ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

VAPOR INTRUSION
Assessment and Mitigation

Dietmar MÜLLER-GRABHERR

Tel Aviv, 15.12.2016

Overview

- Mitigation – broad and/or specific
- Conceptual Site Model
- Comparing Assessment Criteria
- Modelling & / vs. Monitoring

- Factors for selecting technologies
- Technologies

Mitigation – the wider „Universe“

- source-oriented: **soil & groundwater clean-up**
  - long-term solution
  - achieving acceptable risk levels
- pathway-oriented: **building mitigation**
  - controlling vapors entering buildings
- receptor-oriented: **institutional controls**
  - use restrictions and monitoring

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Vapor Intrusion Mitigation Methods

Existing building – working inside or below?

- building pressurisation
- ventilation (indoor air treatment)
- passive barriers
- sealings and aerated floor systems
- Sub-slab depressurisation system
- Sub-slab pressurisation

,

Selecting Mitigation Methods

Crucial considerations

- Conceptual Site Model
- Risk Appraisal
- Long-term performance
  - *unless soil and groundwater remediation (or biodegradation) will decrease contaminant volatilisation reliable within a short timeframe*
- Maintenance and costs

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Conceptual Site Model (1)

Visualisation and description

- contaminant sources, affected media
- processes controlling contaminant fate and transport,
- migration pathways, potential receptors
  - building specifics

for understanding risks and uncertainties

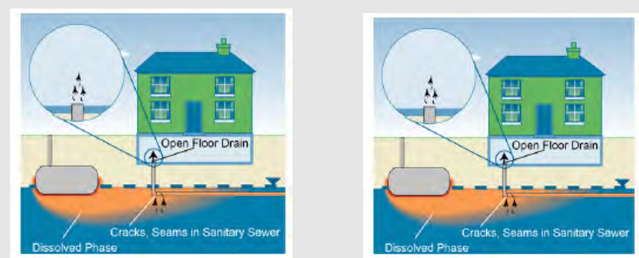
(NOTE: *iterative development with site investigation*!)

Conceptual Site Model (2)

Possibly governing factors

- relative source location (horizontal, vertical distance)
- age of contamination and biodegradability
- soil and groundwater conditions
- basements
- barriers and preferential pathways,
- occupancy and use

Source: ITRC, 2014



ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Soil Vapor Criteria – Comparison

Chemical	IRBCA residential 7-2 (a) AIR residential [mg/m³-air]	Commercial 7-2 (b) MAK/TRK commercial [mg/m³-air]	DE Baden.-W. [2005] trigger value residential [mg/m³-air]	AT ÖNORM S 2088-3 trigger value* commercial [mg/m³-air]	ÖNORM S 2088-1 trigger value groundwater [mg/m³-air]
Benzene	4,04E-02	6,99E-02	1,00E+01	3,20E+02	2,00E+00
BTEX	n.d.	n.d.	n.d.	n.d.	5,00E+00
gasoline C5 - C10	n.d.	n.d.	n.d.	2,50E+04	5,00E+01
Naphthalene	9,28E-03	1,60E-02	n.d.	n.d.	n.d.
Tetrachloroethylene	1,21E+00	2,10E+00	2,00E+02	3,45E+04	2,00E+00
Trichloroethylene	7,69E-02	1,33E-01	9,00E+01	2,50E+04	2,00E+00
Vinyl chloride	1,73E-02	1,24E-01	3,00E+01	4,60E+03	n.d
Cl-HC	n.d.	n.d.	n.d.	n.d.	5,00E+00
Mercury (Elemental)	4,06E-02	5,84E-02	n.d.	n.d.	nd.

General observation:

- **IRBCA criteria much more "sensitive"**
- **2 -3 orders of magnitude lower)**

***TV = MAK x TF**
TF = 100
[TF_{max} = 1000]

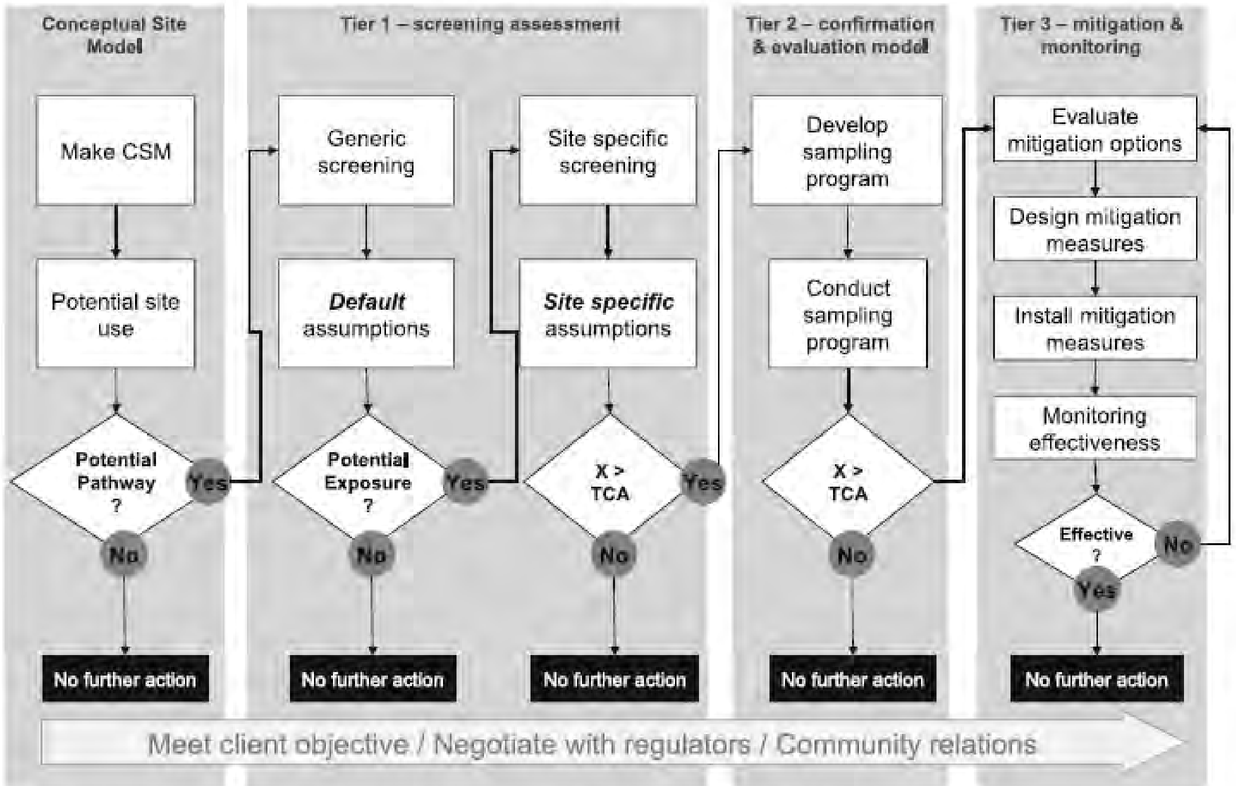
Soil Vapor Intrusion Models

7 algorithms compared [Provoost et. al 2010]

- algorithms tend to overestimate soil air concen-trations more than indoor air concentrations.
- differences between predictions and observations were up to three orders of magnitude.
- highest accuracy for predicting the soil air concen-tration are (in ascending order): Johnson& Ettin-ger model (JEM); Vlier–Humaan; VolaSoil
- Recommendation: a combination of modelling and measurements to produce multiple lines of evidence for HHRA or the need of actions.

Soil Vapor Intrusion

Recommended Tiered Approach [Provoost et. al 2010]



Flow sheet for multiple lines of evidence. *CSM* conceptual site model, *TCA* tolerable concentration in air

Source: Provoost et. al, 2010

Soil Vapor Intrusion
General Approach in Austria [ÖNORM S 2088-3; 2003]

- **Soil Vapour Intrusion Models: uncertainties prevail** – even not allowing for an "educated guess" (?)

- **<u>Stepwise Monitoring Approach</u>**
  i. Task 1 - source zone monitoring: Outdoor air (surface) + existing underground infrastructures (e.g. pipelines, canals, shafts, wells)
  ii. Task 2 - source zone & Pathway control: Soil vapor sampling
  iii. Task 3 – receptor surveillance: Indoor Air Monitoring and Sampling

Indoor Air Criteria – Comparison

	IRBCA	AT-Ord.	AT	
	Commercial	2011-II-429	ÖNORM S 2088-3	
	7-2 (b)	Workplace	[ref. DE/Hessia 1993]	
	AIR	MAK/TRK	**background values**	
Chemical	Indoor	Indoor	rural areas	urban areas
	[mg/m^3-air]	[mg/m^3-air]	[mg/m^3-air]	[mg/m^3-air]
Benzene	6,99E-04	3,20E+00	5,00E-03	5,00E-02
Naphthalene	1,60E-04	5,00E+01	n.r.	n.r.
Tetrachloroethylene	2,10E-02	3,45E+02	2,00E-03	1,50E-02
Trichloroethylene	1,33E-03	2,50E+02	1,00E-03	3,00E-02
Vinyl chloride	1,24E-03	5,00E+00	1,00E-04	3,00E-03
Mercury (Elemental)	5,84E-04	2,00E-02	n.r.	n.r.

General observation:

- **IRBCA criteria much more “sensitive”**
- **3 - 5 orders of magnitude lower)**

Factors for selecting technologies (1)

- location of vapor source
  - Conceptual Site Model
- building size (and height)
  - air volumes, air exchange rates
  - use of buildings (commercial vs. residential)
  - sections of buildings (warehouse vs. offices)

Factors for selecting technologies (2)

- foundation type and condition
  - foundation walls and other interruptions
  - technical underground structures as possible preferential pathways
    - heating and ventilation ducts
    - sumps, drains elevator (shafts)
  - cracks (short circuits) and penetrations

Factors for selecting technologies (3)

- soil conditions
  - permeability & lateral heterogeneity
- water conditions
  - soil water content (saturation)
  - high water table (permanent or periodic)
- contaminant properties
- identified concentration levels

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Passive methods

Barriers

- Asphalt/latex membrane
- Thermoplastic liner
- Epoxy floor sealant systems

Venting

- Subslab venting
- Aerated flooring

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Passive barriers (1)

CHALLENGES:

- fitting to existing surface structures and construction materials
- small imperfections (holes, tears, incomplete seals at pipe penetrations) may provide preferential pathways for significant vapour migration
- chemical and mechanical resistance
- permeability with regard to contaminants

,

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Passive barriers (2)

DESIGN CONSIDERATIONS

- often combined to venting
- combined application specifically to building sections or soil conditions
- enhancement easily possible

ADVANTAGES

- low to moderate capital costs
- regional contractors

Passive barrier systems (3)

- Do not expect complete elimination of vapours
- Need to be fit for normal construction (ab)use: barrier thickness or protective layers
- quality control procedures important
- test barriers integrity after installation
- contingencies for enhancement

Practice in general: "membrane only" is hardly found a long-term solution

Venting systems (1)

PREREQUESITES:

- crawl spaces or highly permeable sediments
- usually combined to a passive barrier

CHALLENGES:

- do not continuously operate
- advective air flow (wind and temperature effects)
- air flow typically less than by active systems

Venting systems (2)

DESIGN CONSIDERATIONS

- application to address possible or low frequency and modest vapor intrusion

ADVANTAGES

- modification for active venting easily feasible
- low maintenance efforts, no/low energy use accordingly low long-term costs

Active methods

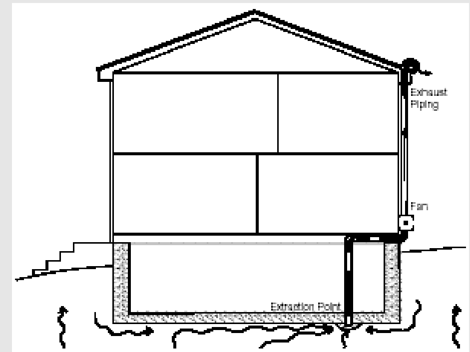
Below the building

- Subslab depressurization
- Subslab ventilation or crawl space venting
- Subslab pressurisation

Inside the building

- Building pressurisation
- Indoor air treatment

Subslab depressurization (1)



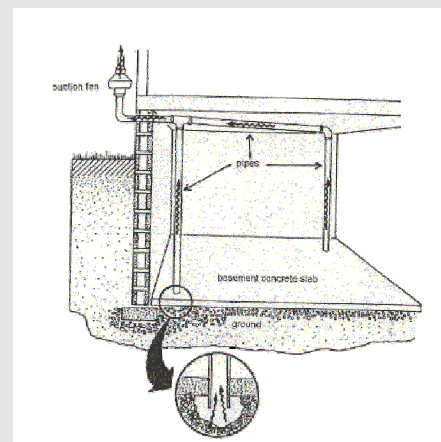
Source: www.nj.gov

TYPICAL APPLICATION

- permanent pressure differential
- most structures; sumps, drain tiles, block wall foundations

CHALLENGES

- low permeable and wet soils



Source: http://www.atsdr.cdc.gov/

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Subslab depressurization (2)

ADVANTAGES

- technology to a wide variety of site conditions
- demonstrated reliable and very effective system
- simple control

DISADVANTAGES

- maintenance, energy and costs
- building-specific conditions increase adaptive efforts

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Subslab pressurization (1)

TYPICAL APPLICATION

- same system like depressurization
- highly permeable soils
- commercial buildings

CHALLENGES

- cracks and penetrations causing short circuits
- air treatment and discharge permits

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Subslab pressurization (2)

ADVANTAGES

- oxygen may enhance biodegradation at shallow sources

DISADVANTAGES

- energy and cost-intensive

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Building pressurization

TYPICAL APPLICATION

- commercial buildings (HVAC Optimization)

CHALLENGES

- requires regular air balancing and maintenance

ADVANTAGES

- considered the most effective technology

DISADVANTAGES

- generally more costly
- performance decrease during power outage

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Indoor Air Treatment

TYPICAL APPLICATION

- immediate response; in parallel to remediation
- low impact

ADVANTAGES

- contaminant removal

DISADVANTAGES

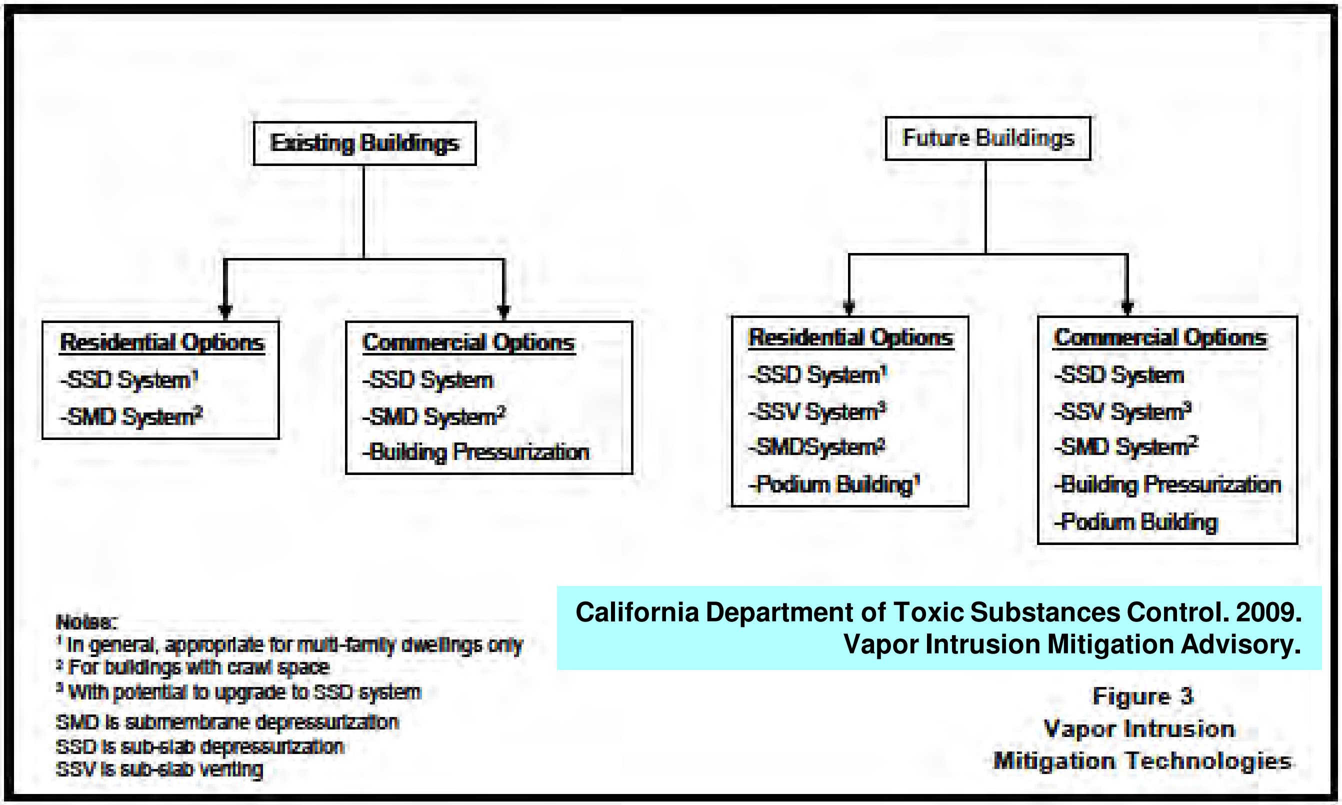
- generally less effective technology
- relatively expensive to install, operate, maintain
- generates waste

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Comparison of Mitigation Technologies

Technology	Typical application	Advantages	Disadvantages	Challenges
Passive barrier				
Venting				
SSD				
SMD				
SSP				
Building pressurisation				
Indoor air treatment				

Mitigation Technologies - Overview



California Department of Toxic Substances Control. 2009. Vapor Intrusion Mitigation Advisory.

Figure 3
Vapor Intrusion
Mitigation Technologies

WATCH OUT: ROBUSTNESS in Risk Management / Mitigation

➔ Combining Technologies („building lines of defense“)

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

THANKS!

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

General Design Considerations

- visual inspection
- design approach
  - detailed diagnostic testing vs. standard system
- discharge permits and emission controls
- preferences of the owner (tenant)
- access and scheduling limitations for installation
- presence of other environmental hazards
- intrinsically safe equipment

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Performance Criteria

benchmarks for monitoring performance and whether mitigation objectives are met

- direct: contaminant concentration
- Indirect:
  - subslab samples (contaminants, CO_2, CH_4, O_2)
  - smoke or tracer gas testing
  - pressure differentials distant to extraction points
  - effective diffusivity testing (manufacturer, contractor)

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

Operation, Maintenance & Monitoring

OM&M-plan is an integral part of mitigation to document and adjust long-term performance, e.g.

- indoor air testing
- regular inspections
- diagnostic tests (and system modifications)
- emission controls
- warning devices
- closure (active methods + OM&M)

,