Countermeasures Against Ground Water and Soil Contaminations and Case studies

Environmental Quality Standards of Soils in Japan

Substance	Target level of soil quality examined through leaching and content tests
cadmium	0.01 mg/l in sample solution and less than 1 mg/kg in rice for paddy fields
total cyanide	not detectable in sample solution
organic phosphorus	not detectable in sample solution
lead	0.01 mg/l or less in sample solution
chromium (VI)	0.05 mg/l or less in sample solution
arsenic	0.01 mg/l or less in SS, and less than 15 mg/kg in soil for paddy fields
total mercury	0.0005 mg/l or less in sample solution
alkyl mercury	not detectable in sample solution
PCBs	not detectable in sample solution
copper	less than 125 mg/kg in soil for paddy fields
dichloromethane	0.02 mg/l or less in sample solution
carbon tetrachloride	0.002 mg/l or less in sample solution
1,2-dichloroethane	0.004 mg/l or less in sample solution
1,1-dichloroethylene	0.02 mg/l or less in sample solution
cis-1,2-dichloroethylene	0.04 mg/l or less in sample solution
1,1,1-trichloroethane	1 mg/l or less in sample solution
1,1,2-trichloroethane	0.006 mg/l or less in sample solution
trichloroethylene	0.03 mg/l or less in sample solution
tetrachloroethylene	0.01 mg/l or less in sample solution
1,3-dichloropropene	0.002 mg/l or less in sample solution
thiuram	0.006 mg/l or less in sample solution
simazine	0.003 mg/l or less in sample solution
thiobencarb	0.02 mg/l or less in sample solution
benzene	0.01 mg/l or less in sample solution
selenium	0.01 mg/l or less in sample solution

Leaching test sample concentration from standard test *mixing method, time, pH* according to the chemical properties

Japan JIS, USEPA TCLP

Standards of Soil Contamination Prevention law

Substance	Leaching concentration (* ST-II)	Total contents	Remarks
cadmium	< 0.01 mg/Lin SS (*0.3mg/L)	< 150mg/kg	
total cyanide	not detectable in SS (*1.0mg/L)	< (Free cyanide)50mg/kg	
lead	< 0.01 mg/Lin SS (*0.3mg/L)	< 150mg/kg	
chromium (VI)	< 0.05 mg/Lin SS (*1.5mg/L)	< 250mg/kg	
arsenic	< 0.01 mg/L in SS (*0.3mg/L)	< 150mg/kg	
total mercury	< 0.0005 mg/Lin SS (*0.005mg/L)	< 15mg/kg	
alkyl mercury	not detectable in SS (*not detected)		
fluorine	< 0.8 mg/Lin SS (*24mg/L)	< 4,000mg/kg	not included in Env St.
boron	< 1 mg/Lin SS (*30mg/L)	< 4,000mg/kg	
(copper)			Item of Env. S
dichloromethane	< 0.02 mg/L in SS (*0.2mg/L)		
carbon tetrachloride	< 0.002 mg/L in SS (*0.02mg/L)		
1,2-dichloroethane	< 0.004 mg/L in SS (*0.04mg/L)		
1,1-dichloroethylene	< 0.02 mg/L in SS (*0.2mg/L)		
cis-1,2-dichloroethylene	< 0.04 mg/L in SS (*0.4mg/L)		
1,1,1-trichloroethane	< 1 mg/L in SS (*3mg/L)		
1,1,2-trichloroethane	< 0.006 mg/Lin SS (*0.06mg/L)		
trichloroethylene	< 0.03 mg/Lin SS (*0.3mg/L)		
tetrachloroethylene	< 0.01 mg/L in SS (*0.1mg/L)		
1,3-dichloropropene	< 0.002 mg/Lin SS (0.02mg/L)		
benzene	< 0.01 mg/Lin SS (0.1mg/L)		
thiuram	< 0.006 mg/Lin SS (*0.06mg/L)		
simazine	< 0.003 mg/Lin SS (*0.03mg/L)		
thiobencarb	< 0.02 mg/Lin SS (*0.2mg/L)		
selenium	< 0.01 mg/Lin SS (*0.3mg/L)	<150mg/kg	
PCBs	not detectable in SS (*< 0.003mg/L)		
organic phosphorus	not detectable in SS ((*1.0mg/L)		

Leaching concentration for the risk from contaminated GW

vs

Total content for risk of direct intake from the soils

Countermeasures against soil contamination

against risks from

Direct intake of soils

- •Restriction of entering the site
- •Pavement
- •Cover by fill or sheet
- •Replacement of top soils
- •In-situ containment by barrier and cover (for small C.)
- •In-situ containment by secured barrier and cover (high C.)
- • In-situ remediation

Intake of ground water

- •In-situ anti-leaching treatment
- •Excavation + anti-leaching +fill
- •Replacement of top soils
- •In-situ containment by barrier and cover (for small C.)
- •In-situ containment by secured barrier and cover (high C.)
- • In-situ remediation
- •Excavation + transport
- •Excavation + site treatment

Remediation of contaminated sites

Prevention of expansion
(*containment, anti-leaching*)

Most passive??

In-situ remediation - Physical *extraction*
sorption
- Chemical *degradation*
- Biological *degradation*
- *Thermal*
- Combination

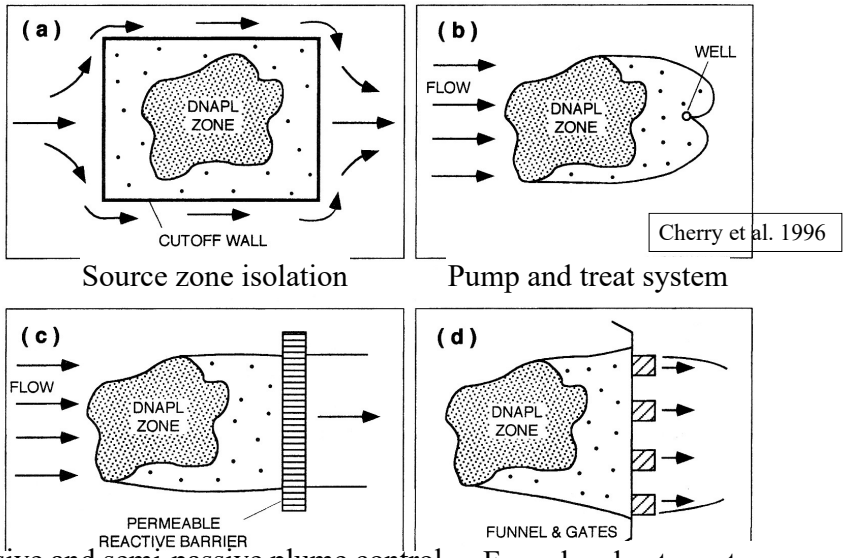
More Geotechnical

Source & ***Plume***

Phytoremediation
plants

Ex-situ remediation - Physical
- Chemical
- Biological
- Thermal

Engineering remedial action on contaminated sites

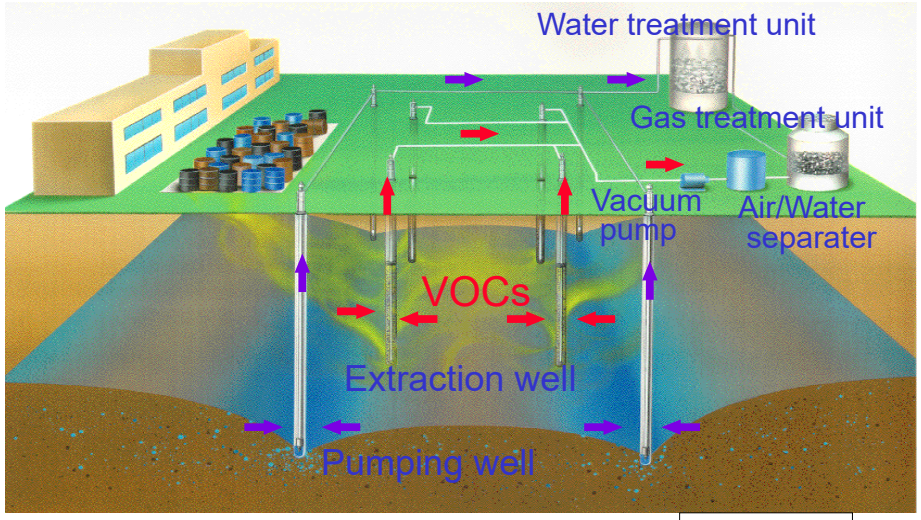


Cherry et al. 1996

Source zone isolation — Pump and treat system

Passive and semi-passive plume control — Funnel and gate system

SVE (Soil Vapor Extraction) System

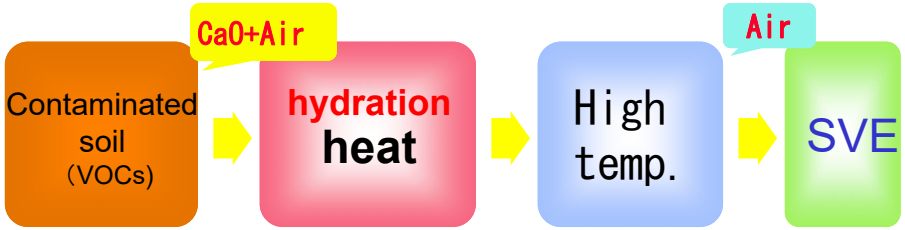


Imamura, 2003

Lime mixing SVE（石灰混合土壌ガス抽出法）

Especially for cohesive soil

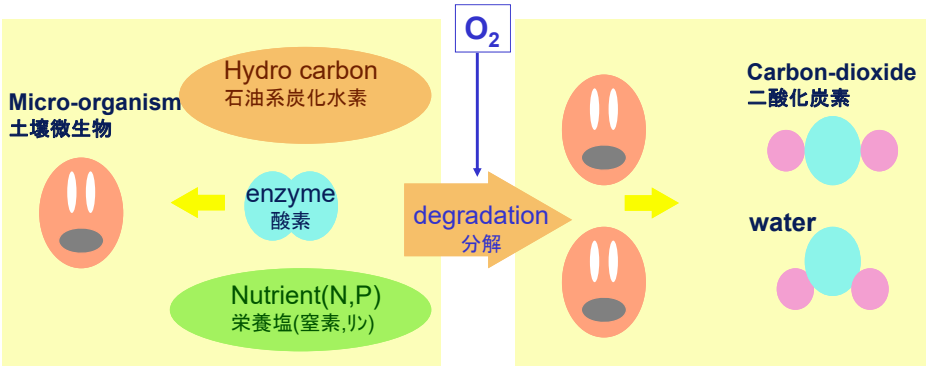
principle



$$CaO + H_2O \rightarrow Ca(OH)_2 + 15.6kcal$$

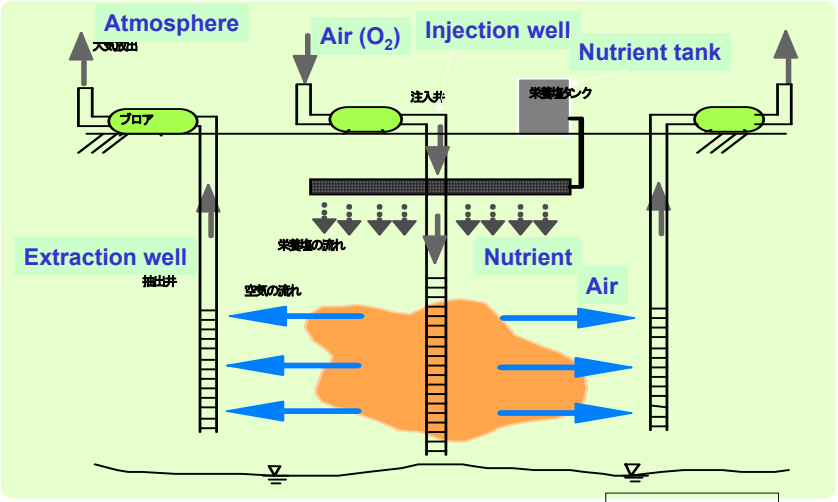
Imamura, 2003

Bio-remediation
～Principle of Fuel Hydrocarbon～



Imamura, 2003

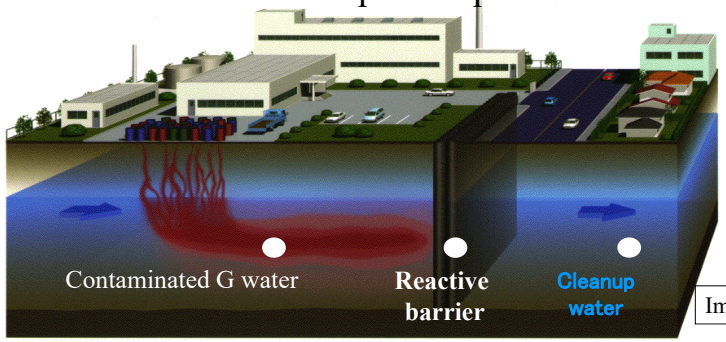
Bio-venting



Imamura, 2003

Permeable reactive barrier(透過性浄化壁)

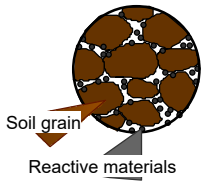
Passive and semi-passive plume control



Imamura, 2003

Reactive materials: Capture and degradation
Ex. iron base， Bio-polymer
Soils ：**high permeability**
Ex:（silica，gravel）

Inside Reactive barrier



Selection and Applicability of Treatment Methods

- System Reliability
- Capital(short and long time)
- Time
- Types of contaminant
- Level of contamination (**Concentration**, **Area**, ***Depth***)
- Types of soils
- Ground water table
- Surrounding environment
- etc.

"Treatment Technologies Screening Matrix and Reference Guide" for hazardous waste remediation by
The Federal Remediation Technology Roundtable (FRTR)

established 1991
an interagency committee
Dept. Defense (AF, Army, Navy)
Dept. Energy, Dept. Interior, EPA,
National Aeronautics and Space Agency

http://www.frtr.gov/matrix2/Preface/foreword.html

https://frtr.gov/matrix2/section3/table3_2.pdf

TABLE 3-2: TREATMENT TECHNOLOGIES SCREENING MATRIX

Rating Codes ● Above Average ◑ Average ○ Below Average N/A - "Not Applicable" I/D - "Insufficient Data" ◈ - Level of Effectiveness highly dependent upon specific contaminant and its application	Development Status	Treatment Train	Relative Overall Cost & Performance: O&M	Capital	System Reliability & Maintainability	Relative Costs	Time	Availability	Nonhalogenated VOC's	Halogenated VOC's	Nonhalogenated SVOC's	Halogenated SVOC's	Fuels	Inorganics	Radionuclides	Explosives
Soil, Sediment, Bedrock, and Sludge																
3.1 In Situ Biological Treatment																
4.1 Bioventing	●	●	●	●	●	●	◑	●	●	◈	●	○	●	○	◈	○
4.2 Enhanced Bioremediation	●	●	○	◑	◑	●	◑	●	●	●	●	◈	●	◈	◈	●
4.3 Phytoremediation	●	●	●	●	○	●	○	◑	◑	◑	◑	◈	◑	◑	○	○
3.2 In Situ Physical/Chemical Treatment																
4.4 Chemical Oxidation	●	●	○	◑	◑	◑	●	●	◑	◑	○	◑	○	◈	○	◑
4.5 Electrokinetic Separation	●	○	○	◑	◑	○	◑	◑	◑	◑	◑	◑	○	●	◑	○
4.6 Fracturing	●	◑	◑	○	◑	◑	◑	●	◑	◑	◑	◑	◑	○	○	○
4.7 Soil Flushing	●	●	○	◑	◑	●	◑	●	●	●	○	◑	◑	●	○	○
4.8 Soil Vapor Extraction	●	○	○	◑	●	●	◑	●	●	●	○	○	●	○	○	○
4.9 Solidification/Stabilization	●	●	◑	○	●	●	●	●	○	○	◑	◑	○	●	●	○
3.3 In Situ Thermal Treatment																
4.10 Thermal Treatment	●	○	○	○	●	◑	●	●	●	●	●	●	●	○	○	○
3.4 Ex Situ Biological Treatment (assuming excavation)																
4.11 Biopiles	●	●	●	●	●	●	◑	●	●	●	◑	◈	●	◈	○	○
4.12 Composting	●	●	●	●	●	●	◑	●	◑	◑	◑	◈	●	○	○	●
4.13 Landfarming	●	●	●	●	●	●	◑	●	◑	◑	●	◈	●	○	○	◈
4.14 Slurry Phase Biological Treatment	●	○	○	○	◑	◑	◑	●	◑	●	●	◈	●	◈	○	●
3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)																
4.15 Chemical Extraction	●	○	○	○	◑	◑	◑	●	◑	◑	●	●	◑	●	◑	○
4.16 Chemical Reduction /Oxidation	●	◑	◑	○	●	◑	●	●	◑	◑	◑	◑	○	●	○	◑
4.17 Dehalogenation	●	◑	○	○	○	○	◑	◑	○	●	○	●	○	○	○	◑
4.18 Separation	●	◑	○	◑	●	◑	●	●	◑	◑	◑	◑	○	◑	○	○
4.19 Soil Washing	●	○	○	○	●	◑	●	●	◑	◑	◑	◑	○	◑	○	○
4.20 Solidification/Stabilization	●	●	◑	○	●	●	●	●	○	○	◑	◑	○	●	●	○

TABLE 3-2: TREATMENT TECHNOLOGIES SCREENING MATRIX

Rating Codes ● Above Average ◑ Average ○ Below Average N/A - "Not Applicable" I/D - "Insufficient Data" ◈ - Level of Effectiveness highly dependent upon specific contaminant and its application	Development Status	Treatment Train	Relative Overall Cost & Performance: O&M	Capital	System Reliability & Maintainability	Relative Costs	Time	Availability	Nonhalogenated VOC's	Halogenated VOC's	Nonhalogenated SVOC's	Halogenated SVOC's	Fuels	Inorganics	Radionuclides	Explosives
Soil, Sediment, Bedrock, and Sludge																
3.6 Ex Situ Thermal Treatment (assuming excavation)																
4.21 Hot Gas Decontamination	○	●	○	○	●	●	●	◑	○	○	○	○	○	○	○	○
4.22 Incineration	●	●	○	○	◑	○	●	●	◑	●	◑	●	◑	○	○	●
4.23 Open Burn/Open Detonation	●	●	○	○	●	●	●	●	○	○	○	○	○	○	○	●
4.24 Pyrolysis	●	●	○	○	○	○	●	●	◑	◑	●	●	◑	○	○	○
4.25 Thermal Desorption	●	●	○	○	◑	●	●	●	●	●	●	●	●	○	○	●
3.7 Containment																
4.26 Landfill Cap	●	●	◑	○	●	●	○	●	◑	◑	◑	◑	◑	◑	○	◑
4.27 Landfill Cap Enhancements/Alternatives	●	●	◑	○	●	●	○	●	◑	◑	◑	◑	◑	◑	○	◑
3.8 Other Treatment																
4.28 Excavation, Retrieval, Off-Site Disposal	●	●	●	●	●	◈	●	●	◑	◑	◑	◑	◑	◑	○	◑

TABLE 3-2: TREATMENT TECHNOLOGIES SCREENING MATRIX

Rating Codes ● Above Average ◑ Average ○ Below Average N/A - "Not Applicable" I/D - "Insufficient Data" ◈ - Level of Effectiveness highly dependent upon specific contaminant and its application	Development Status	Treatment Train	Relative Overall Cost & Performance: O&M	Capital	System Reliability & Maintainability	Relative Costs	Time	Availability	Nonhalogenated VOC's	Halogenated VOC's	Nonhalogenated SVOC's	Halogenated SVOC's	Fuels	Inorganics	Radionuclides	Explosives
Ground Water, Surface Water, and Leachate																
3.9 In Situ Biological Treatment																
4.29 Enhanced Bioremediation	●	●	○	◑	◑	●	◈	●	●	◈	●	◈	●	◈	○	◑
4.30 Monitored Natural Attenuation	●	●	○	◑	◑	●	◈	●	●	◑	◑	◑	●	○	○	○
4.31 Phytoremediation	●	●	●	●	○	●	○	◑	◑	◑	◑	◑	◑	◈	○	○
3.10 In Situ Physical/Chemical Treatment																
4.32 Air Sparging	●	●	●	●	●	●	●	●	●	◑	◑	◑	●	○	○	○
4.33 Biosurping	●	◑	●	●	◑	●	◑	●	◑	◑	●	●	●	◑	○	○
4.34 Chemical Oxidation	●	●	○	◑	◑	◑	●	●	◑	◑	○	◑	○	◈	○	◑
4.35 Directional Wells (enhancement)	●	●	◑	○	◑	◑	◑	●	◑	◑	◑	◑	◑	◑	○	◑
4.36 Dual Phase Extraction	●	○	○	○	◑	◑	◑	●	●	●	●	●	●	○	○	○
4.37 Thermal Treatment	●	○	○	○	◑	◑	●	●	●	●	●	●	●	○	○	○
4.38 Hydrofracturing Enhancements	●	◑	●	●	●	◑	◑	●	◑	◑	◑	◑	◑	◑	○	◑
4.39 In-Well Air Stripping	●	◑	◑	○	◑	◑	○	●	◑	◑	◑	○	◑	○	○	○
4.40 Passive/Reactive Treatment Walls	●	●	◑	○	●	◑	○	●	●	●	●	●	◑	◈	○	●
3.11 Ex Situ Biological Treatment																
4.41 Bioreactors	●	●	◑	○	◑	◑	◑	●	●	●	●	◈	●	○	○	●
4.42 Constructed Wetlands	●	●	◑	○	◈	◑	◈	○	◑	◑	◑	◈	◑	●	○	●
3.12 Ex Situ Physical/Chemical Treatment (assuming pumping)																
4.43 Adsorption/ Absorption	●	◑	○	◑	◑	○	○	●	◑	◑	◑	◑	○	●	◈	○
4.44 Advanced Oxidation Processes	●	◑	○	◑	◑	○	○	●	●	●	●	●	●	◈	○	●
4.45 Air Stripping	●	◑	○	◑	●	●	○	●	●	●	○	○	○	○	○	○
4.46 Granulated Activated Carbon/Liquid Phase Carbon Adsorption	●	◑	○	◑	●	◑	○	●	●	●	●	●	●	◈	○	◈
4.47 Groundwater Pumping/Pump & Treat	●	◑	○	○	●	○	○	●	◑	◑	◑	◈	◑	◑	○	◑
4.48 Ion Exchange	●	◑	○	○	●	◑	○	●	○	○	○	○	○	●	◑	○
4.49 Precipitation/Coagulation/Flocculation	●	◑	◑	○	●	◑	○	●	○	○	○	○	○	●	◑	○
4.50 Separation	●	◑	○	○	●	○	●	●	●	●	●	●	●	◈	◈	○
4.51 Sprinkler Irrigation	●	●	●	●	●	○	○	●	●	●	○	○	○	○	○	○
3.13 Containment																
4.52 Physical Barriers	●	●	●	●	○	●	○	●	●	●	●	●	●	●	●	●
4.53 Deep Well Injection	●	●	●	●	◑	●	○	●	◑	◑	◑	◑	◑	◑	◑	◑

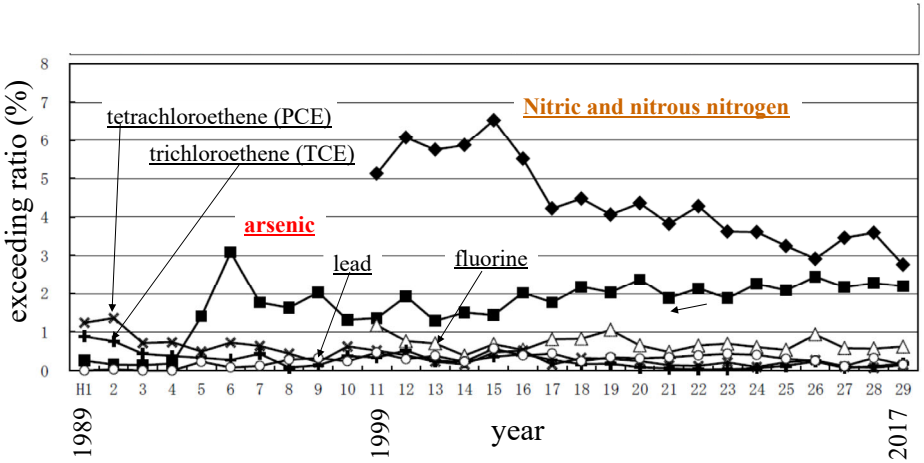
TABLE 3-2: TREATMENT TECHNOLOGIES SCREENING MATRIX

Rating Codes ● Above Average ◑ Average ○ Below Average N/A - "Not Applicable" I/D - "Insufficient Data" ◈ - Level of Effectiveness highly dependent upon specific contaminant and its application	Development Status	Treatment Train	Relative Overall Cost & Performance: O&M	Capital	System Reliability & Maintainability	Relative Costs	Time	Availability	Nonhalogenated VOC's	Halogenated VOC's	Nonhalogenated SVOC's	Halogenated SVOC's	Fuels	Inorganics	Radionuclides	Explosives
3.14 Air Emissions/Off-Gas Treatment																
4.54 Biofiltration	●	N/A	●	●	◈	●	●	○	●	◈	◈	◈	●	○	I/D	◈
4.55 High Energy Destruction	○	N/A	I/D	I/D	○	◑	I/D	◑	●	●	●	●	◑	◑	I/D	○
4.56 Membrane Separation	○	N/A	I/D	I/D	○	◑	I/D	◑	●	●	◑	◑	◑	○	I/D	◑
4.57 Oxidation	●	N/A	●	●	●	●	I/D	●	●	●	●	●	●	○	I/D	◑
4.58 Scrubbers	●	N/A	◑	○	●	●	I/D	●	○	○	○	○	○	●	I/D	I/D
4.59 Vapor Phase Carbon Adsorption	●	N/A	●	●	●	●	I/D	●	●	●	●	●	●	◑	I/D	●

TABLE 3-1: DEFINITION OF SYMBOLS USED IN THE TREATMENT TECHNOLOGIES SCREENING MATRIX

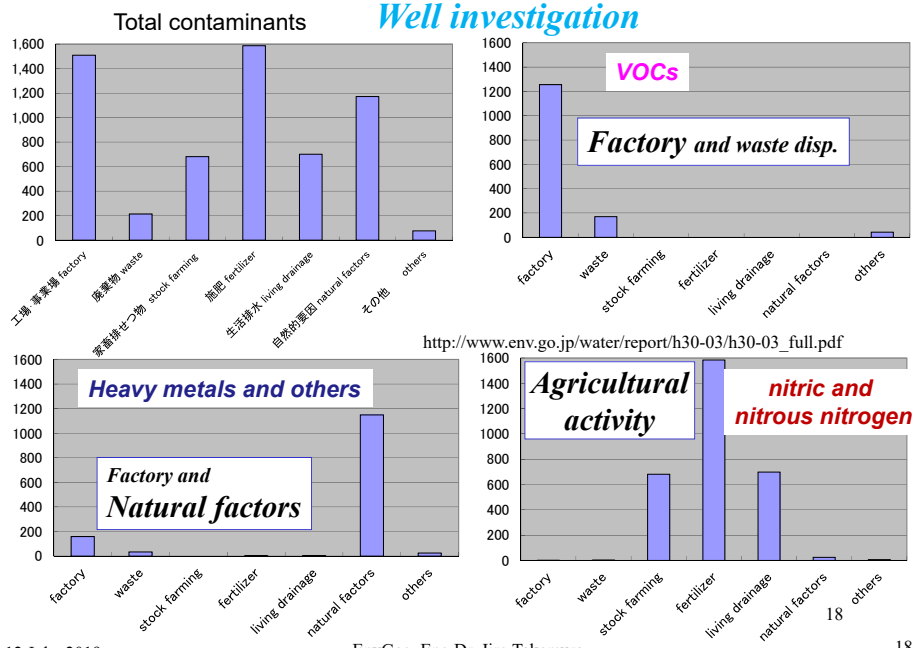
Factors		● Above Average	◑ Average	○ Below Average	Other
Development Status Scale status of an available technology		Implemented as part of the final remedy at multiple sites, well documented, understood, etc.	Has been implemented at full scale but still needs improvements, testing, etc.	Not been fully implemented but has been tested (pilot, bench, lab scale) and is promising	◈ Level of Effectiveness highly dependent upon specific contaminant and its application/ design
Treatment Train Is the technology only effective as part of the treatment train?		Stand-alone technology (not complex in terms of number of media/treatment technologies, maybe one "routine" technology in addition)	Relatively simple (two-car train or so), and well understood, widely applied, etc.	Complex (more technologies, media to be treated, generates excessive waste, etc.)	
Relative overall cost and performance	**O&M** Operation and Maintenance Intensive	Low degree of O&M intensity	Average degree of O&M intensity	High degree of O&M intensity	
	Capital Capital Intensive	Low degree of capital investment	Average degree of capital investment	High degree of capital investment	
	System Reliability /Maintainability The expected range of demonstrated reliability and maintenance relative to other effective technologies	High reliability and low maintenance	Average reliability and average maintenance	Low reliability and high maintenance	N/A "Not Applicable"
	Relative Costs Design, construction, and operations and maintenance (O&M) costs of the core process that defines each and pre-and post-treatment	Low degree of general costs relative to other options	Average degree of general costs relative to other options	High degree of general costs relative to other options	I/D "Insufficient Data"
	Time Time required to clean up a "standard" site using the technology — in situ soil	Less than 1 year	1-3 years	More than 3 years for in situ soil	
	— ex situ soil	Less than 0.5 year	0.5-1 year	More than 1 year for ex situ soil	
	— groundwater	Less than 3 years	3-10 years	More than 10 years for water	
	Availability Number of vendors that can design, construct, and maintain the technology	More than 4 vendors	2-4 vendors	Fewer than 2 vendors	
Contaminants Treated Contaminants are classified into eight groups: - Nonhalogenated VOCs - Halogenated VOCs - Fuels - Inorganics		Effectiveness Demonstrated at Pilot or Full Pilot or Full Scale	Limited Effectiveness Demonstrated at Pilot or Full Scale	No Demonstrated Effectiveness at Pilot or Full Scale	Same as above

Chronological variation of exceeding ratio : General survey investigation



http://www.env.go.jp/water/report/h30-03/h30-03_full.pdf

Sources of GW contamination 2017汚染原因(項目別分類)



http://www.env.go.jp/water/report/h30-03/h30-03_full.pdf

Remediation taken for ground water cleaning 2017

Remedial methods	Number of sites: total †	VOC	Heavy metals	Nitrite Nitrate	combined
地下水揚水処理 P&T	898 (562)	715 (433)	111 (77)	1 (1)	71 (51)
Bioremediation	123 (79)	112 (72)	1 (1)	0 (0)	10 (6)
Other in-situ treatment)	152 (65)	123 (48)	13 (8)	0 (0)	16 (9)
Soil vapor gas extraction	262 (184)	245 (174)	1 (1)	0 (0)	16 (9)
Contaminated soil treatment	548 (291)	371 (181)	125 (73)	0 (0)	52 (37)
Others Removal, containment, Barrier well, etc.	170 (131)	120 (94)	31 (23)	5 (3)	14 (11)
母 数	1, 289 (779)	988 (575)	201 (133)	6 (4)	94 (67)

http://www.env.go.jp/water/report/h30-03/h30-03_full.pdf

Status of GW remediation work 2017

http://www.env.go.jp/water/report/h30-03/h30-03_full.pdf

Status of remediation work	Base number	number: Source of contamination: Factory: Polluter known	Factory: Polluter unknown	waste: Polluter known	waste: Polluter unknown	Agriculture	Natural factors	Source unknown
実 Done, under operation	1, 289 (779)	1, 056 (646)	9 (5)	119 (68)	10 (6)	3 (1)	7 (1)	136 (86)
休 Under consideration	453 (393)	112 (89)	6 (5)	17 (12)	2 (1)	216 (193)	13 (13)	94 (81)
Not scheduled	5, 774 (4, 410)	281 (158)	45 (34)	49 (32)	16 (10)	1, 393 (1, 205)	1, 098 (970)	1, 265 (995)
Base number	7, 516 (5, 582)	1, 449 (893)	60 (44)	185 (112)	28 (17)	1, 586 (1, 388)	1, 172 (1, 031)	3, 038 (2, 086)

Reasons of these difference?

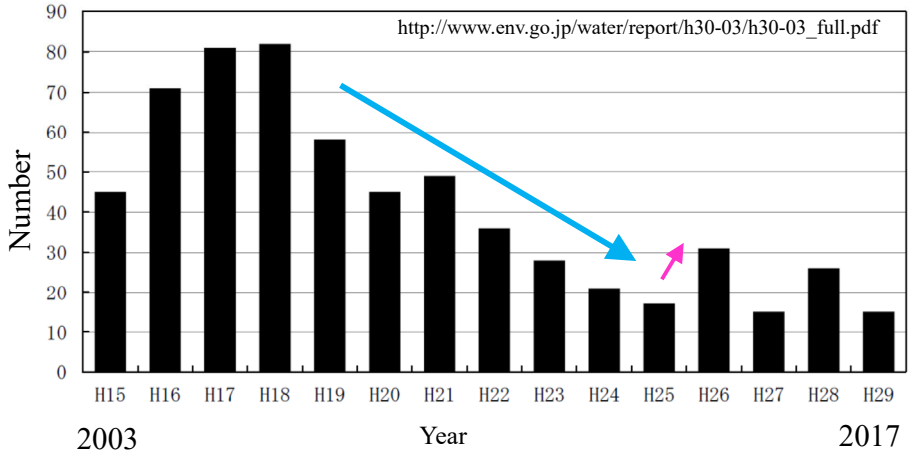
Body taking GW remediation 2017

http://www.env.go.jp/water/report/h30-03/h30-03_full.pdf

number

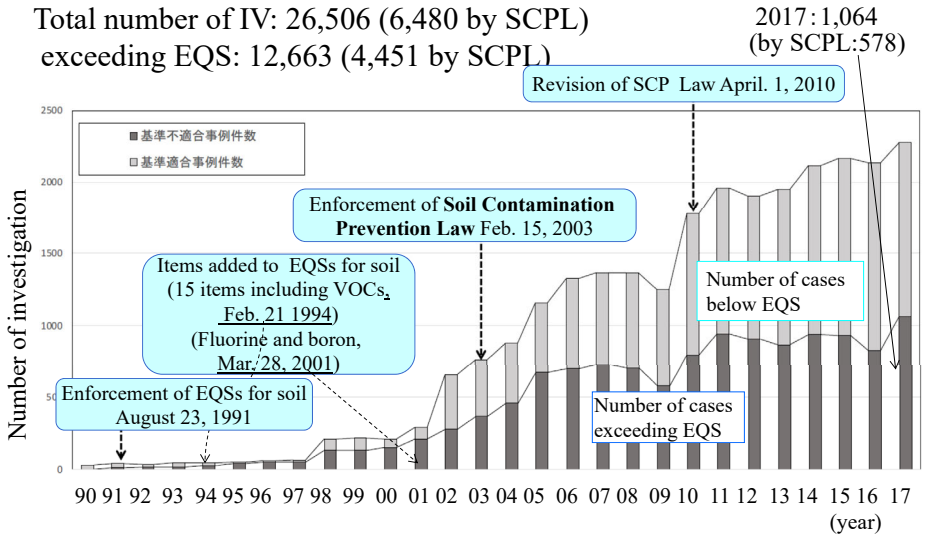
Body taking remediation	母数 Base number	汚染原因 Source of contamination: factory Polluter known	factory Polluter unknown	waste Polluter known	waste Polluter unknown	Agri-culture 地下浸透	natural factors	汚染 source unknown
polluter	998 (591)	935 (560)	0 (0)	99 (55)	0 (0)	1 (0)	0 (0)	19 (12)
multi- polluter	15 (13)	13 (12)	0 (0)	3 (2)	0 (0)	0 (0)	0 (0)	1 (1)
land owner（注３）	178 (100)	71 (40)	7 (5)	12 (7)	3 (2)	0 (0)	7 (1)	81 (47)
local gov.（注３）	83 (65)	48 (42)	2 (0)	9 (7)	4 (2)	1 (0)	0 (0)	26 (20)
その他 others	24 (18)	12 (9)	0 (0)	3 (2)	0 (0)	1 (1)	0 (0)	7 (6)
不明 **unknown**	11 (8)	2 (2)	0 (0)	1 (1)	3 (2)	1 (1)	0 (0)	5 (3)
Base number	1, 289 (779)	1, 056 (646)	9 (5)	119 (68)	10 (6)	4 (2)	7 (1)	136 (86)

Number of GW contamination caused by factory found in general survey



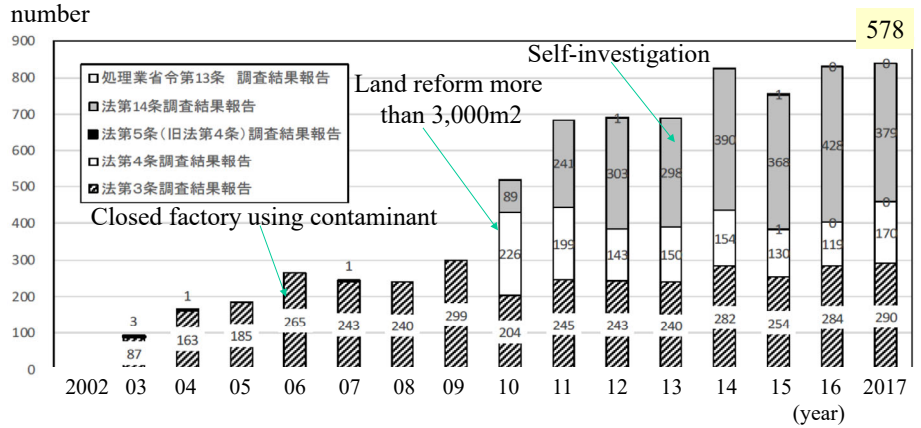
Number of soil contamination cases identified in Japan

Total number of IV: 26,506 (6,480 by SCPL)
exceeding EQS: 12,663 (4,451 by SCPL)



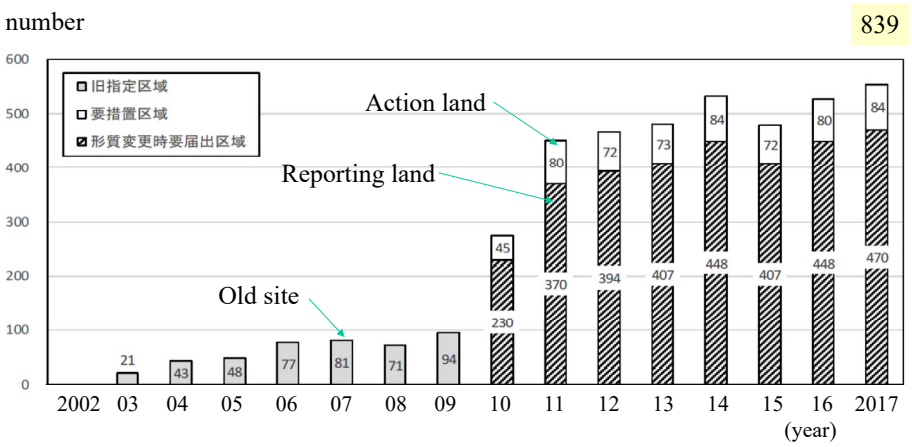
http://www.env.go.jp/water/report/h31-01/full.pdf

Reported number of soil contamination investigation in Japan by SCPL



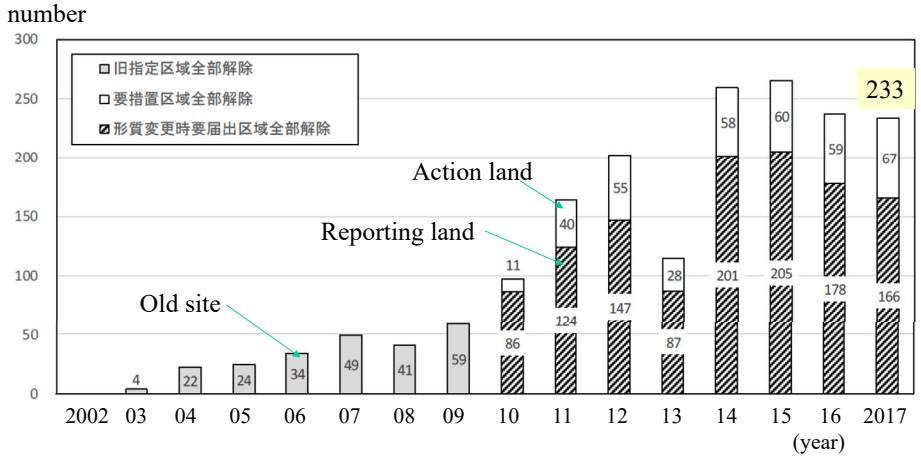
http://www.env.go.jp/water/report/h31-01/full.pdf

Soil contamination **designated** site by SCPL



http://www.env.go.jp/water/report/h31-01/full.pdf

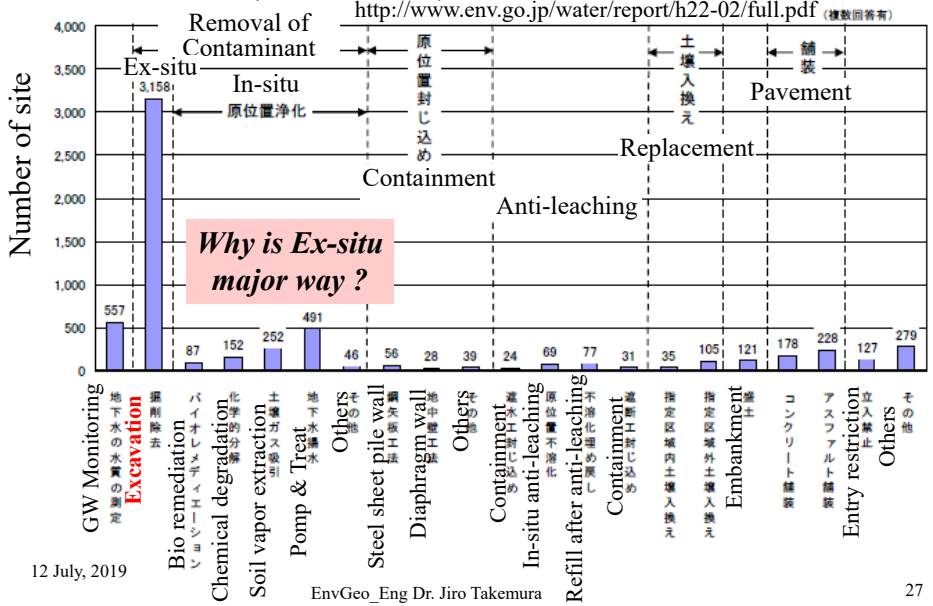
Unlisted sites from SC designation under SCPL



http://www.env.go.jp/water/report/h31-01/full.pdf

Remediation at the sites of ***soil contamination*** (1991-2009) Report by MOE

http://www.env.go.jp/water/report/h22-02/full.pdf (複数回答有)



Remediation of soil contamination reported by MOE

http://www.env.go.jp/water/dojo/gb_me/index.html

http://www.env.go.jp/water/report/h31-01/full.pdf

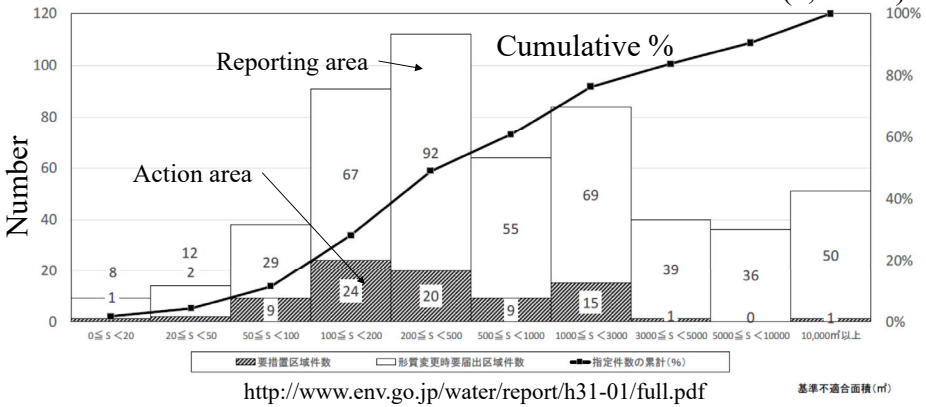
		Action land		Reporting land		Total site number		VOCs		Heavy Metals		Pesicids		Combined	
Measures		2017	10-'17	2017	10-'17	2017	10-'17	2017	10-'17	2017	10-'17	2017	10-'17	2017	10-'17
Pavement		2	15	8	124	10	139	1	3	8	106	0	0	1	30
off-limit		0	20	3	58	3	78	0	2	2	64	0	0	1	12
soil replacement	with area soils	0	5	1	34	1	39	0	1	1	32	0	0	0	6
	with out area soils	0	3	1	11	1	14	0	0	1	13	0	0	0	1
Embankment		0	4	1	55	1	59	0	0	1	44	0	0	0	15
GW monitoring		**29**	**210**	**14**	**233**	**43**	**443**	7	48	33	333	0	0	3	62
in-situ containment (barrier wall)		1	8	1	8	2	16	0	1	2	7	0	0	2	8
liner containment		0	4	0	6	0	10	0	2	0	4	0	0	0	4
prevention of expansion		0	18	0	17	0	35	0	18	0	4	0	0	0	12
strictly controlled containment		0	0	1	2	1	2	0	0	1	1	0	0	0	1
unti-leaching	in-situ	0	6	1	4	1	10	0	0	1	5	0	0	1	5
	ex-situ and fill	0	7	0	15	0	22	0	0	0	13	0	0	0	9
cont soil removal	Excavation	**72**	**539**	**233**	**2,091**	**305**	**2,630**	32	177	240	2,095	2	4	33	355
	in-situ remeadiation	11	121	5	90	16	211	12	113	0	23	0	1	4	74
others		0	7	7	122	7	129	0	10	3	98	0	0	4	21
Total reported sites		92	731	265	2,622	357	3,533	44	315	276	2,536	0	5	37	497

What are differences in the groups? How to interpret the data?

Area of Soil Contamination found in Japan (2017)

	All (action A)	VOCs	HM	Pesticide	Combined
Average:	5.36 (1.11)	14.6	3.29	0	13.7
Max:	237.9 (41.1)	198.2	237.9	0	221.7
Total area:	2,890 (91.1)	738.0	1,435	0	727

(1,000m^2)



http://www.env.go.jp/water/report/h31-01/full.pdf

Depth of Soil Contamination found in Japan (2017) after enforcement of SCPL

	All (action A)	VOCs	HM	Pesticide	Combined
Average:	3.4 (2.6)	3.5	3.3	0	5.7
Max:	10.1 (75.0)	10.0	75	0	15.0

(m)

Soil contamination :relatively shallow

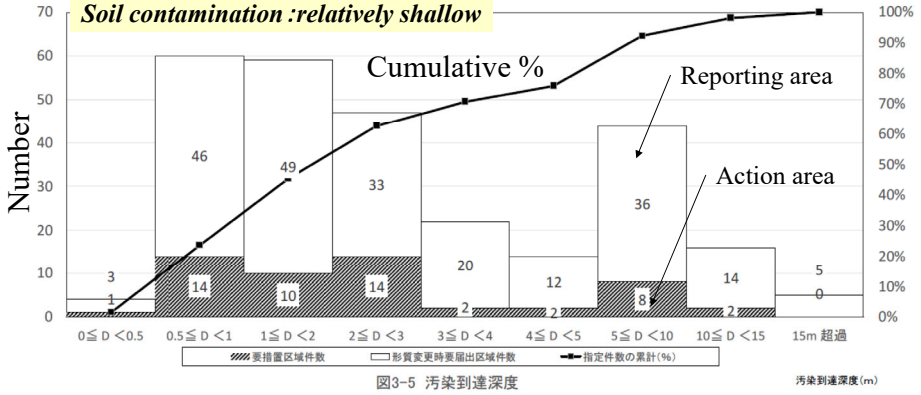


図3-5 汚染到達深度

Volume of Soil Contamination found in Japan (2017)

	All	(action A)	VOCs	HM	Pesticide	Combine
Average:	1,307	(747)	1,101	1,308	0	2,263
Max:	25,529	(7,387)	5,597	25,529	0	3,120
Total:	200,038	(22,415)	15,411	177,838	0	6,789

(m^3)

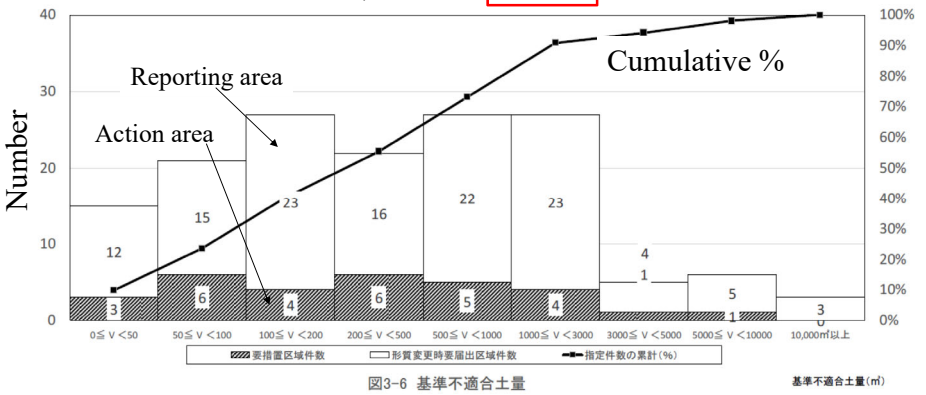
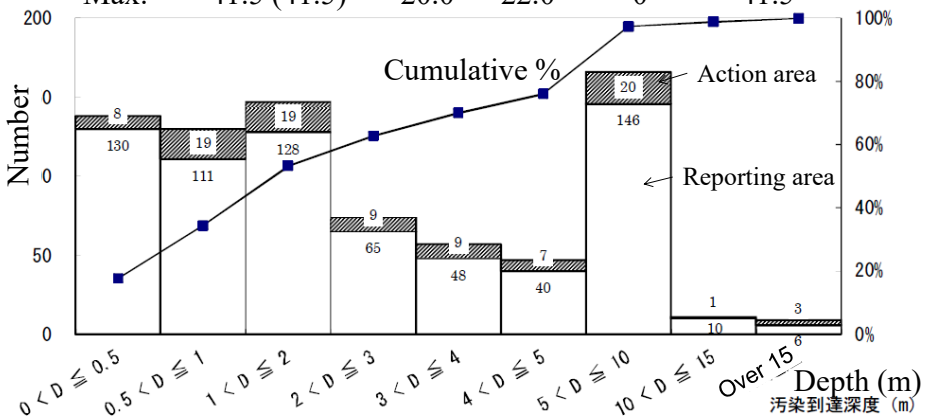


図3-6 基準不適合土量

Depth of Soil Contamination found in Japan (2002-2011) after enforcement of SCPL

	All (action A)	VOCs	HM	Pesticide	Combined
Average:	3.0 (4.1)	3.4	1.8	0	4.0
Max:	41.5 (41.5)	20.0	22.0	0	41.5

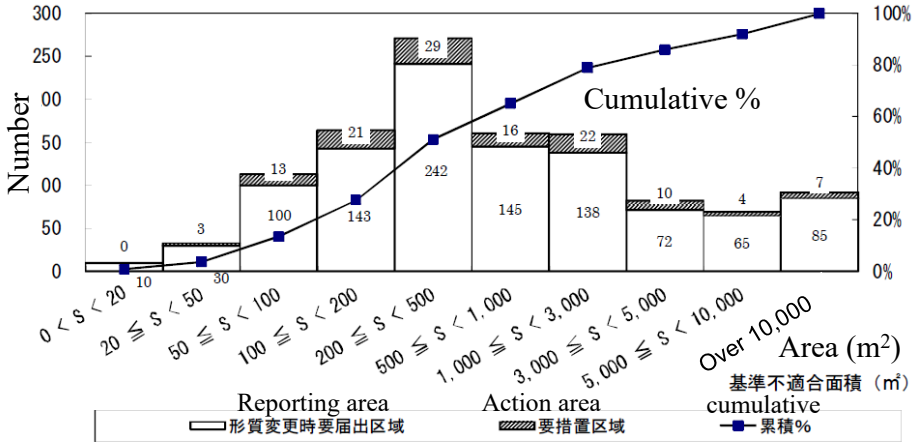
(m)



http://www.env.go.jp/water/report/h25-01/full.pdf

Area of Soil Contamination found in Japan (2002-2011)

	A ll	(action A)	VOCs	HM	Pesticide	Combined	
Average:	4.99	(0.90)	1.06	3.96	0	18.37	
Max:	890.6	(21.9)	21.8	277.4	0	890.6	(1000m^2)

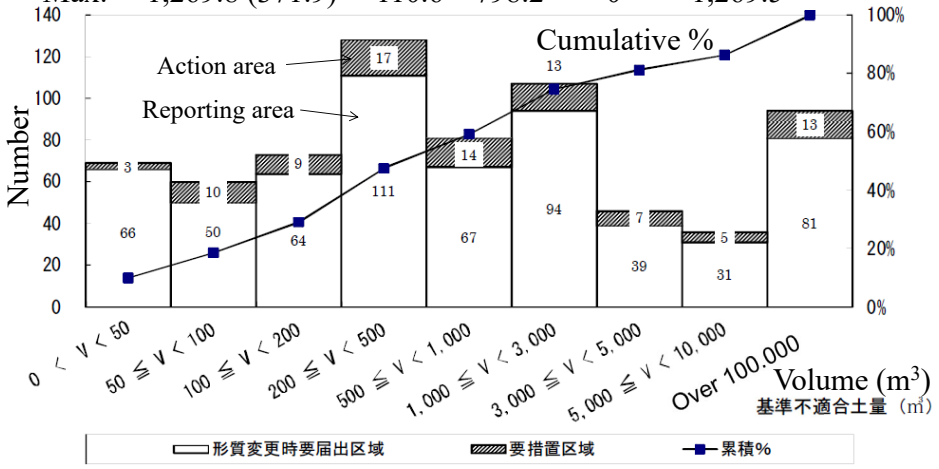


注） 平成 21 年度以前の指定区域は形質変更時要届出区域に含む。

http://www.env.go.jp/water/report/h25-01/full.pdf

Volume of Soil Contamination found in Japan (2002-2011)

	All (action A)	VOCs	HM	Pesticide	Combined	
Average:	14.6 (7.9)	4.4	11.0	0	67.2	
Max:	1,269.8 (371.9)	110.6	798.2	0	1,269.5	(1000m^2)



http://www.env.go.jp/water/report/h25-01/full.pdf

Brownfield

Definition:

(**US_EPA**: http://www.epa.gov/brownfields/index.html)

Real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Cleaning up and reinvesting in these properties protects the environment, reduces blight, and takes development pressures off greenspaces and working lands.

Small Business Liability Relief and Brownfields Revitalization Act

= "the Brownfields Law", 2002.

Increasing the value of BF, creating business chance, and job (1$=>18$, 61,000 jobs)

Japan:土壌汚染をめぐるブラウンフィールド問題の実態等について中間とりまとめ

http://www.env.go.jp/houdou/gazou/8300/9506/2641.pdf

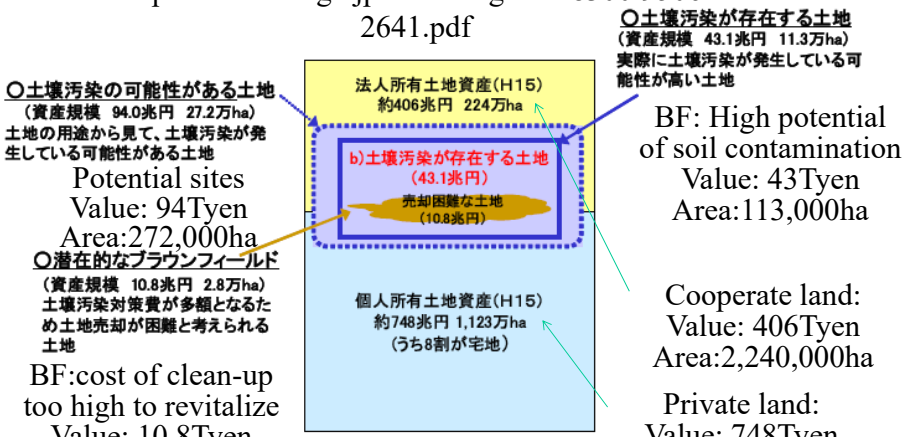
「土壌汚染の存在、あるいはその懸念から、本来、その土地が有する潜在的な価値よりも著しく低い用途あるいは未利用となった土地」

Concerns: Increase **brown-field abandonment** without investigation/remediation.

High cost of remediation, even investigation

Survey about BF in Japan

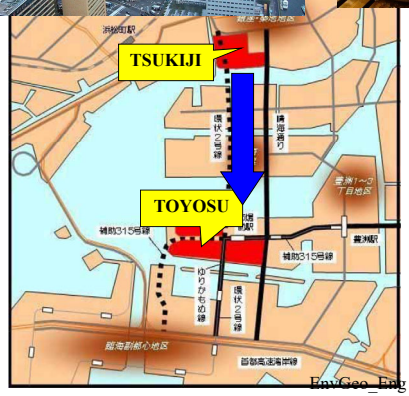
http://www.env.go.jp/houdou/gazou/8300/9506/2641.pdf



Case Study
Toyosu
Former Tokyo Coal Gas factory

Moving of Tsukiji Market



Tsukiji market has supplied steadily the perishable foods to the citizens of Tokyo since 1935.

However, Tsukiji market gets older and becomes narrower.

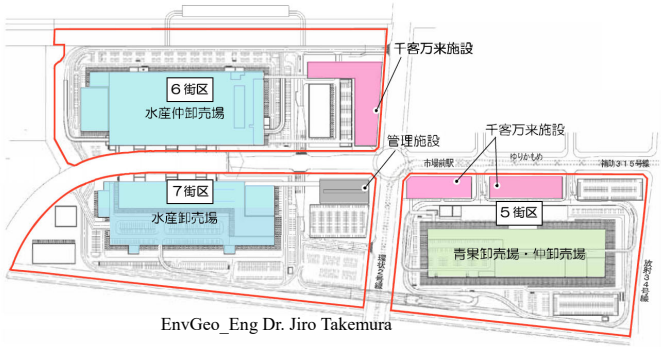
The Tokyo Metropolitan Government decided to move the market to Toyosu.

Plan of New Toyosu Market

at 2013

Project cost: 450By

- construction:153By (50%up)
- remediation: 67By (15%up)
  (280Km^3=> 410Km^3)
- land price +other:230By

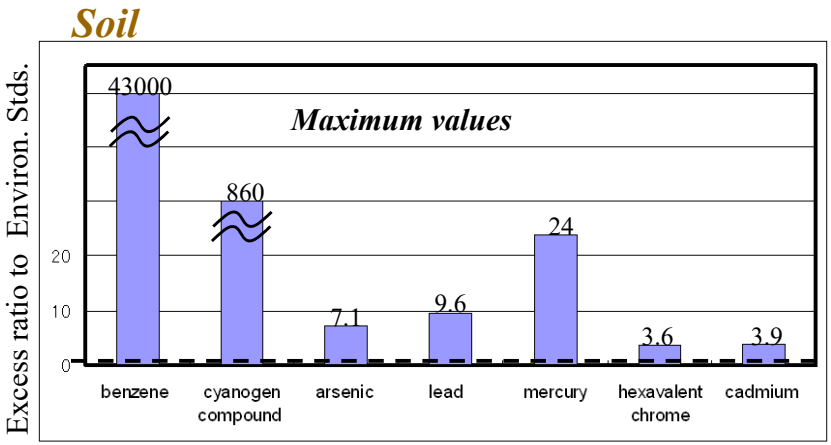


Former Tokyo **Coal Gas** factory for producing urban gas

Tokyo Gas Corp. was producing the coal gas from 1956 to 1976. In the manufacturing process of the coal gas, arsenic compounds were used as a catalyst, and benzene and the cyanide were generated as by-products. Treatment of by-products is insufficient and benzene and cyanogens compound accumulated in the soil.

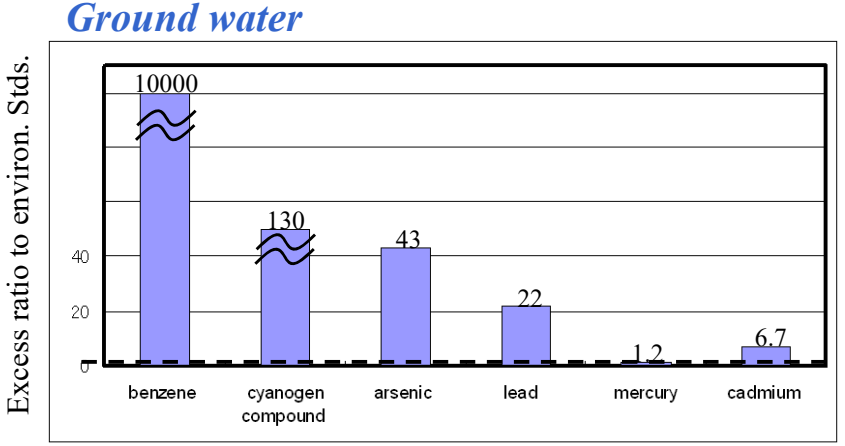
Toxic chemicals found in soil and ground water

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



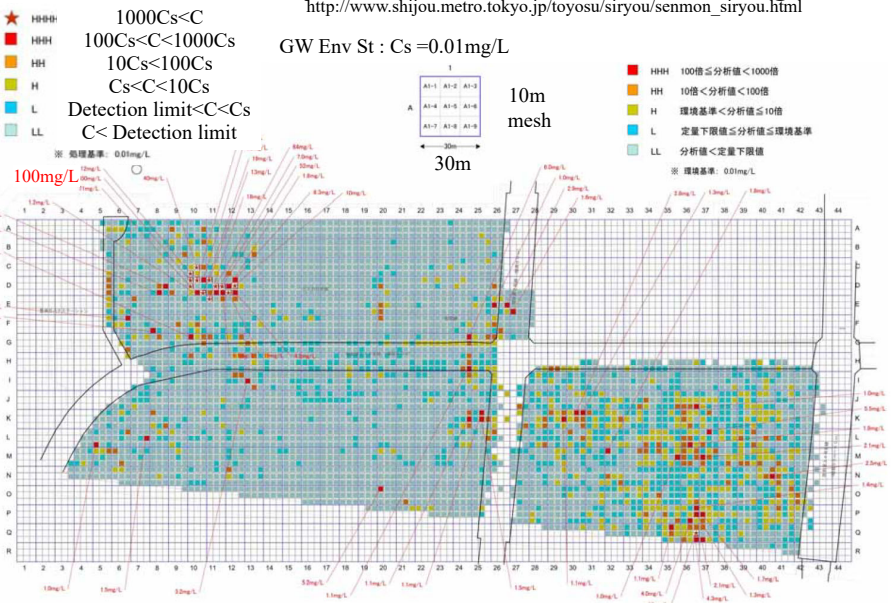
Toxic chemicals found in soil and ground water

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



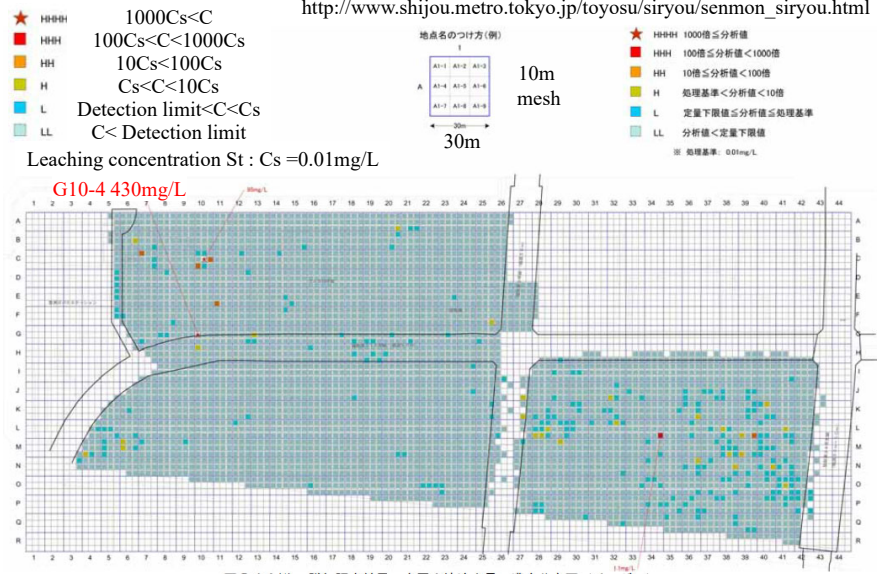
GW contamination by benzene found in detail investigation

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



Soil contamination by benzene found in detail investigation

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



Additional investigation

benzene　cyanogens compound　GW　Soil leaching　Soil content

G10-4a

標高 (A.P.m)	深度 (m)	ベンゼン 地下水 (mg/L)	ベンゼン 土壌溶出量 (mg/L)	シアン化合物 地下水 (mg/L)	シアン化合物 土壌溶出量 (mg/L)	シアン化合物 土壌含有量 (mg/kg)
+4.5	+0.5		0.001未満		不検出	0.5未満
+3.5	−0.5	0.013	0.084	0.2	0.1	3.7
+3.0	−1.0		1.1		0.7	16.0
+2.0	−2.0		3.3		0.7	0.6
+1.0	−3.0		0.32		0.1	0.5未満
+0.0	−4.0	1.0	0.052	不検出	不検出	0.5未満
−1.0	−5.0		0.31		0.1	1.5
−2.0	−6.0		0.026		0.1	0.5未満
−3.0	−7.0		0.002		不検出	0.5未満
−4.0	−8.0		0.009		不検出	0.5未満

G10-4

標高 (A.P.m)	深度 (m)	ベンゼン 地下水 (mg/L)	ベンゼン 土壌溶出量 (mg/L)	シアン化合物 地下水 (mg/L)	シアン化合物 土壌溶出量 (mg/L)	シアン化合物 土壌含有量 (mg/kg)
+4.5	+0.5		0.001未満		不検出	0.5未満
+3.5	−0.5	0.13	420	0.4	69	70
+3.0	−1.0		0.003		不検出	0.5未満
+2.0	−2.0		0.075		不検出	0.5未満
+1.0	−3.0		0.001未満		0.2	0.5未満
+0.0	−4.0	0.001未満	0.022	0.4	不検出	0.5未満
−1.0	−5.0		0.054		不検出	0.5未満
−2.0	−6.0		0.38		不検出	1.3
−3.0	−7.0		0.024		不検出	0.5未満
−4.0	−8.0		0.001		不検出	0.5未満

凡　例
● : 詳細調査地点
● : 周辺調査地点

G10-4a　G10-4b　G10-4　G10-4c　G10-4d　5m

G10-4b

標高 (A.P.m)	深度 (m)	ベンゼン 地下水 (mg/L)	ベンゼン 土壌溶出量 (mg/L)	シアン化合物 地下水 (mg/L)	シアン化合物 土壌溶出量 (mg/L)	シアン化合物 土壌含有量 (mg/kg)
+4.5	+0.5		0.001未満		不検出	0.5未満
+3.5	−0.5	0.005	0.004	不検出	0.2	0.8
+3.0	−1.0		0.001未満		不検出	0.5未満
+2.0	−2.0		0.001		不検出	0.5未満
+1.0	−3.0		0.001未満		不検出	0.5未満
+0.0	−4.0	0.006	0.004	0.2	不検出	0.5未満
−1.0	−5.0		0.001		0.2	1.2
−2.0	−6.0		0.001未満		不検出	0.5未満
−3.0	−7.0		0.001未満		不検出	0.5未満
−4.0	−8.0		0.001未満		不検出	0.5未満

G10-4c

標高 (A.P.m)	深度 (m)	ベンゼン 地下水 (mg/L)	ベンゼン 土壌溶出量 (mg/L)	シアン化合物 地下水 (mg/L)	シアン化合物 土壌溶出量 (mg/L)	シアン化合物 土壌含有量 (mg/kg)
+4.5	+0.5		0.001未満		不検出	0.5未満
+3.5	−0.5	0.002	0.001未満	不検出	不検出	0.5未満
+3.0	−1.0		0.001未満		不検出	0.5未満
+2.0	−2.0		0.001		不検出	0.5未満
+1.0	−3.0		0.001未満		不検出	0.5未満
+0.0	−4.0	0.001	0.030	不検出	不検出	0.5未満
−1.0	−5.0		0.23		0.2	1.2
−2.0	−6.0		0.16		不検出	0.5未満
−3.0	−7.0		0.001		不検出	0.5未満
−4.0	−8.0		0.001未満		不検出	0.5未満

benzene

G10-4d

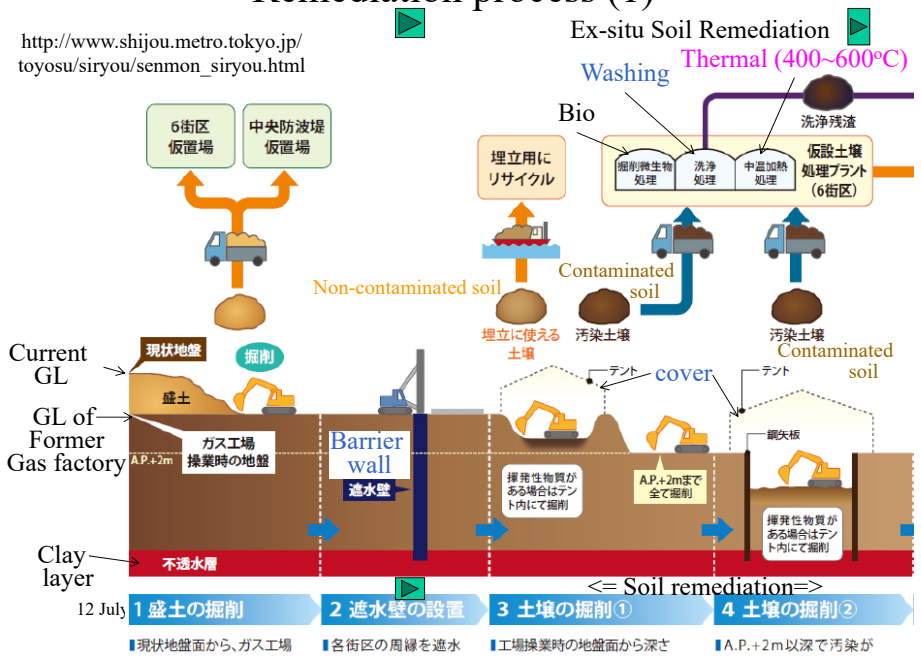
標高 (A.P.m)	深度 (m)	ベンゼン 地下水 (mg/L)	ベンゼン 土壌溶出量 (mg/L)	シアン化合物 地下水 (mg/L)	シアン化合物 土壌溶出量 (mg/L)	シアン化合物 土壌含有量 (mg/kg)
+4.5	+0.5		0.001未満		不検出	0.5未満
+3.5	−0.5	0.001未満	0.001未満	0.2	不検出	0.5未満
+3.0	−1.0		0.001未満		不検出	0.5未満
+2.0	−2.0		0.001未満		不検出	0.5未満
+1.0	−3.0		0.001未満		不検出	0.5未満
+0.0	−4.0	0.001未満	0.001未満	0.2	不検出	0.5未満
−1.0	−5.0		0.001未満		不検出	0.5未満
−2.0	−6.0		0.001未満		不検出	0.5未満
−3.0	−7.0		0.001未満		不検出	0.5未満
−4.0	−8.0		0.001未満		不検出	0.5未満

注）1.■は、土壌溶出量及び土壌含有量：処理基準、地下水：環境基準の超過を示す。
2.処理基準（土壌溶出量）、環境基準（地下水）は以下のとおりである。
【ベンゼン】土壌溶出量及び地下水：0.01mg/L 以下
【シアン化合物】土壌溶出量及び地下水：検出されないこと（0.1mg/L 未満）、土壌含有量：50mg/kg 以下
3.G10-4 の調査結果のうち、*斜体*は詳細調査の結果を示す。
4.深度は、旧地盤面（A.P.+4m）からの深度を示す。

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html

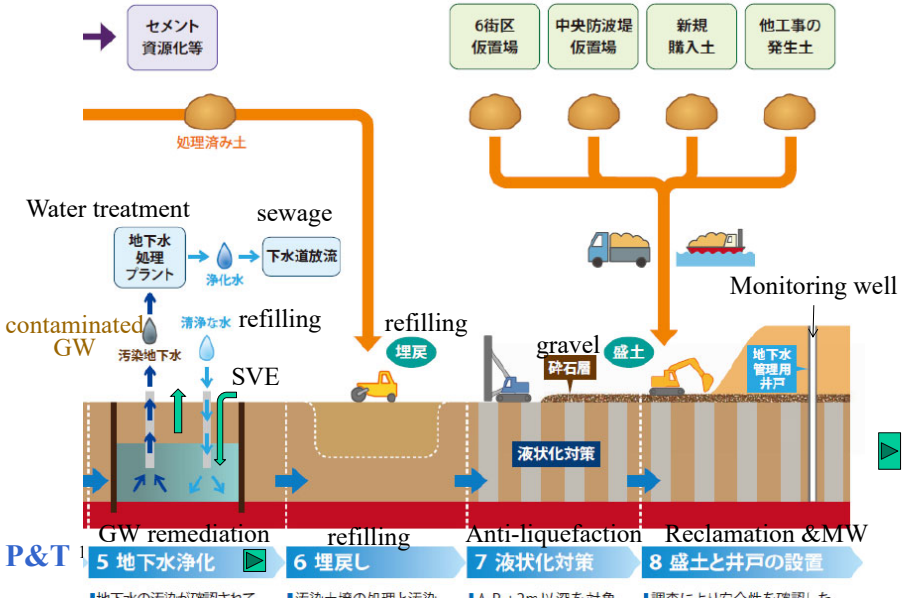
Remediation process (1)

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



Remediation process (2)

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



Countermeasures

Whole area

(road side) Steel pipe sheet pile
(sea side) soil cement + steel sheet pile

-The containment using sheet pile wall surrounding each block to prevent the movement of the pollutant between the outside and the market planned site.

Soil

-Excavation and replacement of the soil from the old ground surface to 2m depth (entire area) and deep depth (contaminated area) will be implemented.

-After excavation and replacement, 4.0m reclamation

P44

Ground water

-Groundwater remediation for reducing concentration of benzene and cyanide to meet the ground water environmental standards (P&T and SVE)

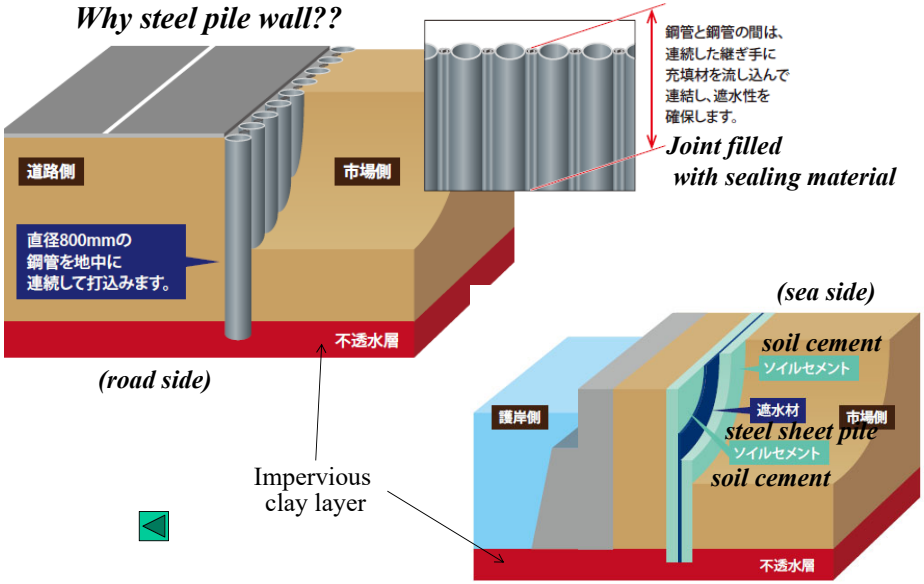
-Gravel layer placement to prevent the capillary rise of GW

-Ground water monitoring will be implemented to prevent the rise of ground water level.

-The new market planned site will be covered with a concrete floor of thickness 25-40cm or asphalt of thickness 30-40cm.

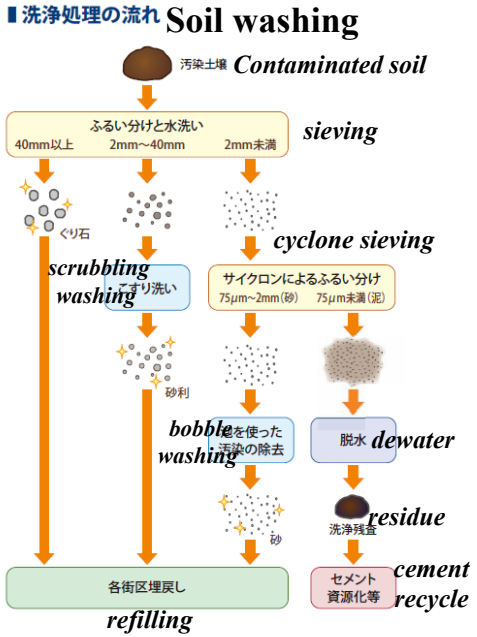
Containment wall

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



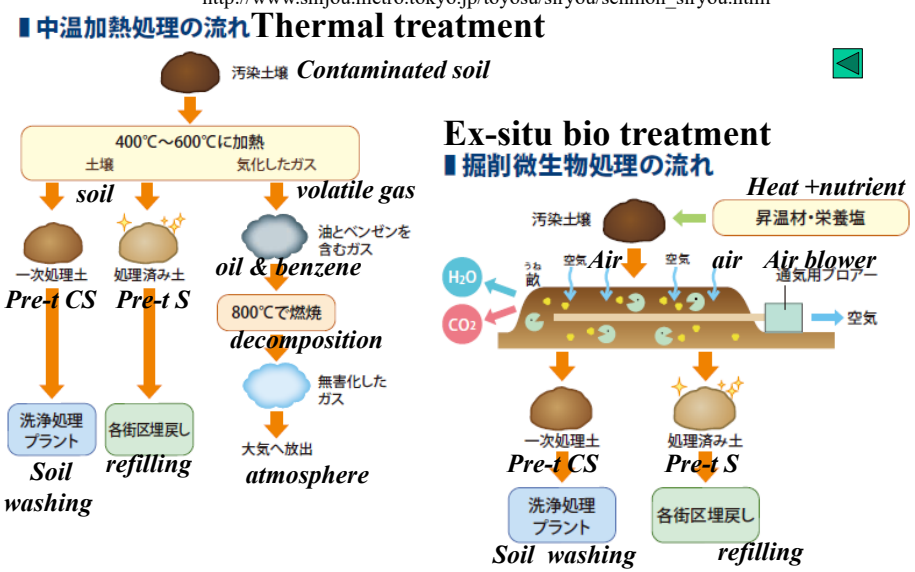
Soil clean-up

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



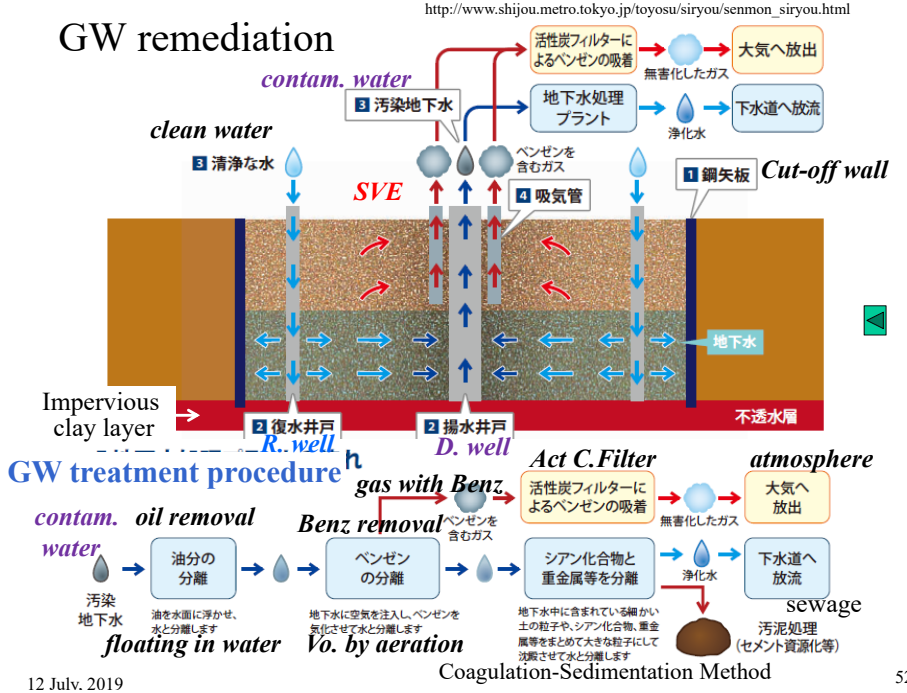
Soil clean-up

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



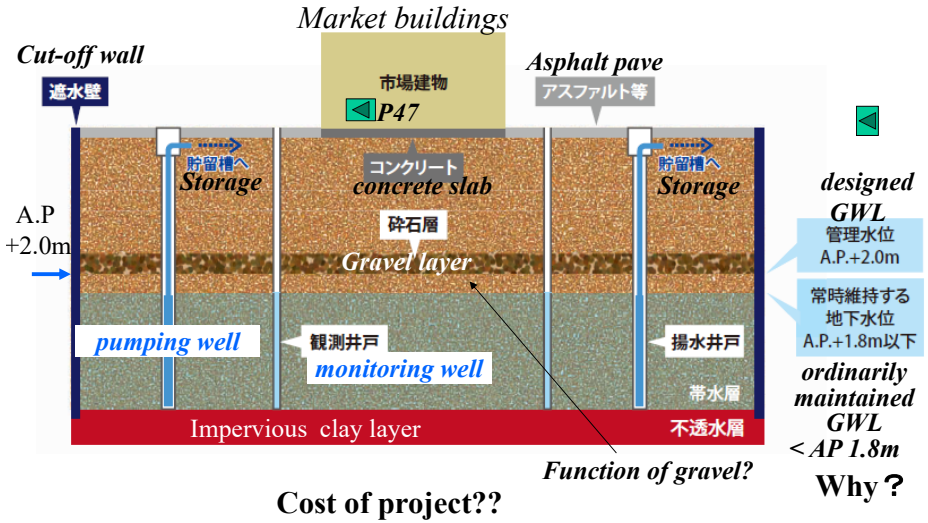
GW remediation

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



GW monitoring and control

http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou.html



Huge remediation cost => deserved?

浄化対策費用？？ ＝＞ 価値があるか？？

(100Myen) 億円	2009.2	2011.2	2013.3	2015.3	2016.3
Construction	990	990	1,532	2,752	2,747
Remediation	586	586	741	849	858
Land	2,370	1,980	1,859	1,859	1,859
others	370	370	389	424	420
total	4,316	3,926	4,521	5,884	5,884

http://www.shijou.metro.tokyo.jp/toyosu/situation/photo-p6/

Huge remediation cost => deserved?

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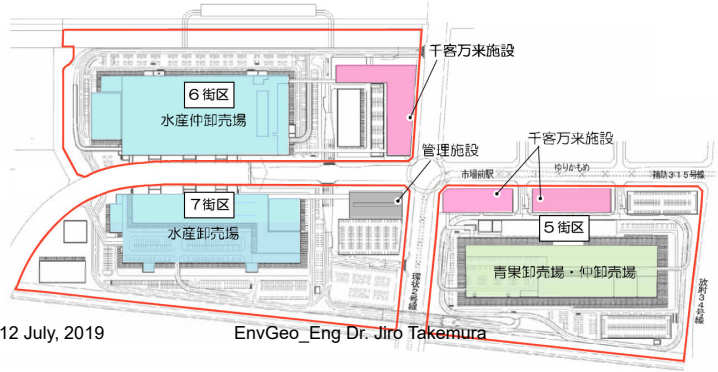


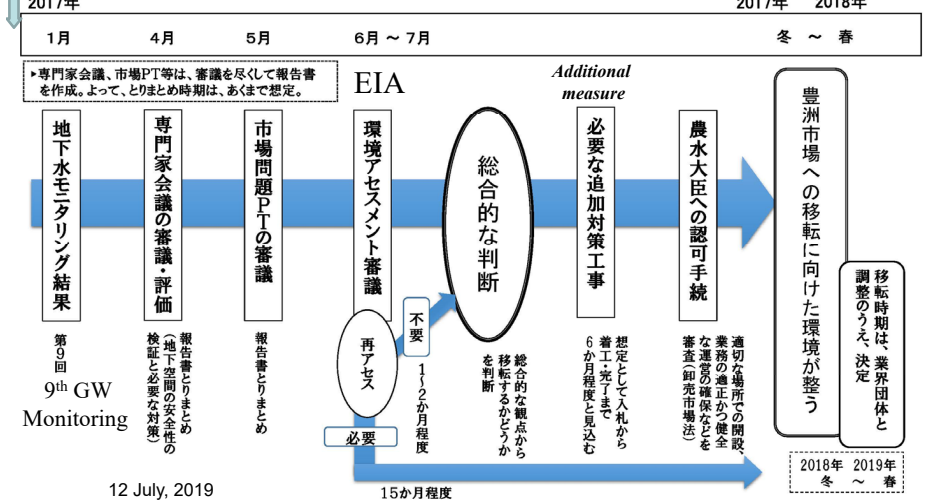
Newly found problems at Toyosu
豊洲の新たな問題

Postpone of opening
2016.11の移転延期

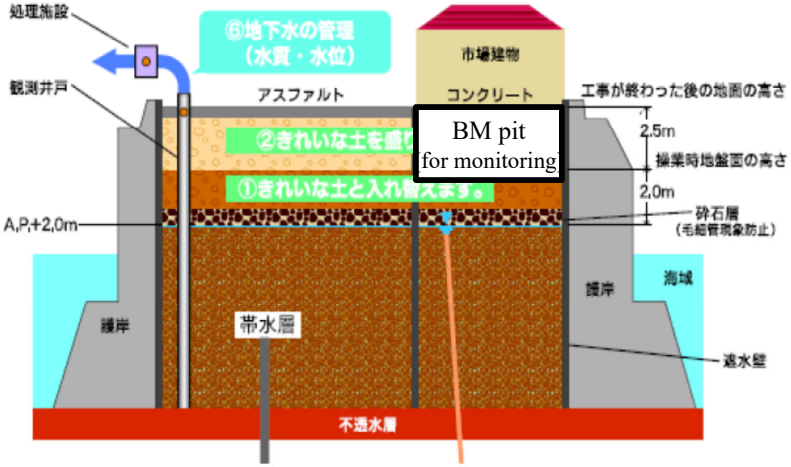
Food safety and security
食の安全と安心 ??

All info: Open to public いる
http://www.shijou.metro.tokyo.jp/toyosu/

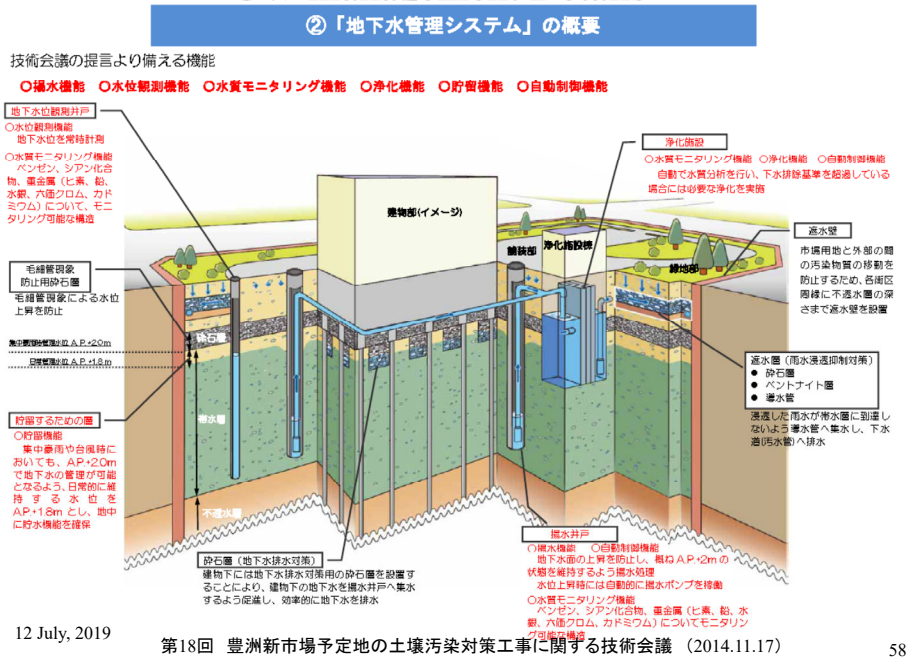
Open 2018.10



Ground water management outline after remediation (by mid 2016)



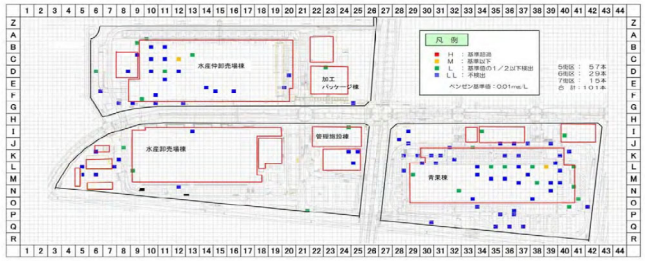
GW management Details



GW monitoring after the remediation

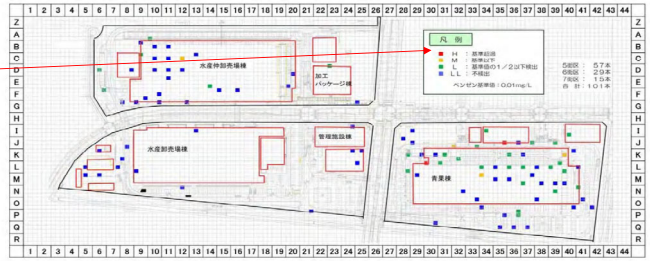
2014.11~
9 times

7th Monitoring (2016.5)(Benzne)



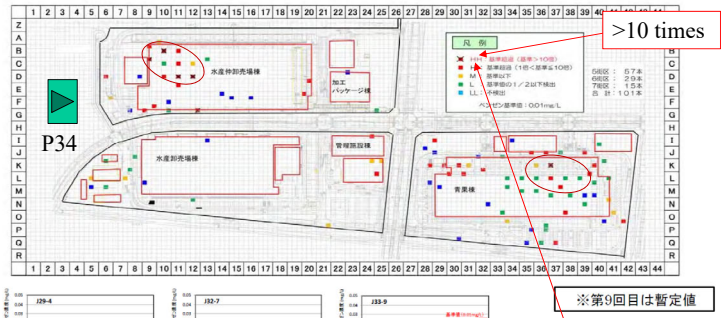
8回目モニタリング2016.8-9)結果(ベンゼン)

Over Env Standard



GW monitoring after the remediation

9th monitoring (2016.11-12) (Benzene)



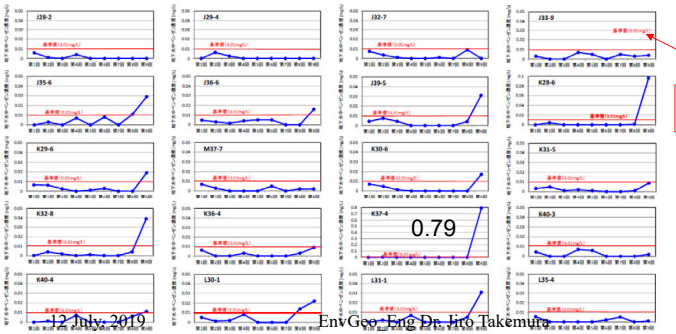


図２（１） 地下水のモニタリング結果（ベンゼン、５街区）（その１）

Objectives 対策の要件

①Prevention of exposure against the health problems

生涯曝露による健康被害を防止

- Intake of soil (汚染土壌を直接曝露)、
- Intake of GW (汚染地下水等を曝露)
- Continuing exposure of contaminated air (汚染空気の継続的曝露)

②Food safety and Security

食の**安全・安心**の観点

-Contamination of food by volatized gas (Benzene and Cyanide gas)

揮発ガス成分(ベンゼン、シアン化合物)が隙間や亀裂から建物内に侵入することによる生鮮食料品への影響防止。

Fill＝＞basement
(盛土)　(地下ピット)

GW monitoring
地下水モニタリング

Over ES
地下水環境基準超過

Remediation of Soil Contamination

土壌汚染対策の内容

			対象	対策の内容
Underneath building	建物建設地	全体		①各街区の周縁部を止水矢板でそれぞれ囲むことにより、市場予定地と外部との間での汚染物質の移動を防止。 ②各街区とも、建物の周囲を止水矢板等で囲むことにより、建物建設地とそれ以外の部分の間での汚染物質の移動を防止。
		土壌	A.P.+2.0mより上部	①旧地盤面（A.P.+4.0m）から2m（A.P.+2.0m）までの土壌を掘削し、入れ換え。 ②さらに上部に2.5mの盛土。
			A.P.+2.0mより下部	①操業由来により処理基準を超過した土壌を処理基準以下に処理。
		地下水		①地下水中のベンゼン、シアン化合物の濃度が地下水環境基準に適合することを目指した地下水浄化を建物建設前に行う。 ②地下水管理を行い、地下水位の上昇を防止。
Outside building	建物建設地以外	土壌	A.P.+2.0mより上部	①残地構造物撤去、地盤改良を実施することから、旧地盤面（A.P.+4.0m）から2m（A.P.+2.0m）までの土壌を掘削し、入れ換え。 ②さらに上部に2.5mの盛土。
			A.P.+2.0mより下部	①操業由来により処理基準を超過した土壌を処理基準以下に処理。
		地下水		①地下水管理を行い、地下水位の上昇を防止する。 ②揚水した際に処理を行うことなく下水に放流できる濃度レベル（排水基準に適合する濃度）で地下水管理を実施し、将来的にベンゼン、シアン化合物の濃度が地下水環境基準を達成することを目指す。 ③液状化対策として地盤改良工事を行う際に、合わせて地下水中のベンゼン、シアン化合物の濃度の低下を図る。

※新市場予定地は、その大部分が建物建設および道路・駐車場用地であり、厚さ25～40cmのコンクリート床または厚さ30～40cmのアスファルトで覆われる計画である。

Validation of fill (盛土の根拠)

Estimation of exposure of contaminated gas from ground water

土壌中からの汚染空気の曝露による影響の評価

第7回豊洲新市場予定地における土壌汚染対策等に関する専門家会議(2008. 7)
http://www.shijou.metro.tokyo.jp/toyosu/siryou/senmon_siryou/#kaigi07

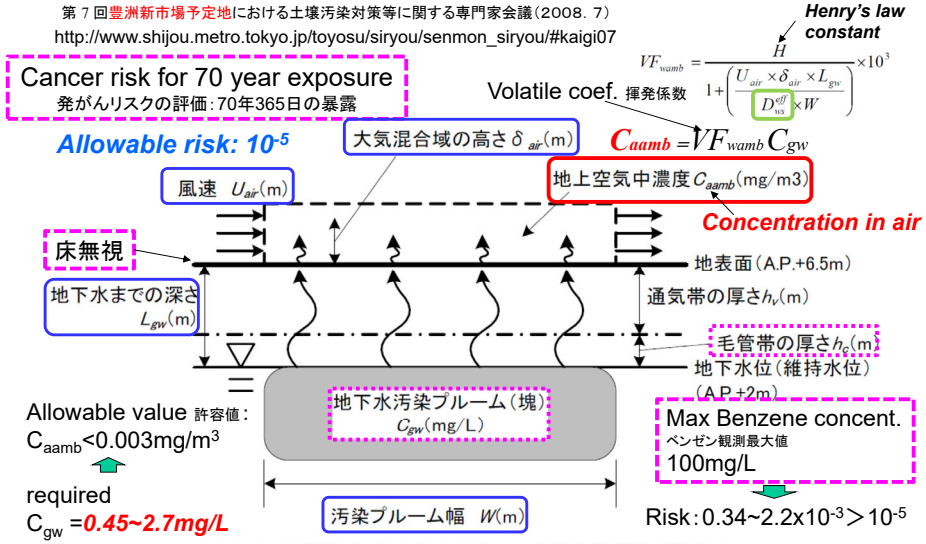


図 1- 2　汚染地下水から地上空気への汚染物質移動の概念図

Effective diffusion coefficient in vadose zone

不飽和地盤内の有効拡散係数

$$VF_{wamb} = \frac{H}{1+\left(\frac{U_{air}\times\delta_{air}\times L_{gw}}{D_{ws}^{eff}\times W}\right)}\times 10^3 \quad [L/m^3]$$

200cm　2.27×10^{-1} [ND] Benzane ベンゼン　0.625cm/s　450cm　cm^2/s　4500cm

If fill replaced by air with basement?
ここで盛土が空間(:空気)であったら?

$$D_{ws}^{eff} = D_{air} = 8.8\times10^{-2}$$

$1.6\sim0.2\times10^{-4}$

Effective diffusion coefficient of Vadose zone

$$D_{ws}^{eff} = (h_c + h_v)\times\left(\frac{h_c}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right)^{-1}$$

100cm　350cm

D_e at capillary done
毛管帯における有効拡散係数

$$D_{cap}^{eff} = D^{air}\times\frac{\theta_{acap}^{3.33}}{\theta_T^2} + \left(\frac{D^{wat}}{H}\right)\times\left(\frac{\theta_{wcap}^{3.33}}{\theta_T^2}\right)$$

De of air 気相中の拡散係数　8.8×10^{-2}
porosity 間隙率(n)　0.33~0.57
De of water 液相の拡散係数　9.8×10^{-6}
Volumetric air content 毛管帯の気相率　0.015~0.058
Volumetric water content 毛管帯の体積含水率　0.32~0.55

D_e at aeration zone
通気帯における有効拡散係数

$$D_s^{eff} = D^{air}\times\frac{\theta_{as}^{3.33}}{\theta_T^2} + \left(\frac{D^{wat}}{H}\right)\times\left(\frac{\theta_{ws}^{3.33}}{\theta_T^2}\right)$$

De of air 通気帯の気相率　0.048~0.21
De of water 通気帯の体積含水率　0.28~0.52

Risk evaluation

リスク評価モデルでの検討結果

Exposure risk
曝露のリスク

ベンゼン：仮定C_{gw}に対するC_{aamb}=0.14~0.041mg/m³
（基準値0.003mg/m³）

がん発生リスク：
0.34~2.2x10⁻³＞10⁻⁵

基準値C_{aamb}<0.003mg/m³を満たすC_{gw}
0.45~3.1 (平均1.1)mg/L

Food safety and Security
生鮮食料品への影響

生鮮食料品に付着した水分の汚染物染物濃度：Cw

$$C_w = \frac{C_{aamb}}{H}\times\frac{1}{1000}$$

C_{aamb}=0.013mg/m³

C_w=5.7x10⁻⁶mg/L

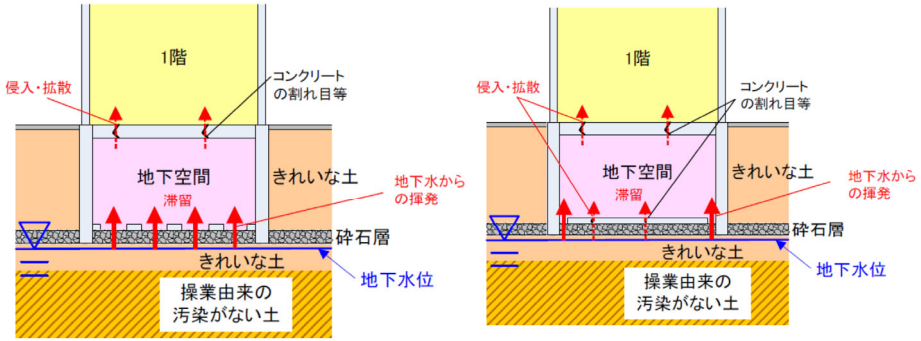
環境基準の1/1000未満
(0.01mg/L)

Future Risk by the residual concontaminat

残存する汚染物の将来的なリスク

第5回豊洲市場における土壌汚染対策等に関する専門家会議資料 (7-5)

http://www.shijou.metro.tokyo.jp/toyosu/expert/index.html



青果棟(5街区)

6街区：水産仲卸売場棟

水産仲卸売場棟(6街区)
加工パッケージ棟(6街区)
水産卸売場棟(7街区)

Relocation of the market

In the original plan, November 2016,
but suspended.
Finally Toyosu M opened
Oct 11, 2018

Oil leak from varied pile in Makati City, Manila, Philippines

See the materials in OCWi
NAPLs_spill_Makati
NAPLs_spill_Makati_2
NAPLs_spill_Makati_3

安全と安心

Safe and secure

安心

Free from care

100%安全なリスクのない世界？

99% ＝＞99.9%＝＞99,99%

Risk management , Risk communication
リスクマネージメント, リスクコミュニケーション