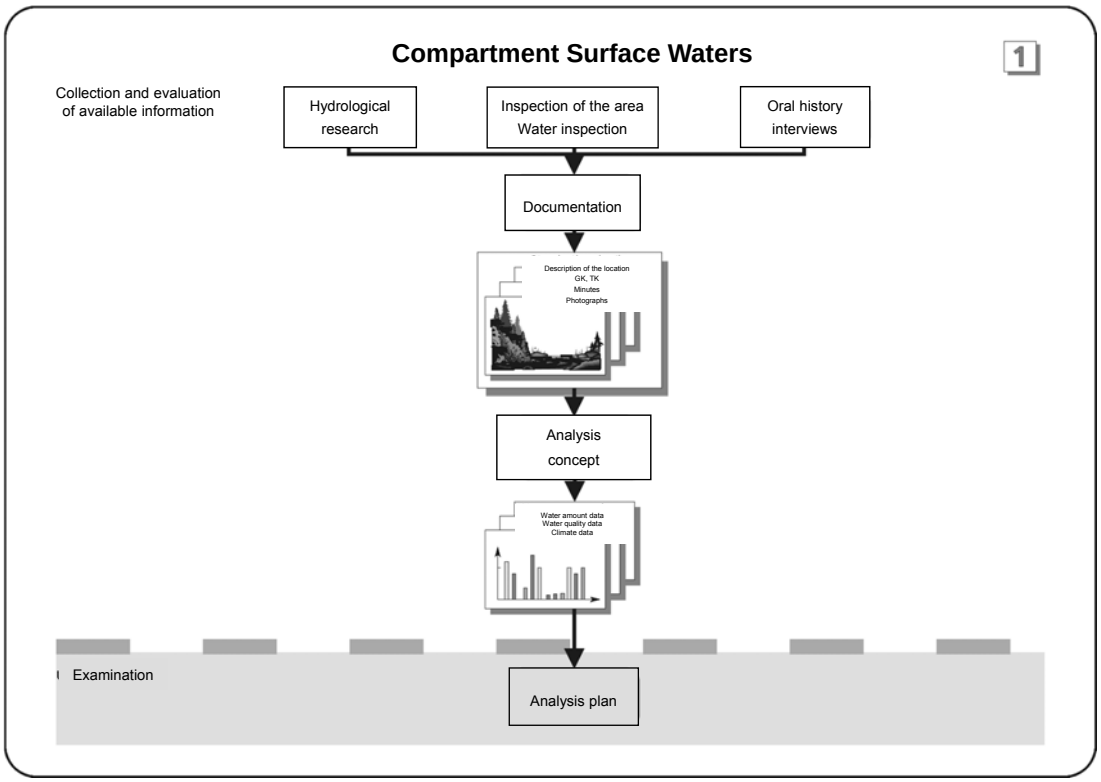


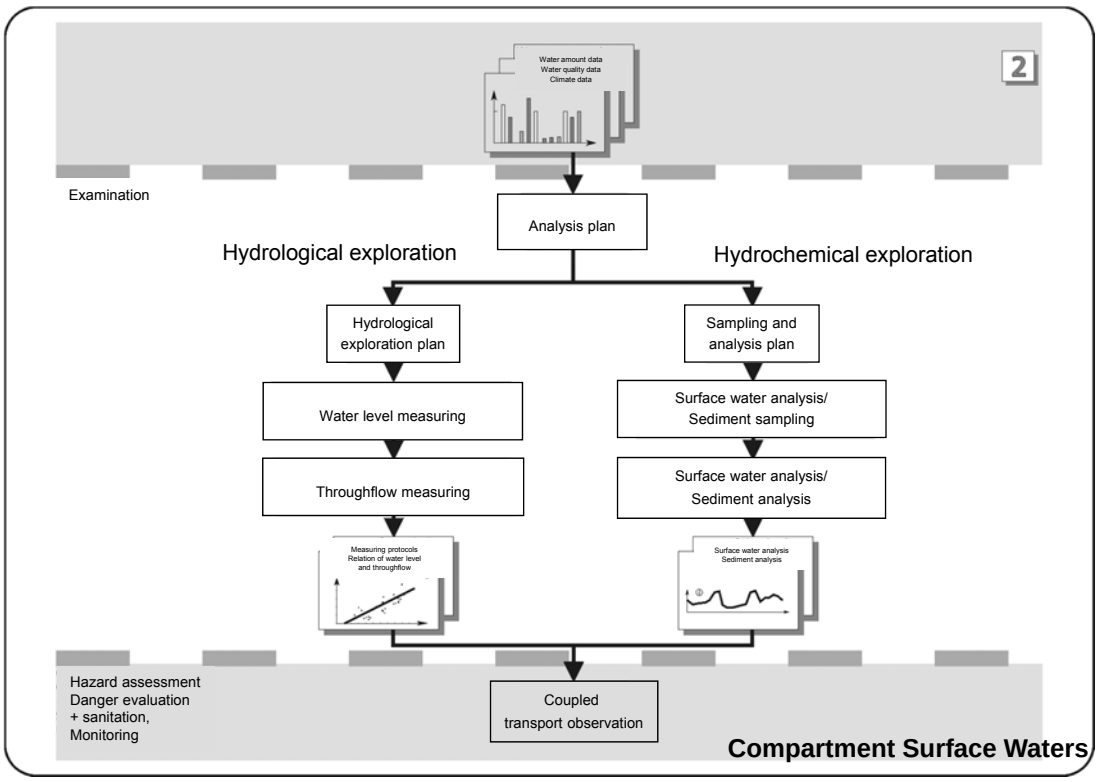
Solid Waste Management
Dr.-Ing. Dirk Weichgrebe
Leibniz Universität Hannover

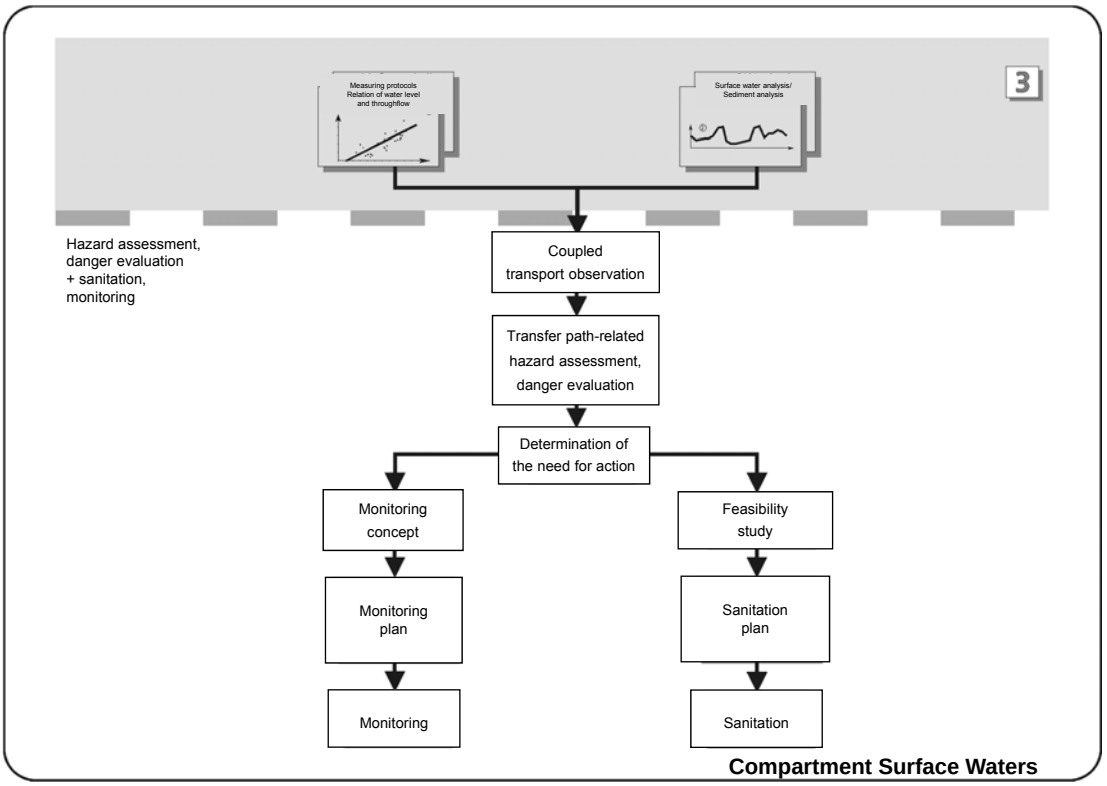

2
Examination Step 1
Geophysical surface exploration
Exploration plan
Sampling and analysis plan
Geological analysis of aerial photos
Geological exploration
Hydro-geological/hydro-chemical exploration
Rock cuttings analysis
Trial drilling
Groundwater observation well
Grounwater level measuring on key date
Groundwater properties on key date, on-site parameters
Screen analysis, rock parameter determination
Geophysical drilling Hole measuring methods
Development/ annulus control
Examination Step II
Geological evaluation
Hydraulic tests
Groundwater level measuring
Groundwater sampling
Groundwater analysis
Compartment Groundwater

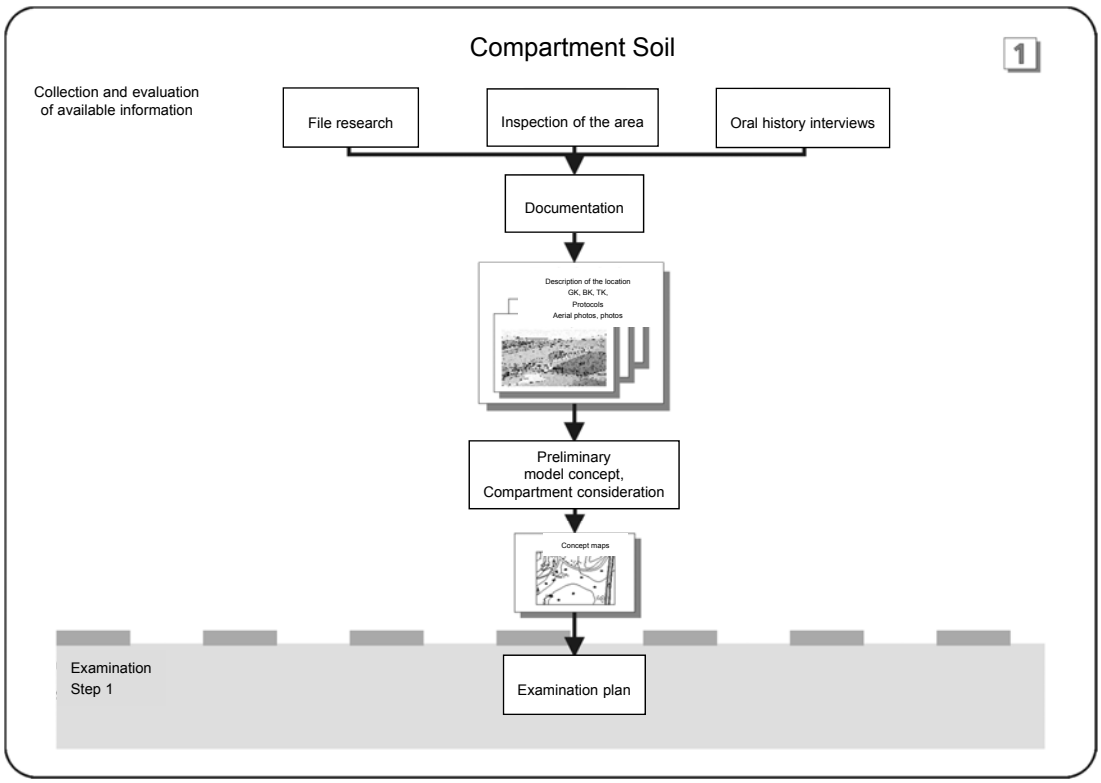

3
Examination Step II
Geological evaluation
Hydraulic tests
Groundwater level measuring
Groundwater sampling
Groundwater analysis
Hydro-geological model concepts
Contamination situation
Hazard assessment
Danger evaluation
+ sanitation,
Monitoring
Coupled transport observation
Selection of relevant pollutants
Kompartiment Grundwasser

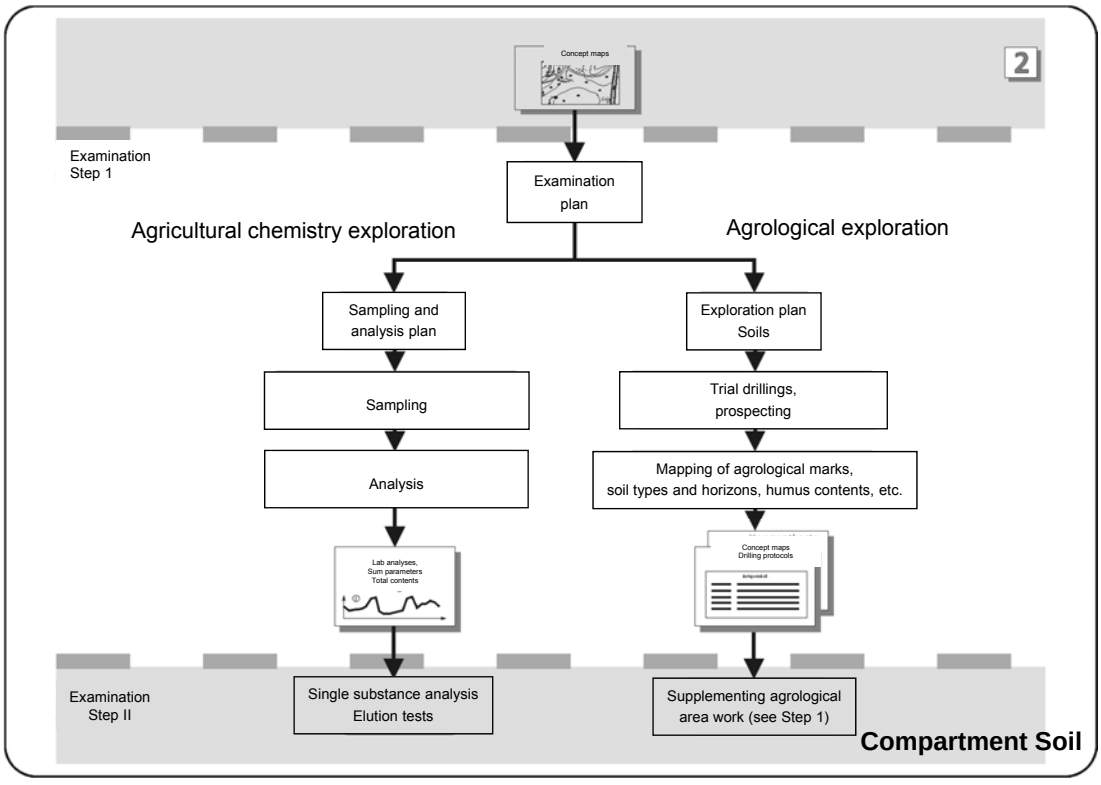

Hydro-geological map
Source Term
Hydro-geological cross-sections
Concentration map
Evaluation diagram
4
Hazard assessment,
Danger evaluation
+ sanitation,
Monitoring
Coupled transport observation
Selection of relevant pollutants
Hazard Assessment
Danger evaluation
Determination of the need for action
Monitoring concept
Monitoring plan
Monitoring
Feasibility studies
Sanitation concept
Sanitation
Compartment Groundwater

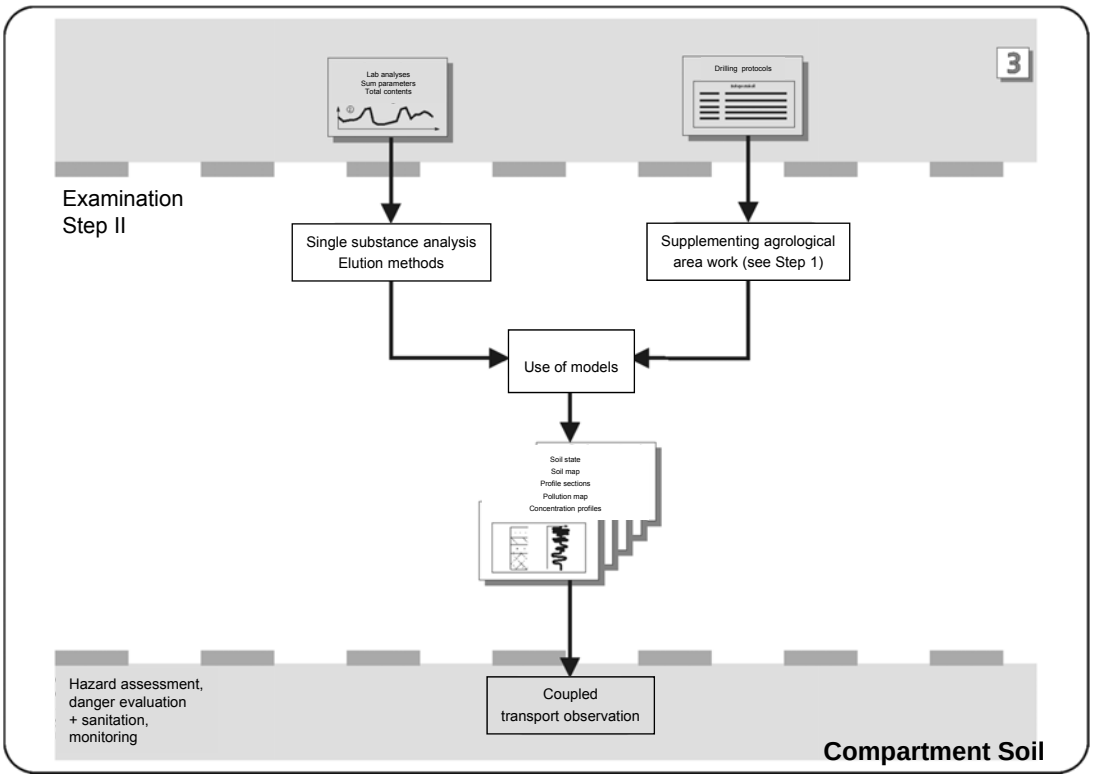

Compartment Surface Waters
1
Collection and evaluation of available information
Hydrological research
Inspection of the area
Water inspection
Oral history interviews
Documentation
Description of the location
GK, TK
Minutes
Photographs
Analysis concept
Water amount data
Water quality data
Climate data
Examination
Analysis plan

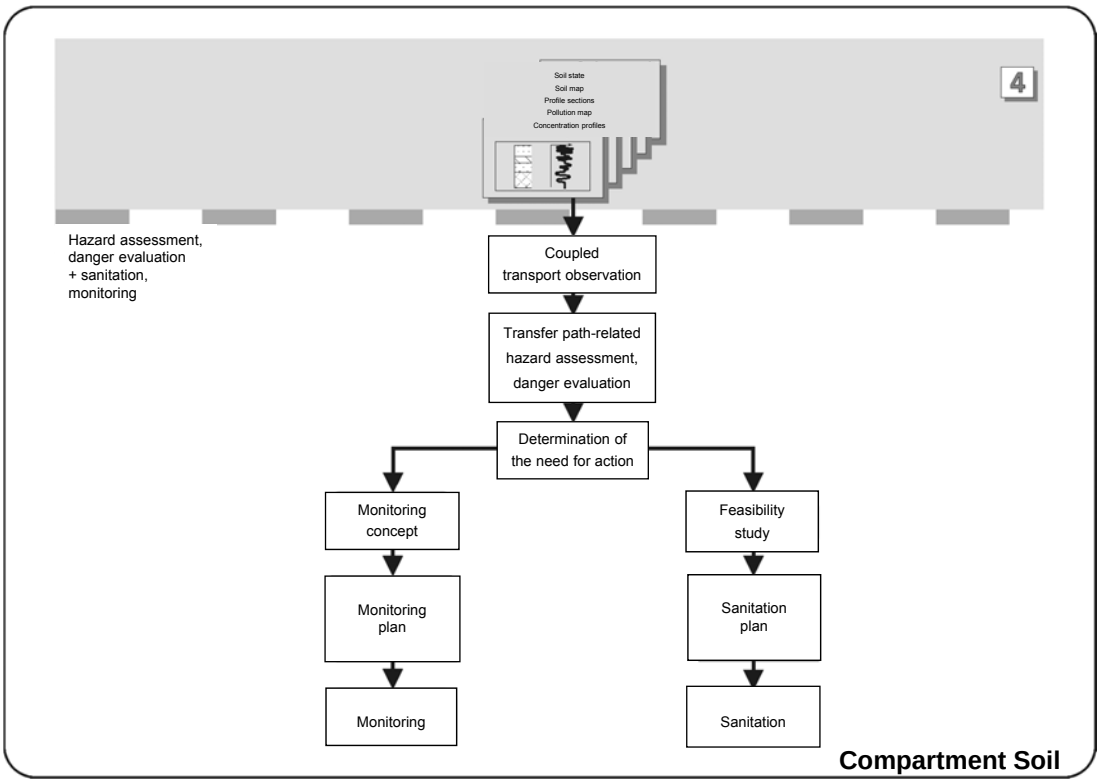

2
Water amount data
Water quality data
Climate data
Examination
Analysis plan
Hydrological exploration
Hydrochemical exploration
Hydrological exploration plan
Sampling and analysis plan
Water level measuring
Throughflow measuring
Surface water analysis/ Sediment sampling
Surface water analysis/ Sediment analysis
Measuring protocols Relation of water level and throughflow
Surface water analysis Sediment analysis
Hazard assessment Danger evaluation + sanitation, Monitoring
Coupled transport observation
Compartment Surface Waters


3
Measuring protocols Relation of water level and throughflow
Surface water analysis/ Sediment analysis
Hazard assessment, danger evaluation + sanitation, monitoring
Coupled transport observation
Transfer path-related hazard assessment, danger evaluation
Determination of the need for action
Monitoring concept
Monitoring plan
Monitoring
Feasibility study
Sanitation plan
Sanitation
Compartment Surface Waters

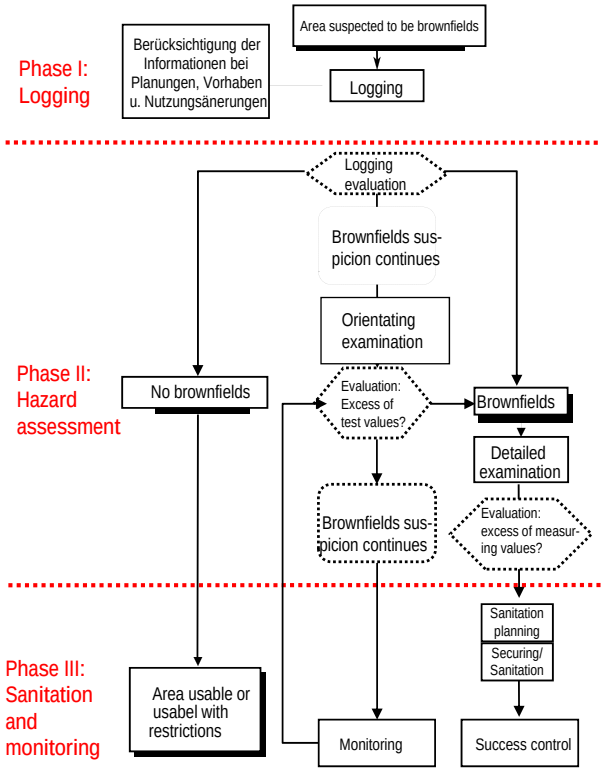

Compartment Soil
1
Collection and evaluation of available information
File research
Inspection of the area
Oral history interviews
Documentation
Description of the location
GK, BK, TK,
Protocols
Aerial photos, photos
Preliminary model concept, Compartment consideration
Concept maps
Examination Step 1
Examination plan


2
Concept maps
Examination Step 1
Examination plan
Agricultural chemistry exploration
Agrological exploration
Sampling and analysis plan
Exploration plan Soils
Sampling
Trial drillings, prospecting
Analysis
Mapping of agrological marks, soil types and horizons, humus contents, etc.
Lab analyses,
Sum parameters
Total contents
Concept maps
Drilling protocols
Examination Step II
Single substance analysis Elution tests
Supplementing agrological area work (see Step 1)
Compartment Soil


3
Lab analyses
Sum parameters
Total contents
Drilling protocols
Examination
Step II
Single substance analysis
Elution methods
Supplementing agrological
area work (see Step 1)
Use of models
Soil state
Soil map
Profile sections
Pollution map
Concentration profiles
Hazard assessment,
danger evaluation
+ sanitation,
monitoring
Coupled
transport observation
Compartment Soil


4
Soil state
Soil map
Profile sections
Pollution map
Concentration profiles
Hazard assessment,
danger evaluation
+ sanitation,
monitoring
Coupled
transport observation
Transfer path-related
hazard assessment,
danger evaluation
Determination of
the need for action
Monitoring
concept
Monitoring
plan
Monitoring
Feasibility
study
Sanitation
plan
Sanitation
Compartment Soil

Flow Chart Logging – Evaluation – Sanitation according to SRU, 1990; LAGA,1989; BBodSchV



- In Germany in 2011:
  - 121.231 old deposits
  - 322.298 sites suspected to be brownfields

(http://www.umweltbundesamt.de/boden-und-altlasten/index.htm)

- In the USA in 2011:
  - There are an estimated 450,000 abandoned and contaminated waste sites in America

(source www.epa.org/brownfields/)

Examples of sites suspected to be brownfields and possible relevant substances

- generally relevant substances and branch-specific substances

Branch	Typical pollutants
Dry cleaning	gasoline, benzene, dichloroethane, tetrachloroethane, trichloroethane, trichloroethene, trichloromethane
Hard coal mining, gas works, coking plants	ammonium, anthracene, arsenic, (asbestos), benzo(a)pyrene, benzene, lead, chromium, cyanides, ethylbenzene, fluorene, fluorene, cresol, mesitylene, mineral oil, naphthalene, PAH, phenole, acids, lyes, creosote, thiocyanate, toluol, xylol

Examination Planning after the Assessment of the Pollutant Distribution via Distribution Coefficients

(BRUCKNER et al., 1996, s. 412)

- K_H or H distribution coefficient soil ↔ air

  with H_P Henry Constant [(Pa · L / mol]

  p^0 Saturation steam pressure [Pa]

  S Water solubility [mol / L]

$$H_P = \frac{p^o}{S}$$

In practical operation, pollutant concentrations are used rather than partial pressure, thus the Henry Constant in its dimensionless version:

with c_W and c_G concentration in the aqueous or gaseous phase;

H Henry Constant [-],

R general gas constant [J / (mol · K)]

T Temperature [K]

$$H_P = \frac{c_G}{c_W} = \frac{p^o}{S \cdot R \cdot T}$$

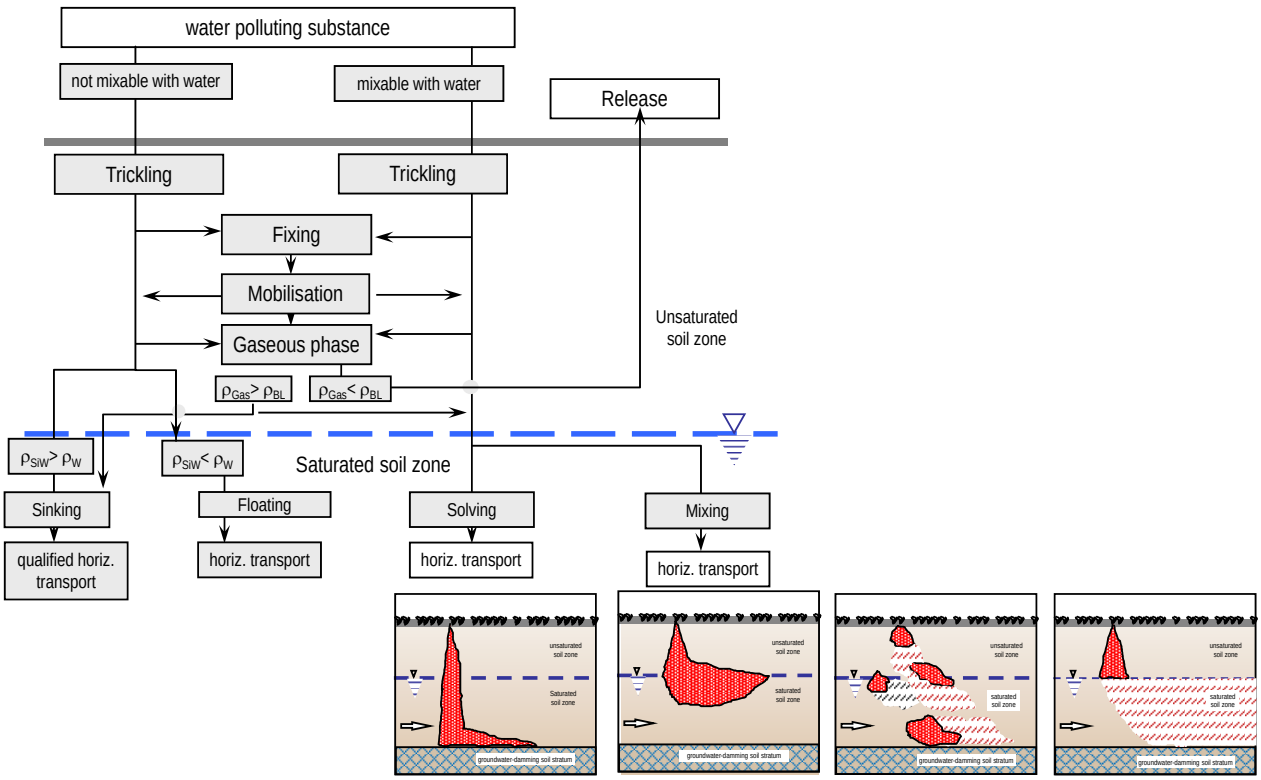
- K_D Distribution coefficient soil ↔ water

  K_{SG} Distribution coefficient soil ↔ gaseous phase via medium water = H / K_D

  K_J soil ↔ gaseous phase directly (not relevant with soil air extraction)

Examination Planning according to the Migration Behaviour of Different Contaminants

according to DARIMONT and LÜHR, 1985; verändert



Soil Samples and Analyses

- Sampling depth according to BBodSchV, Appendix 1
  for the effects soil – humans and soil – agricultural crops

Effects	Utilisation	Sampling depth
Soil - Humans	Playgrounds, residential area	0-10 cm [1] 10-35 cm [2]
Soil – Humans	Playground, residential area	0-10 cm [1] 10-35 cm [2]
	Park or recreation centres	0-10 cm [1]
	Industrial and commercial premises	0-10 cm [1]
Soil – Agricultural crops	Grassland	0-30 cm [3] 30-60 cm
	Agriculture, kitchen garden	0-10 cm [4] 10-30 cm

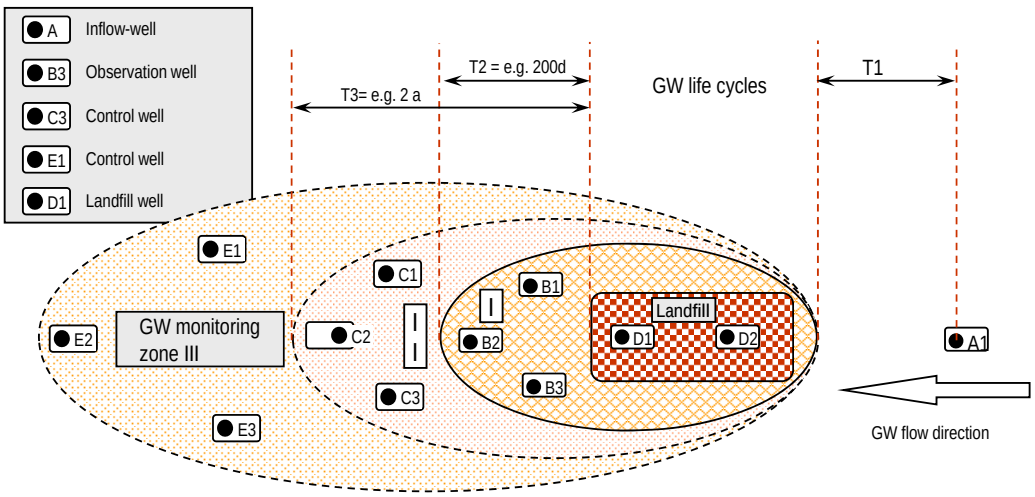
1) Contact range for oral and dermal pollutant intake; additionally 0-2 cm if the respirational intake path is relevant.
2) 0-35 cm: average thickness of applied soil layers, also the maximum depth which children can reach.
3) Treatment horizon.
4) Primary root area.

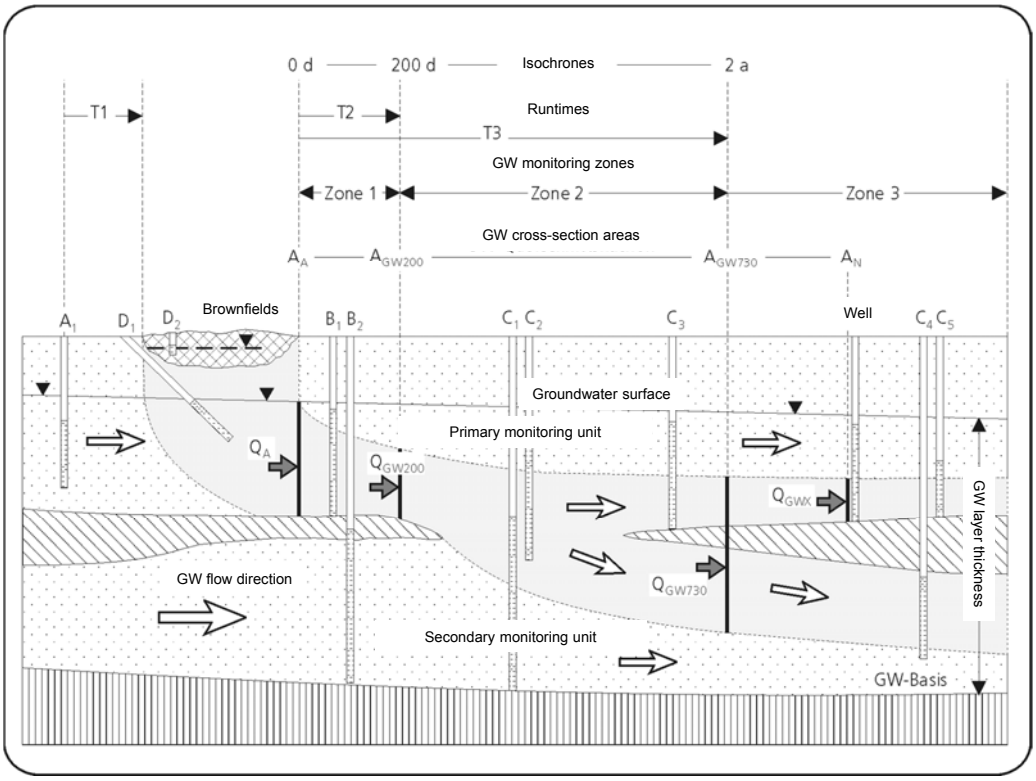
- Sampling horizontally or – with disturbed horizons – in layers, representative up to ca. 30 cm.
- Soil analysis according to Appendix 1 of the BBodSchV
- Total error of the analysis result (S= Variance):

$$s^2_{total} = s^2_{Sampling} + s^2_{Sample\ processing} + s^2_{Measuring}$$

GW Monitoring Concept on Landfills according to Dörrhöfer, 1993

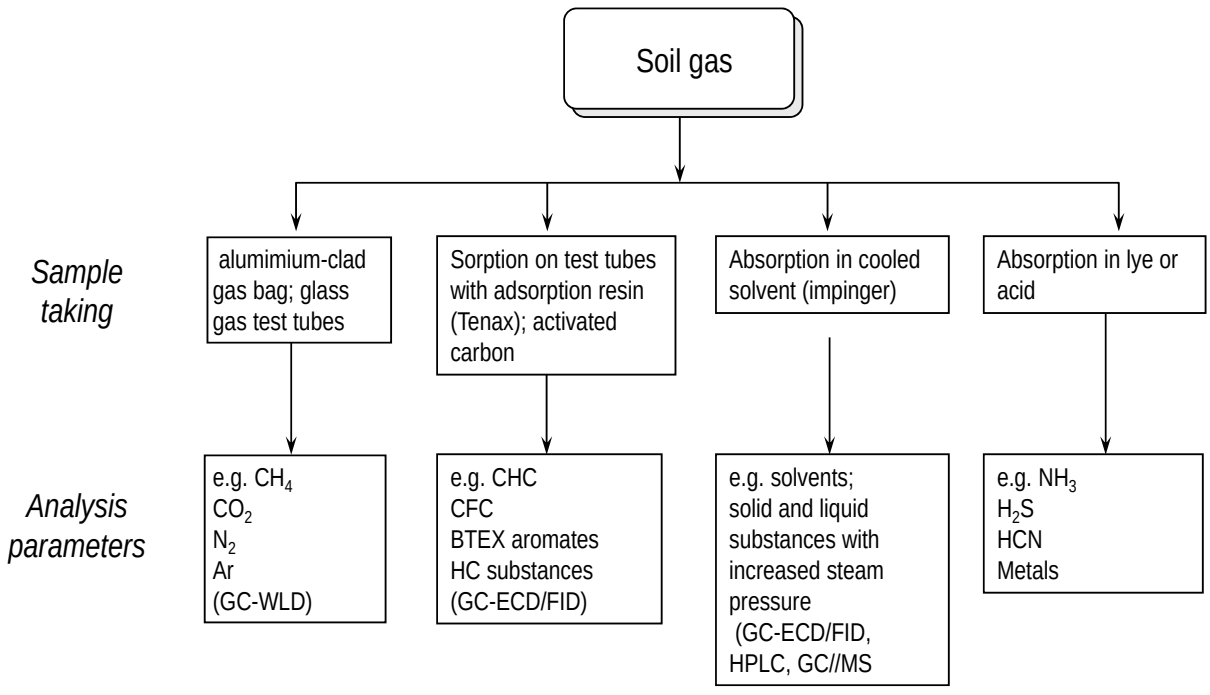
- Hydro-geological model concept
  - Groundwater flow directions and potential distributions,
  - Free and stretched groundwater pressures on maps
  - Relative pressure differences between hydro-stratigraphic units
  - Hydraulic connections between hydro-stratigraphic units
  - Distance velocities ($v_a = k_f * i / n$) (with n = effective hollow space ratio); GW flow amounts
  - Vertical hydraulic gradients to determine the position of the GW new production areas or GW discharge areas





Analysis Scheme for Soil Gas with Offline Measuring

according RUMPP et al., 1996

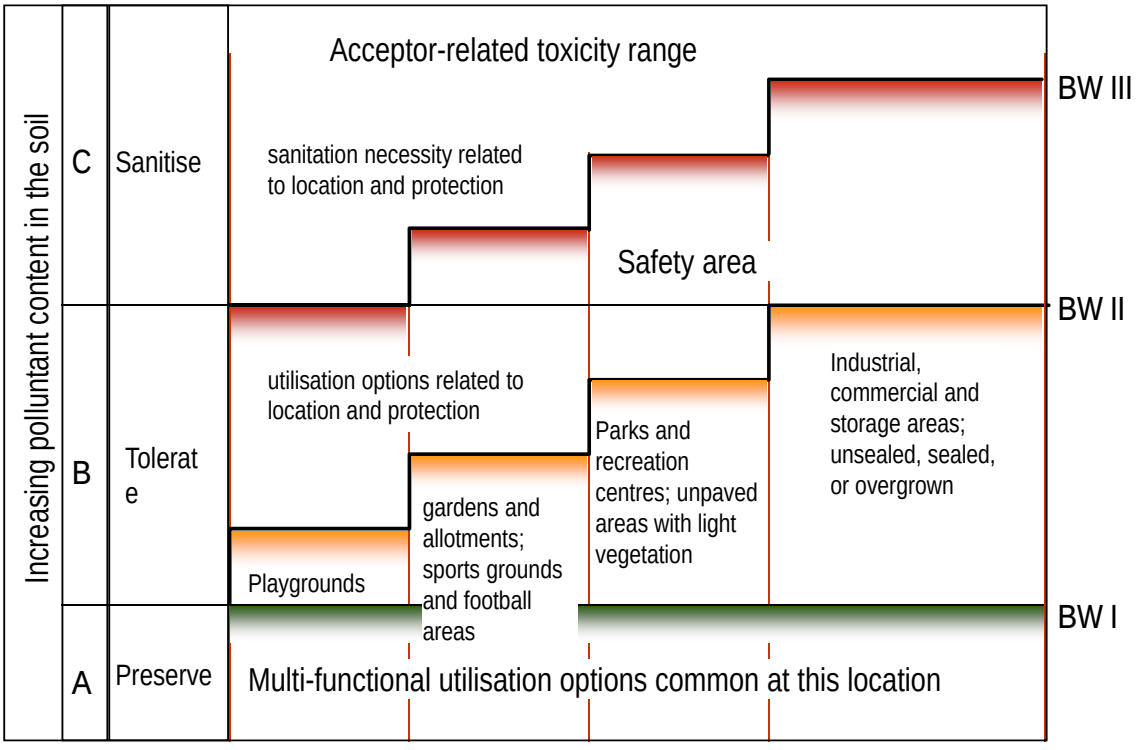


Principal Parameters

- Boron in the groundwater as indication of domestic waste
- Sulphate in the groundwater as indication of building rubble
- AOX in the groundwater as indication of special waste
- org. Cl in the gas/soil air as indication of special waste
- CH_4 in the gas/soil air as indication of biologically anaerobically convertible organic substances (e.g. domestic waste)

Stage Model of the Utilisation of Urban Soils with Pollutant Contents

according Lühr/ Eikmann/ Kloke, 1994



Test and Measurement Values (Appendix 2 BBodSchV,1999)

Soil ⇒ Humans Test values [mg/kg DM]					Soil ⇒ Agricultural plant [mg/kg DM]	[mg/kg DM]	[mg/kg DM]
Substance	Playgrounds	Residential areas	Parks and recreational centres	Industrial and commercial premises	Agriculture/ kitchen garden 0-30 cm depth	Grassland Plant quality Measurement values 0-10 cm	Grassland Growth of agricultural crops 0-10 cm
Arsenic	25	50	125	140	200 test value	50	0,4 test value
Lead	200	400	1 000	2000	0,1 test value	1.200	
Cadmium	10 [1]	20 [1]	50	60	0,04 / 0,1 measure	20	
Cyanide	50	50	50	100			
Chromium	200	400	1 000	1000			
Copper						1.300 / 200(sheep)	1 test value
Nickel	70	140	350	900		1.900	1,5 test value
Mercury	10	20	50	80	5 test value	2	2 test value
Thallium					0,1 test value	15	
Aldrin	2	4	10	-			
Benzo(a)pyrene	2	4	10	12	1 test value		
DDT	40	80	200	-			
Hexachlorobenzene	4	8	20	200			
Hexachlorocyclohexan (HCH-mixture or b HCH)	5	10	25	400			
Pentachlorophenol	50	100	250	250			
Polychl. Biphenyle (PCB6) [2]	0,4	0,8	2	40		0,2	

1) In gardens and allotments which are used both as playing area for children and the growing of food plants, the test value to be used for cadmium is 2,0 mg/kg DM

2) If the total contents of PCB area determined, the gained average values must be divided by the factor 5.

Measurement value for dioxin and furan (ng i-TEQ/kg DM)				
PCDD / PCDF	100	1.000	1.000	10.000

Contamination Ways

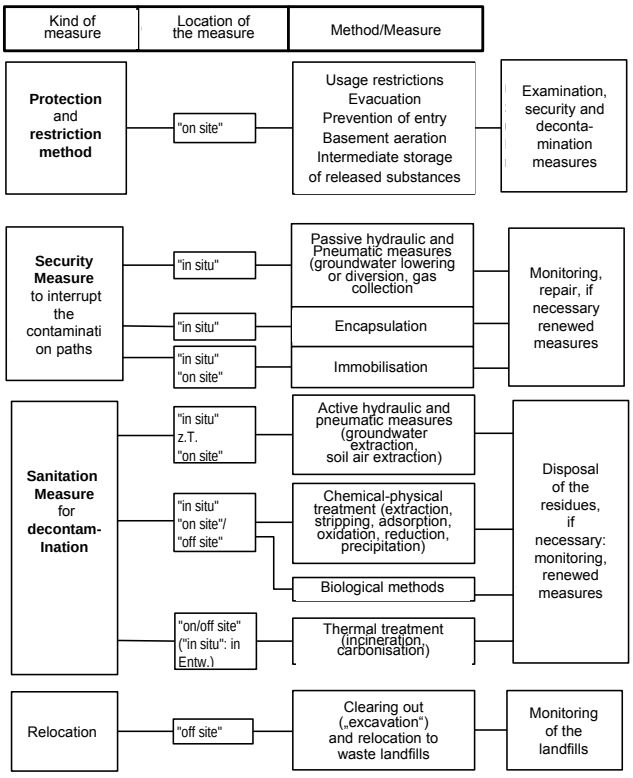
Methods and MScales for the Derivation of the Test and Measurement Values according to BBodSchV (BAnz. of 28. August 1999

- **oral** = intake as food via the mouth
  - direct intake via the **soil** with children; 0,5 g/d soil to the age of 6
  - indirect intake via **food** (ingestion) (Food Reference Values of the German Health Authority; intake via **drinking water** of 2 l per day for adults and 1 l per 10kg body weight for children)
- **Respiratory** = intake via breathing
  - 20 m^3/d **respiratory volume** for adults and 5 m^3 for small children
  - **Calculation** of the emission concentrations from emissions (chimneys, soil air) with dilution factors (for chimneys: distribution model) or **emission measuring**
  - **Comparison** of emission concentrations with (background) values in clean air and urban air areas and with MIK values of the VDI or alternatively with 1/100 of the MAC values (maximum acceptable concentrations); cf. TRGS 900 (Technical Regulations on Hazardous Substances) or TRC values (Technical Reference Concentrations) for carcinogenic substances (no MAC value) (TRCS 102)
- **dermal** = intake via the skin
- **Combination effects**
  - Insights limited. Alternative for MAC values for several substances: sum of the exhaustion quotas ≤ 1.

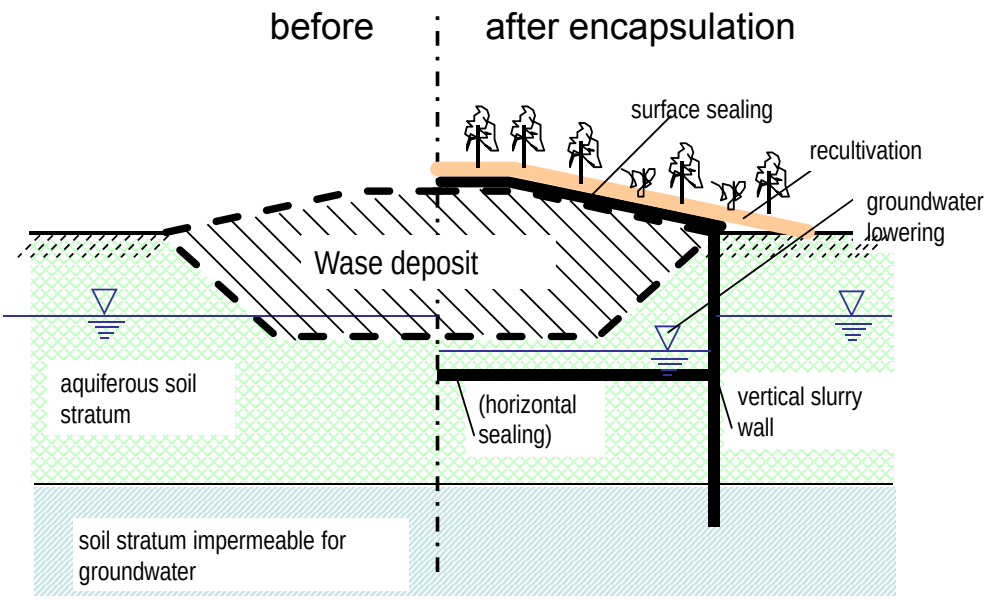
Evaluation Criteria

- **LOAEL** lowest observed adverse effect level = the lowest dose or concentration of a given hazardous substance at which (in the present study) adverse effects were still observed.
- **NOAEL** no observed adverse effect level = the highest dose or concentration of a given hazardous substance at which no adverse effects were observed anymore.
- **TRD** or **ADI** = tolerable reabsorbed doses. Ideal if these values are directly available from experiences with humans (human data); otherwise extrapolation of data from animal experiments;
  Safety factor (e.g.100) · NOAEL = **TRD**

Securing and Sanitation of Abandoned Polluted Areas



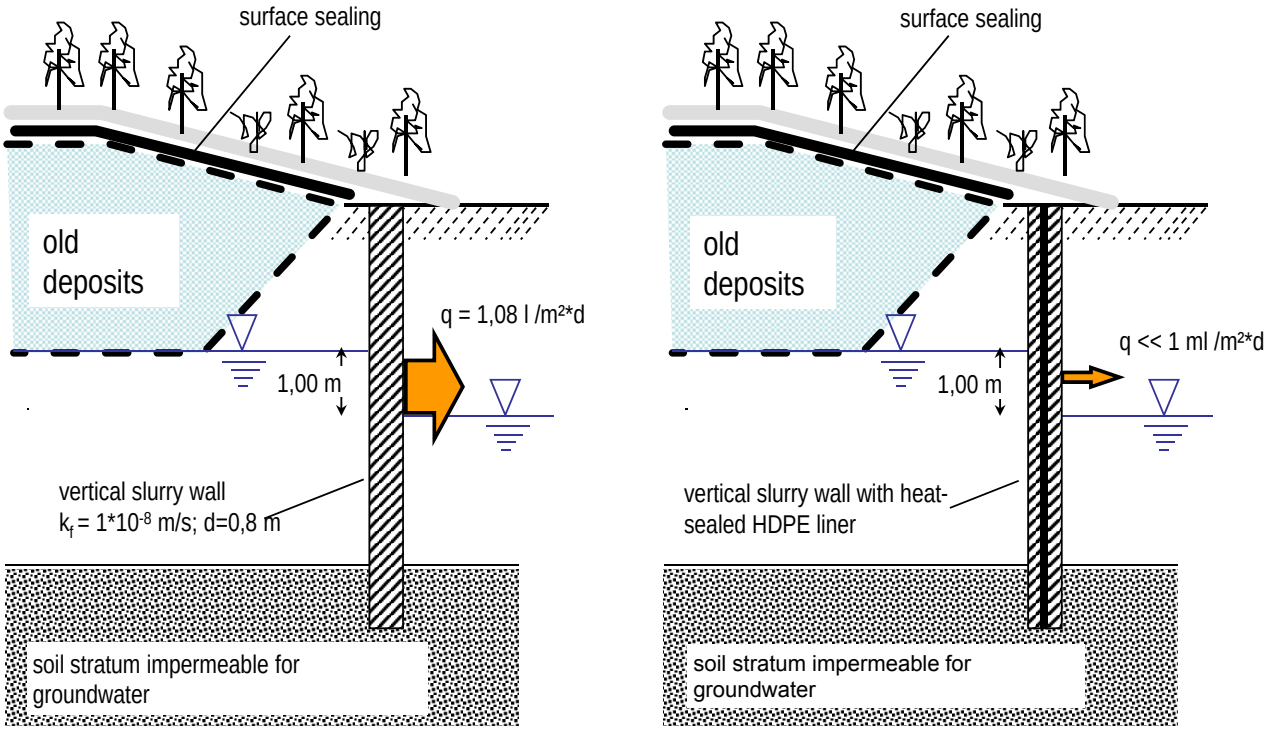
Encapsulation of Old Deposits



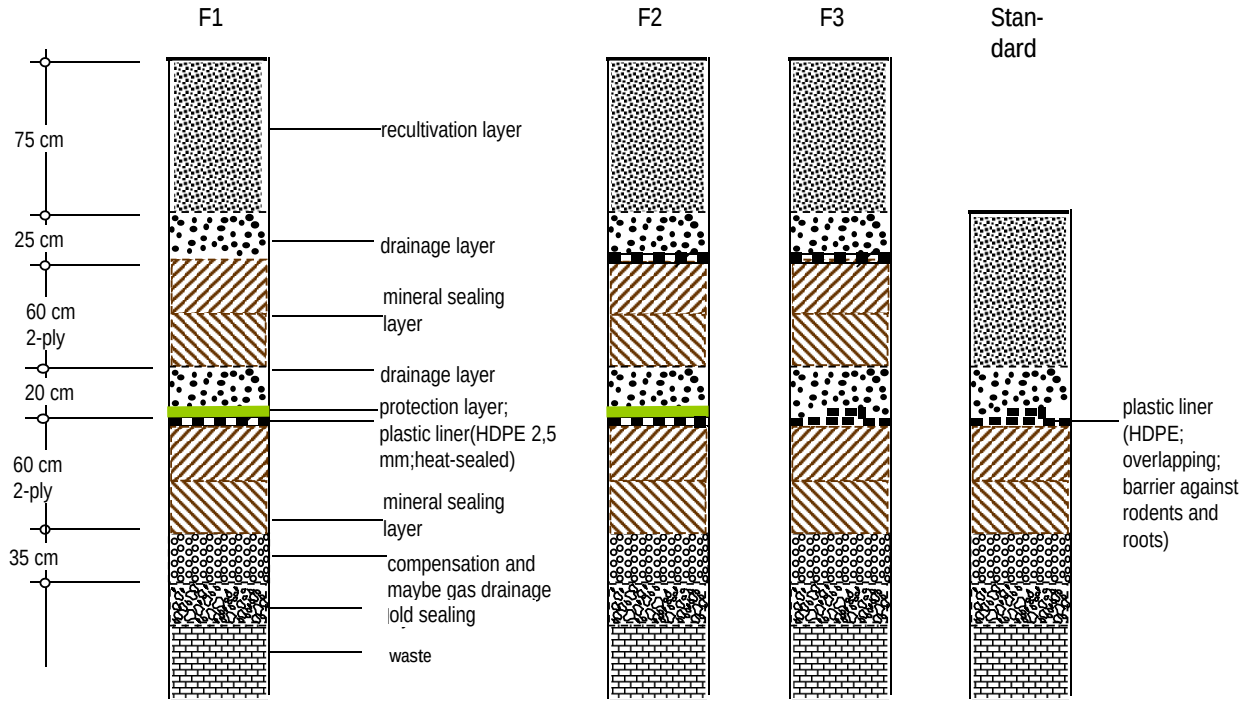
- With slurry wall encapsulation, the inside groundwater level must always be kept lower than the outside one

Permeation Rates through Slurry Walls for Damming with or without HDPE Liner

according to SRU.1989. S. 133



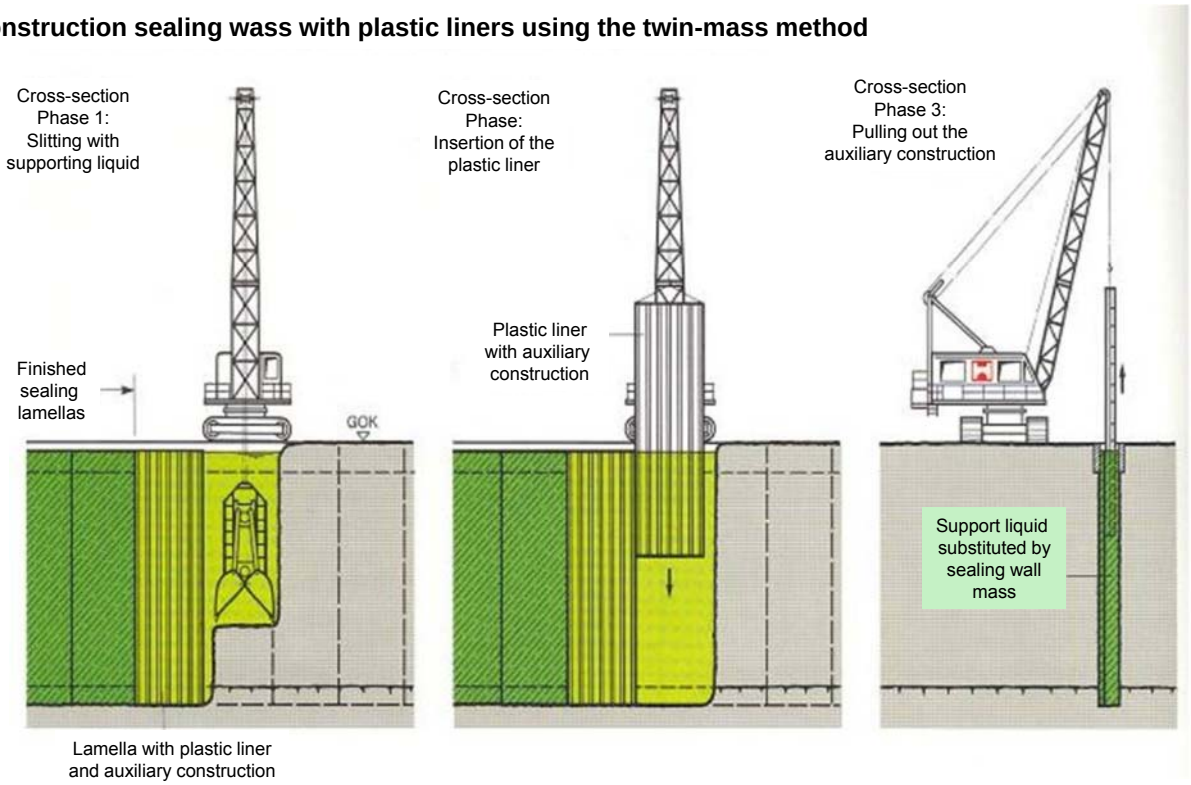
Surface Sealing Systems at the Landfill in Hamburg-Georgswerder



Vertical shielding systems and experience values

Principle	Sealing wall system	Soils	Material	Depth [m]	Thickness [m]	k-value [m/s]
Excavation of the in-situ soil and filling in of sealing material	slurry wall one-phase method	application restricted for turf/humic acids	bentonite-cement-suspension with/without filler	ca. 35	0.5 - 1.5	$< 5 \cdot 10^{-10}$
	Slurry wall two-phase method		bentonite-cement-suspensions, soil cement	> 50	0.4 - 1.5	$< 1 \cdot 10^{-10}$
	Slurry wall combination sealing		bentonite-cement-suspensions, plastic liner (e.g. PEHD)	ca. 35	> 0.6	see above
	Contiguous pile wall	no restrictions with tubed cuttings	Soil cement	ca. 20	0.6 - 0.8	$< 1 \cdot 10^{-10}$
Displacement of the in-situe soil and filling in of sealing material	Thin diaphragm wall	pileable or compactable	bentonite-cement-suspensions with filler	ca. 25	0.07 - 0.20	$< 1 \cdot 10^{-10}$
	Sheet pile		Steel	ca. 25	0.01 - 0.02	-
	Piled slurry wall		Soil cement	15 - 20	0.4	$< 1 \cdot 10^{-9}$
Reduction of the permeability of the in-situ soil	Injection wall	injectable	Cement, clay-cement suspensions, silica gels	> 100	adjustable	$< 1 \cdot 10^{-8}$
	High-pressure injection wall	also in very fine grained ones	bentonite-cement-suspensions with/without filler	> 100	0.2 - 0.8	$< 1 \cdot 10^{-10}$
	freezing wall		Freezing plant liquid nitrogen	> 100	> 0.8 - 1.0	-

Construction sealing wass with plastic liners using the twin-mass method



Securing through Immobilisation

- Compacting; ramming
  - reduction of the elutable surfaces
- Stabilisation
  - chemical reaction
- Encapsulation, enclosing
- Fixation
- Vitrification
  - enclosing with glass (radioactive waste
- Glazing
  - burning into clay (harbour silt; sewage sludge)

Hydraulic Measures

The targets of hydraulic measures: prevention/reduction of further contamination of the (ground) water through:

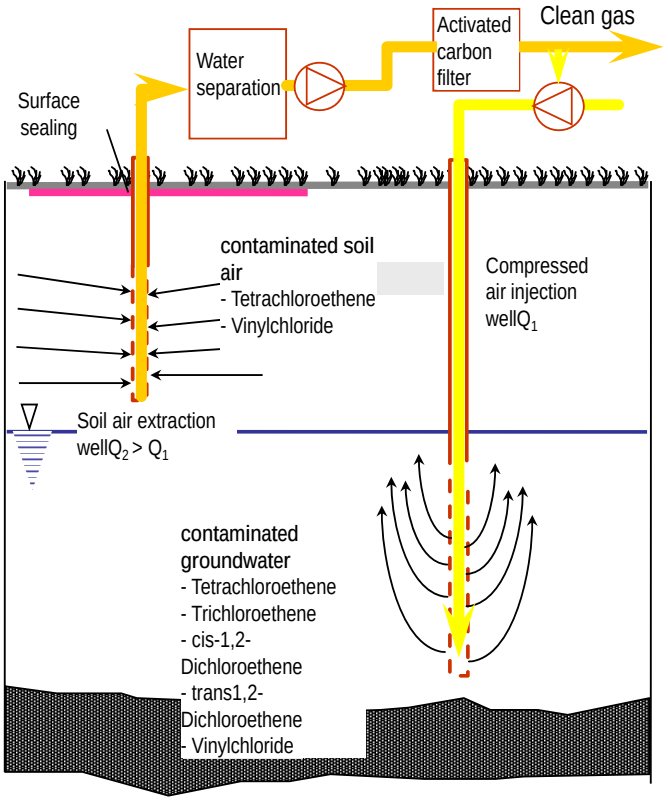
- Groundwater extraction and treatment underflow an old deposit
- Leachate extraction and treatment through the drilling of well in a pit landfill with leachate damming
- Drainage of a deposit through which groundwater flows through lowering of the groundwater level (if need be, in a „sealing crock"
- Gallery of extraction well to revert or divert the original groundwater flow direction to protect the groundwater usage
- Purposeful extraction/disposal of liquid pollutants – such as oil – at the groundwater surface or CHCs (heavier than water) at the bottom of the aquiferous stratum

Pneumatic Measures

Pneumatic measures with soil air extraction to collect and decontaminate highly volatile gaseous pollutants:

- **Landfill gas extraction** (at ca. 99 Vol.-% CO_2 and CH_4)
  - prevention of explosion risks (explosion at 5-14 Vol.-% CH_4) and danger of suffocation
  - toxicological dangers caused by trace substances
  - particularly in danger are buildings near or on landfills, especially with upper sealing of the landfill and with thick surface soils. Sanitation through:
  - active extraction of the landfill for the (partial) reversal of these migration paths, possibly with thermal treatment
  - reduction of gas concentrations under building baseplates and cellars, interruption of gas migration through gas separation ditches, injection of fresh air under buildings or extraction from below building basements
- **Stripping of organic impurities**
  - injection of air or steam (for substances with an increased boiling range, such as CFC, PAHs, and phenoles) from the bottom groundwater

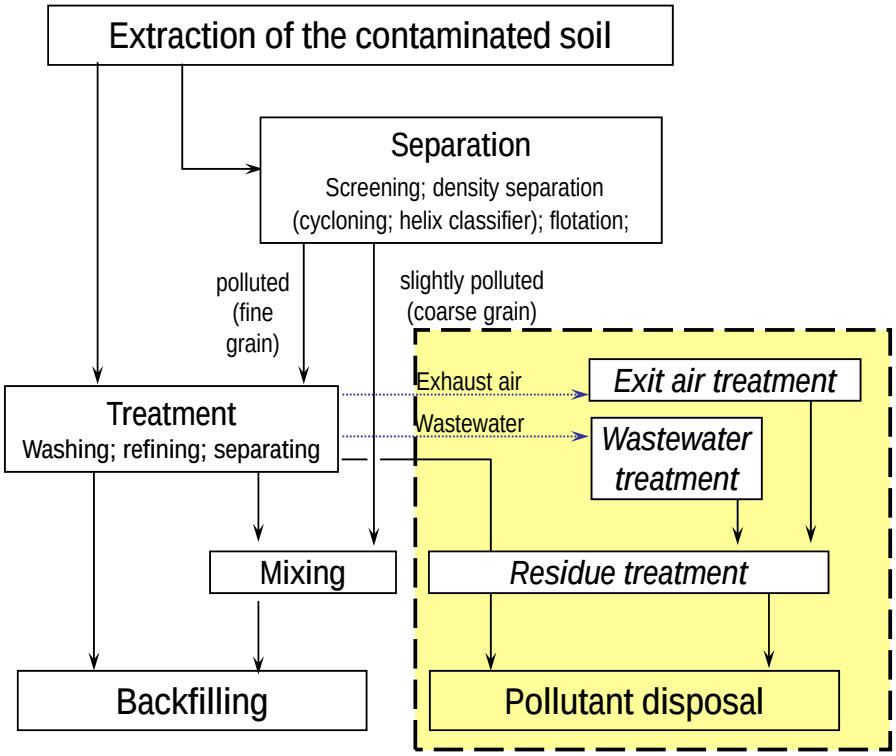
Pneumatic Measures - In-Situ Stripping of Contaminations in Groundwater and Soil Air



Chemico-Physical Measures – Extraction and Scrubbing Methods

Methods	Extractants/ Additives/Energy input	Separation of the soil from the pollutant-extractant mixture	Pollutant suitability	Process agent processing	Throughput t/h	Mobility degree
Scrubbing/ Wet classification (water-based)	H_2O/ weak acids, lyes; biodegradable tensides, complexing agents; vibration screw	Multi-stage reactor, hydro-cyclone, corrugated sheet classifier	Heavy metals and cyanides; cf. additives; mineral oil derivates, PCB	Flotation, flocculation/precipitation, stripping, adsorption	20-30	portable
	H_2O high-pressure water jet	Hydro-cyclone, sedimentation in the settling tank	Heavy metals, cyanides, mineral oil derivates, PCB	Flocculation/precipitation, filtration	15 - 40	portable
	H_2O/demulgator; scrubbing screw	Washing and classification drum	Mineral oil derivates	Oil separator, reverse flow turbo-floatation	20	portable
	H_2O; centrifugal scrubber	Sedimentation	Mineral oil derivates	Flotation, filtration	3,5	stationary
	H_2O; tensides, paddle scrubber	Sedimentation	not mentioned	not mentioned	10	mobile
	H_2O; additives; stirrer		not mentioned	not mentioned	3	mobile
	H_2O/ organic acids; washing drum	Flotation	Heavy metals	Biological degradation and transfer	not given	not mentioned
Solvent extraction	Pentane, petroleum ether; reverse flow extractor	Washing column, scrubbing screw	Mineral oil derivates, possibly PCB	Distillation	10	mobile
Not water-based	Triethanolamine (TEA), reverse flow extractor	Scrubbing screw	Oily substances; compounds building complexes with triethanolamine	Extraction, distillation	not given	mobile
	Petroleum ether	Washing drum	Oils, tars, PCB	Distillation	10	mobile

Sanitation through Soil Scrubbing



Division into High-Load and Low-Load Fractions

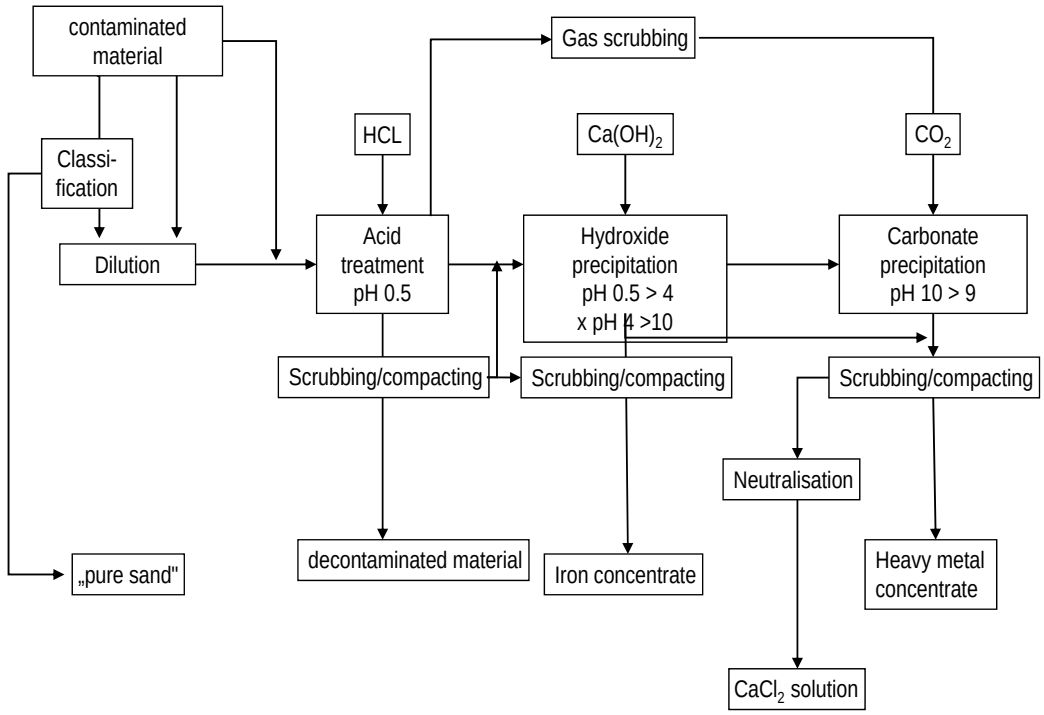
- Pollutants tend to adsorb at the surface
- Fine-grain materials are thus polluted more heavily

O / V ball (m^2/m^3) = 6 / d (m)

	´Grain size (mm)	specific surface (m^2/g DS)
Fine grain, clay	< 0,002	150 - 250
Silty, claey loam	0,002 – 0,006	120 - 200
Silt loam	0,006 – 0,02	50 - 100
Sandy loam	0,02 – 0,06	10 - 40
Silt	0,002 - 0,06	5 - 20
Fine sand	0,063 - 0,1	0,03

- Screening or cycloning; e.g. METHA at Hamburg harbour; improved with scrubber
- Utilisation of the low-load material and disposal of the high-load material
- or decontamination and complete utilisation

Heavy Metal Decontamination



Chemico-Physical Methods - excluding Extraction and Scrubbing Methods

Treatment method	Treated medium	Place of treatment	Transport medium, process medium	Reagents, auxiliary materials	Separation of cleaned flow and process flow	Restrictions, problems
Adsorption	Stripped gas phases, contaminated water	on site	Activated carbon, molecular sieves, adsorber resins		Screen, conveyance	Adsorption equilibriums, disposal
Ion exchange	Contaminated water	on site	Ion exchanger resins	Buffering	Screen	only for certain ions
Membrane separation method	Contaminated liquids	on site	Water		Membrane	Coating, suspended solids contents
Sedimentation; Flotation	Process water, thin slurry	on site	Water	Flocculation and flotation agents	Hydro-cyclone, Centrifuge, flotation	Grain size distribution, disposal
Evaporation	Highly contaminated water	on site	Water			Residue disposal
Precipitation, flocculation, colloid effect	Contaminated process water	on site	Water	Precipitation agent, auxiliary agents	Screen, filter, sedimentation, flotation	Toxic by-products, disposal
Chemical conversion	Aqueous phases	on site	Water	Reagents	e.g. sedimentation	
Oxidation, reduction, dehalogenisation	Oleaginous phases (trickling oil)	on site; off site	If needed organic solvent	Metallic sodium, H_2	Distillation, scrubbing	
	Soil	in situ	air	Ozone	Conveyance (compressed air)	Soil conditions, toxic metabolites

Microbial Degradability of Substances relevant for Abandoned Polluted Areas

(Gillmann et al., 1999 in Görner, Hübner, 1999)

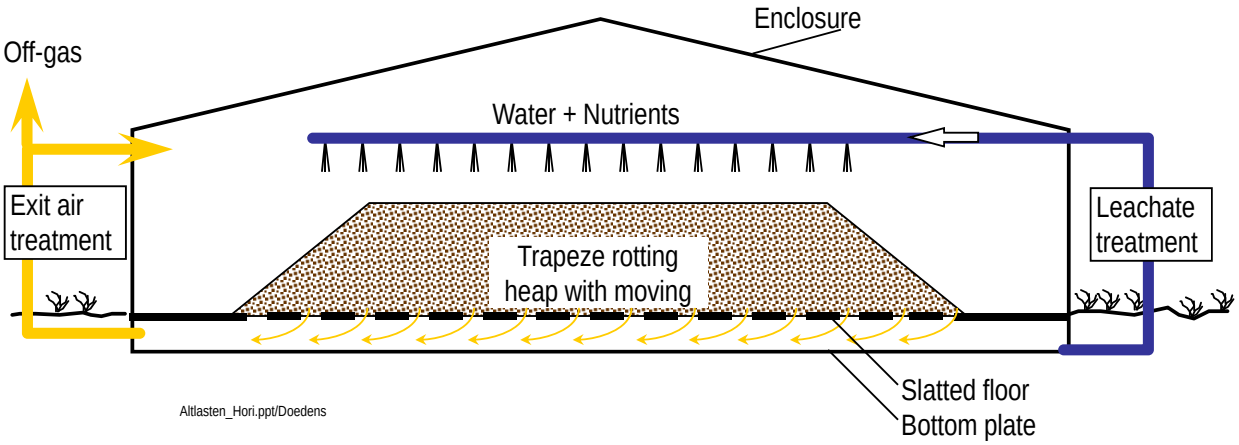
- Pre-conditions:
  - prevention of toxicity, prevention of substrate inhibition
  - surface structure, comminution of contaminated soils
  - supply with nutrients and – with aerobic processes – with sufficient **oxygen** (air, O_2, H_2O_2, NO_3, O_3)
  - safeguarding of the substance transfer (mixing, transport processes, solution agents, emulsifiers, gas permeability)
  - if need be, inoculation with adapted micro-organisms

Substance Category	Generally well degradable	Generally hardly degradable
aliphatic hydrocarbons (HC), mineral HCs, and their derivates	+	
Mono-cyclical aromatic hdrocarbons (e.g. BTX aromates) and hetero-cyclical hdrocarbons (e.g. pyridine, quinolene)	+	
Poly-cyclical aromatic hdrocarbons (PAH)	+ [a]	+ [b]
Lightly volatile halogenated hydrocarbons, particularly chlorinated ones(LCHC)		
Poly-chlorinated biphenyles (PCB)		+ [c]
Poly-chlorinated dibenzodioxins and furans (PCDD and PCDF)		+ [c]
Pesticides and their derivates		+ [c]
Heavy metals		Not degradable

a up to 4-ring PAH
b 5 and 6 ring PAH
c some low chlorinated congeners are principally degradable/dehalogenatable; degradation currently not detectable for highly chlorinated congeners

Biological On-Site and Off-Site Methods

- Land farming
  - Scarifying through ploughing, application of necessary nutrients, micro-organisms and water
- Rotting methods
  - (trapeze) heaps
  - tunnel methods
  - box/container methods

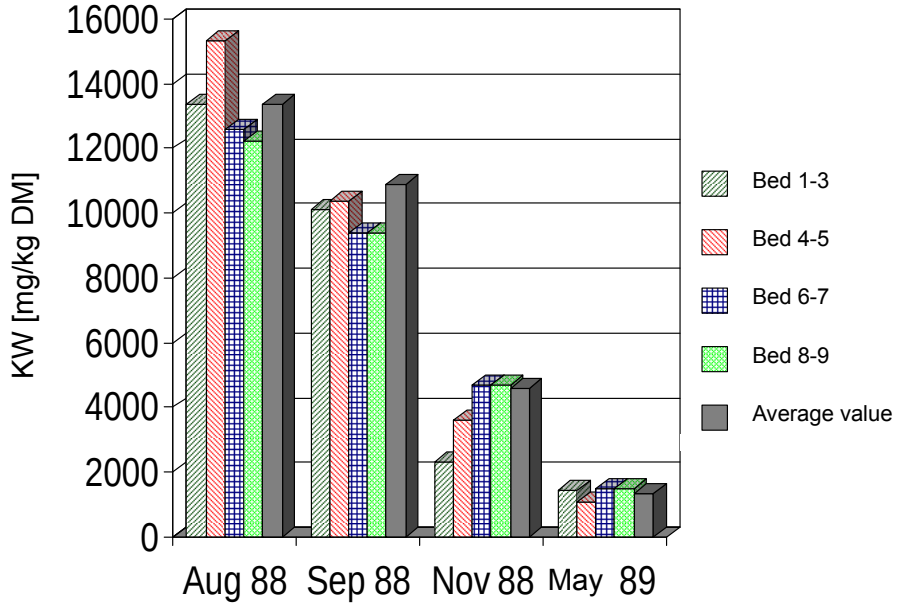


Altlasten_Hori.ppt/Doedens

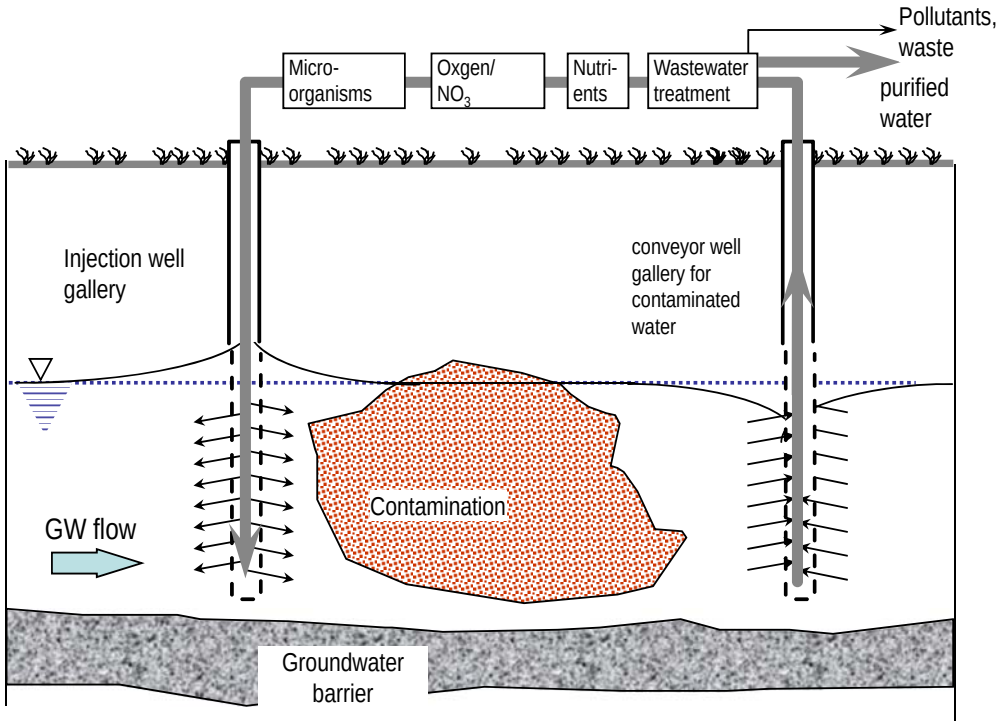
Micro-Biological Soil Sanitation of Soil Contaminated with Heating Oil

Source: ALTLASTEN 3, 1989, S. 465

for comparison:
DepV LC III ≤ 4% = 40.000 mg/kg DM
AbfABlV LC II ≤ 0,8% = 8.000 mg/kg DM
AbfABlV LC I ≤ 0,1% = 1.000 mg/kg DM
LAGA Z2 = 1.000 mg/kg D M (utilisation)



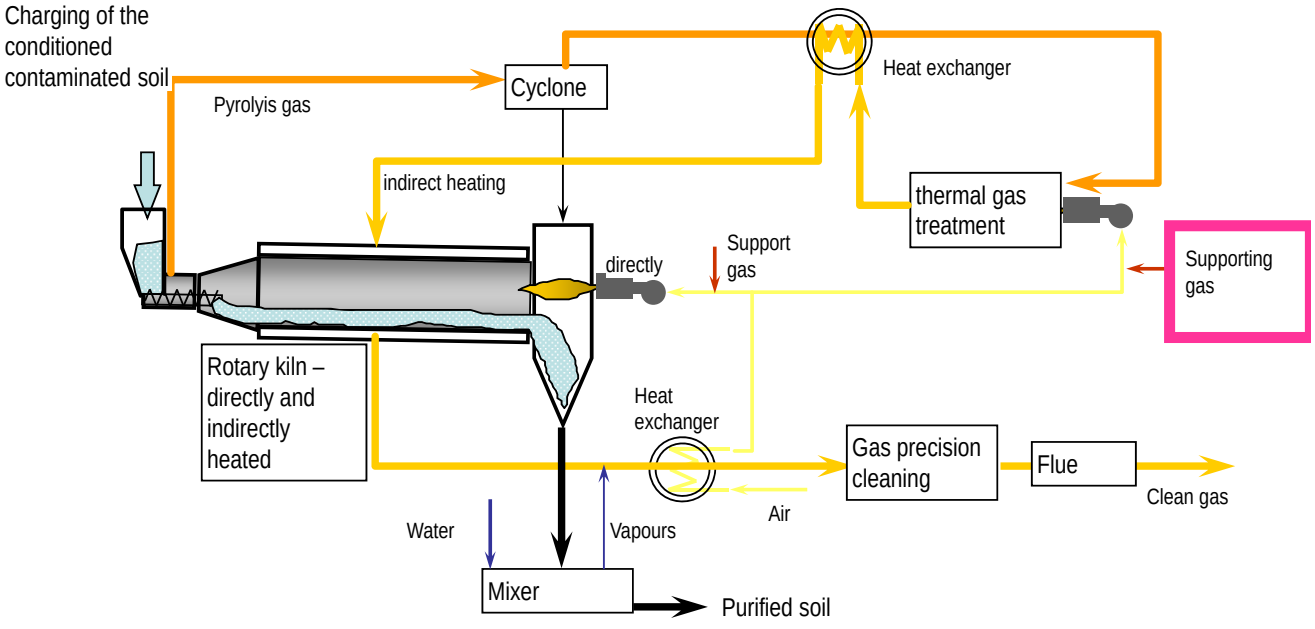
Biological In-Situ Groundwater Sanitation



Thermal Soil Treatment

- Thermal decontamination of polluted soils or – also possible, but as yet hardly practised – polluted waste from old deposits with degassing, gasification, or incineration methods.
  Thermal soil sanitation is suitable for the following pollutant groups:
  - **volatile halogen-free organic compounds**, e.g. hydrocarbons from mineral oil and coal refining (gasoline, kerosene, heating oil, diesel oil, BTX, PAH)
  - **halogenated organic compounds**, CHC, chlorous pesticides, PCB, PCDD, PCDF (as impurity of many products and of waste)
  - **volatile elements and inorganic compounds,** such as cyanide, Hg, Cd, Zn, Sb, As, F Cl, N, or P
  - the suitability for certain pollutants depends mainly on the boiling point of these substances and the temperatures which can be reached in the treatment chamber

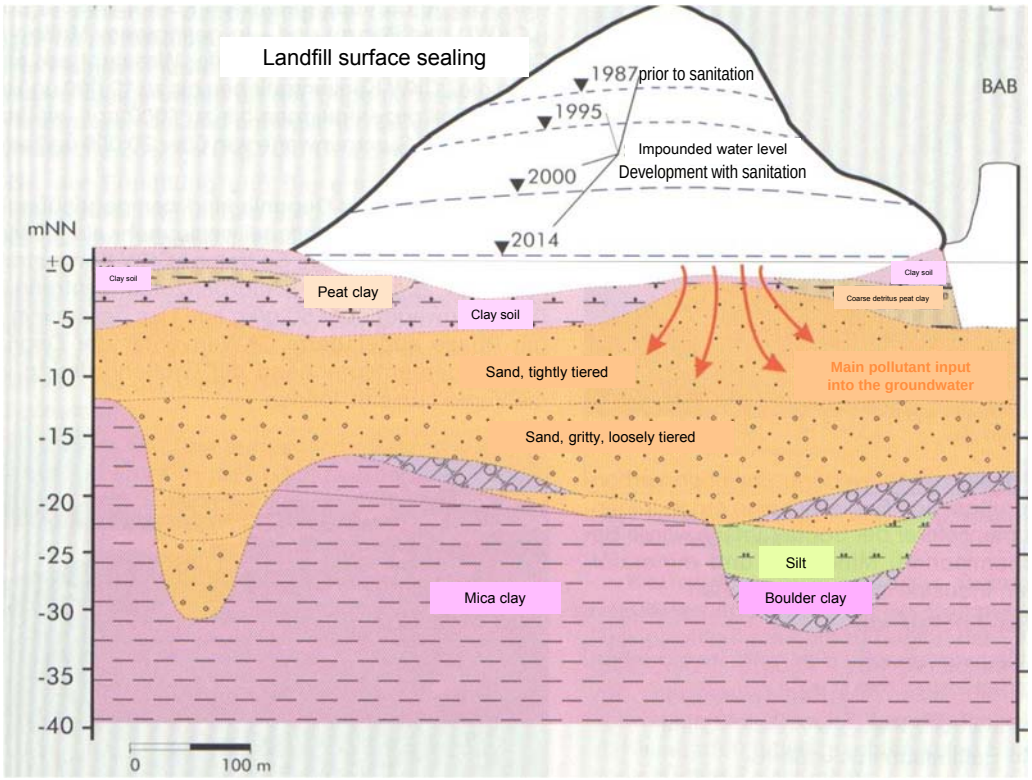
Thermal Soil Treatment: Satem Ecotechniek or Ruhrkohle-Umwelttechnik



Thermal Soil Treatment

Hot gas filter of the pyrolysis plant of the BRZ company in Herne

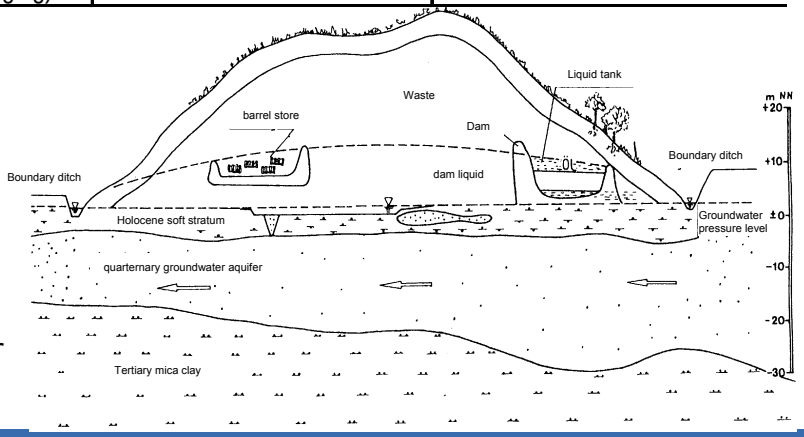
Sanitation Example Hamburg-Georgswerder – Impounded Water and Geology



Basic Situation Brownfields at Hamburg-Georgswerder

Parameter	Dimension	Pollutant concentration in the oleaginous phase of the leachate	
		Range	Average value
Density	(g/L)	0,932 - 0,957	0,040
TOCl	(%)	3,9 - 4,5	4,2
Sum of the chlorcbenzenes	(mg/kg)	4.133 - 39.870	27.305
Sum of the chlorophenoles	(mg/kg)	83 - 1.169	693
PCB	(mg/kg)	14 - 222	130
HV-CHC	(mg/kg)	20 - 63	36
Aromatic solvents (BTEX)	(mg/kg)	6.060 - 24.423	11.987
Sum of the PAHs	(mg/kg)	1.823 - 2.357	2.062
2,3,7,8-TCDD	(µg/kg)	14,5 - 60	32
Sum of PCDD/PCDF	(µg/kg)	22.225 - 54.878	42.531

- 44 ha;
  operation from 1948-1979;
  7-8 Mio. m³ Volume;
  also several 100.000 m³ special waste;
  13-26 Mg dioxin!!!
- no technical sealing or drainage
- over 1 m m³ impounded water



Hamburg-Georgswerder –

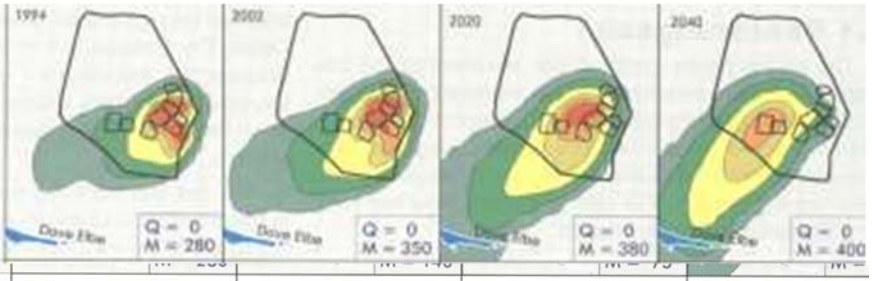
Tank for Liquid Special Waste

Barrel Store for Special Waste

Hamburg-Georgswerder – Groundwater Sanitation Concept

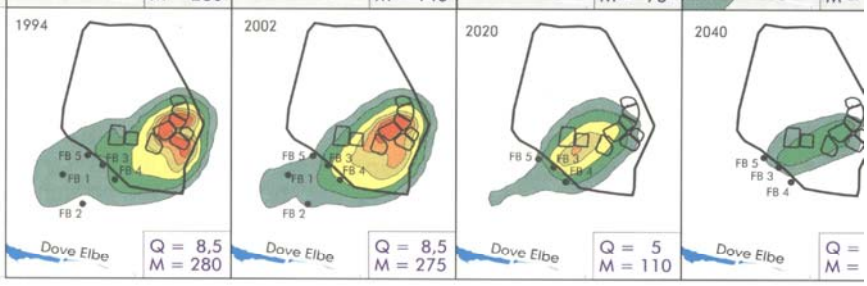
1st Strategy

No sanitation

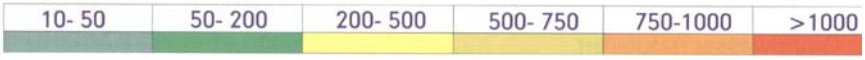


5th Strategy

Sanitation since 1994
(partial sanitation:
pollution front)



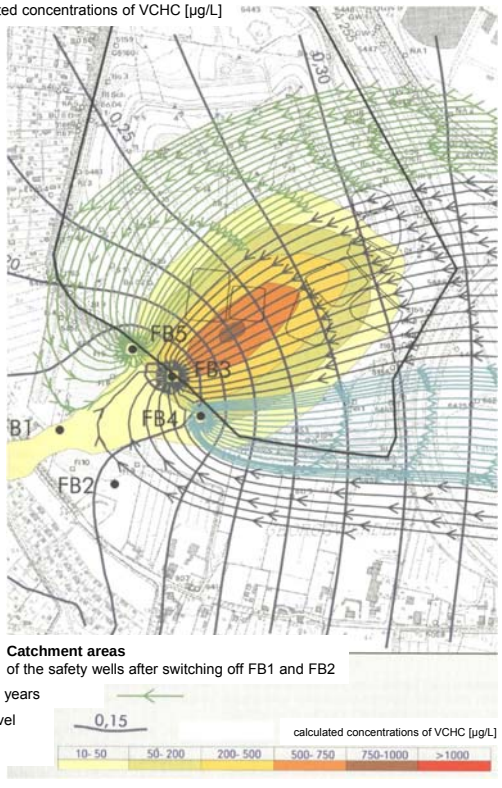
Calculated concentration ranges [µg/L]



Q	feed rate [m³/h]
M	pollutant mass (VCHC) in aquifer [kg]
S1 … S11	terms for the calculated well sites
FB1 … B5	terms for the sanitation wells

Hamburg-Georgswerder – Groundwater Sanitation with 5 wells after switching off Wells 1 and 2

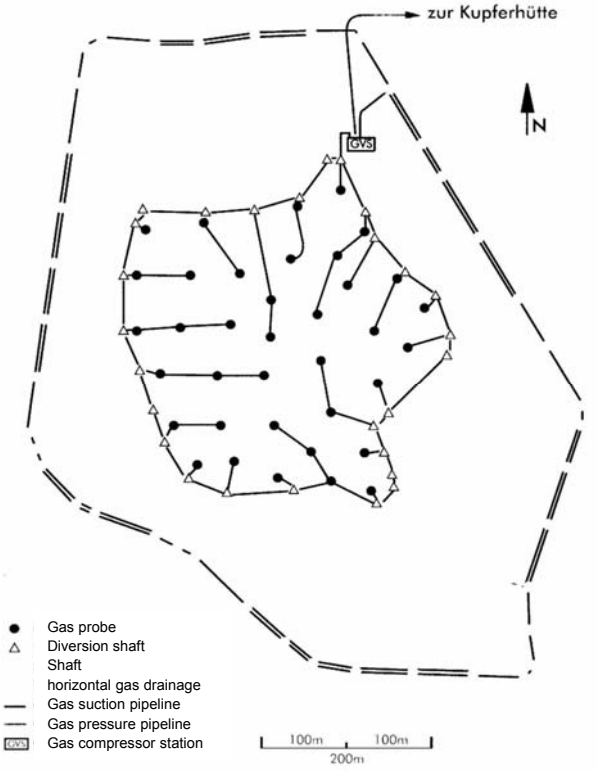
calcualted concentrations of VCHC [µg/L]



Catchment areas
of the safety wells after switching off FB1 and FB2

…distance 10 years
…over sea level
…ranges

Hamburg-Georgswerder - Degassing



- The relatively low-pollutant gas can be transferred without preliminary treatment to the nearby North German Finery.

The area of the Bille settlement, where particularly because of the gas no further living was possible, shall in future be used as green space. According to a ruling of the Hamburg Senate, a public golf links will be built there [4]. A private investor is planning to start the construction of a 9-hole course by 1999. As part of the building activities, the entire area will be covered with a 60 cm thick layer of uncontaminated soil as protection against direct contact and drifts. The Environmental Agency supports these safety costs up to a total sum of about 2.12 m €.

Sanitation Concept Landfill Hamburg-Georgswerder 1995