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1.

Love Canal (1979)

가

가

가

1980 Superfund

가

Superfund

가

가

2, 3 가

가

2.

(10 20)

가 가

(), Pump-and-treat(

) 가

SVE(Soil Vapor Extraction)

(
in-situ)

가

(VOC:

Volatile Organic Compounds, PAHs: Poly-Aromatic Hydrocarbons) 가

, in-situ

NA(Natural Attenuation)

NA

NA

가

Monitoring

USEPA(United States Environmental Protection Agency) 7

, / 64 (

, -32 , ,

-17 , 가 -5)

(< 1 >) Love Canal 1980 Superfund , 1982 1997

, in-situ SVE 27%, Solidification/Stabilization 6%, Bioremediation 5% , ex-situ Incineration 21%(off-site 14%, on-



[1] Bioaugmentation (Dover, AFB, Delaware)

site 7%), Solidification/Stabilization 19%, Thermal desorption 8%, Bioremediation 6%, 8%

가

SVE, Solidification/

Stabilization, Incineration .(US EPA, 1998) 가

NA PRB(Permeable Reactive Barrier)

. VEGAS(Versuchse-

inrichtung zur Grundwasser-und Altlastensan-

VEGAS in-situ

pump-and-treat, Soil flushing

, NAPLs(Non-Aqueous

Phase Liquids) ,

in-situ microbial reductive

dechlorination , PAHs

in-situ bioremediation

1980 10

(),

< 1 > / (USEPA)			
Treatment		Contaminated Source	
		Soil, Sediment, Sludge	Groundwater, Surface water, Leachate
in-situ	Biological	1 Bioventing 2 Enhanced Bioremediation 3 Land Treatment 4 Natural Attenuation 5 Phytoremediation	33 Co-metabolic Treatment 34 Enhanced Bioremediation 35 Natural Attenuation 36 Phytoremediation of Organics
	Physical/chemical	6 Electrokinetic Separation 7 Fracturing 8 Soil Flushing 9 Soil Vapor Extraction 10 Solidification/Stabilization	37 Aeration 38 Air Sparging 39 Bioslurping 40 Directional Wells 41 Dual Phase Extraction 42 Fluid/Vapor Extraction 43 Hot Water or Steam Flushing/Stripping 44 Hydrofracturing 45 In-Well Air Stripping 46 Passive/Reactive Treatment Walls
	Thermal	11 Soil Vapor Extraction (Thermally Enhanced)	
ex-situ	Biological	12 Biopiles 13 Composting 14 Fungal Biodegradation 15 Landfarming 16 Slurry Phase Biological Treatment	47 Bioreactors 48 Constructed Wetlands
	Physical/chemical	17 Chemical Extraction 18 Chemical Reduction/Oxidation 19 Dehalogenation 20 Separation 21 Soil Washing 22 Soil Vapor Extraction 23 Solar Detoxification 24 Solidification/Stabilization	49 Adsorption/Absorption 50 Air Stripping 51 GAC/Liquid Phase Carbon Adsorption 52 Ion Exchange 53 Precipitation/Coagulation/Flocculation 54 Separation 55 Sprinkler Irrigation 56 Ultraviolet Oxidation
	Thermal	25 Hot Gas Decontamination 26 Incineration 27 Open Burn/Open Detonation 28 Pyrolysis 29 Thermal Desorption	
Containment		30 Landfill Cap 31 Landfill Cap Enhancements	57 Deep Wall Injection 58 Ground Water Pumping 59 Slurry Walls
Other treatment		32 Excavation, Retrieval, and Off-Site Disposal	
Air Emissions/Off-Gas Treatment Technologies			
60 Biofiltration 61 High Energy Corona 62 Membrane Separation 63 Oxidation 64 Vapor Phase Carbon Adsorption			
) Remediation Technologies Screening Matrix and Reference Guide(http://www.clu-in.org)			

Landfarming (Solidification/stabilization),

3.

in-situ

가 , in-situ

3.1

15 , 5

3 , 1998 2,993 (

: 998, : 1995)

12 (6, 5, pH), 9

(PCB,)

2,993 , 18 (

0.6%)

) 12 As, Cu, Cd, Pb

3

가

8, 3, 1

5, 3,

2, 2 , 2,

1

SVE, ex-situ

(Landfarming, composting), in-situ (Soil

flushing, bioremediation)

Hg

3

2, 2, 2

1,

2 , 1,

2

(Containment),

(Excavation), (Pump and treat),

Soilventing 가 ,

3 가 ,

in-situ bioremediation , Soil washing (Benzene, Toluene, Ethylbenzene, Xylene)

BTEX

TPH(Total Petroleum Hydro-carbon,)
 40,000528,000m
 2,400m
 801,00017,270,000m
 가

3.2 6.7% , 1995
 100
 (TCE : 60ppb, PCE : 20
 ppb) TCE 38%, PCE 14%
 (TCE : 30ppb, PCE :
 10 ppb) TCE 15.6%, 9.1%
 , PCE 6.2%, 3.6%
 가

3.2
 1,500 2
 1994 1998
 < 2>
 TCE(Tetrachlo-
 roethylene) , 0.7 2.9%
 가 , PCE
 (Perchloloethylene) 1.3%
 가 /
 STAR Project(

4.
 1994
 , 1995
 (G-7 Project:
 , 1994 2000)
 STAR Project(

< 2>														
Year	TPH	TCE	PCE	Cd	Pb	Cr ⁶⁺	pH	COD	NO ₃ -N	C ⁻	Water Quality (%)			
											TCE	PCE	Cd	
1994	1,539	185	12.0	188	11	8	8	6	-	52	-	103	-	
1995	1,546	156	10.1	169	19	10	-	2	-	7	8	101	17	
1996	1,527	110	7.2	127	26	6	-	-	-	9	10	42	34	
1997	1,513	153	10.1	163	44	13	1	-	1	5	5	81	13	
1998	1,538	154	10.0	154	45	20	-	1	1	2	7	10	49	19

< 3> NRC Ranking Criteria for Difficulty in Remediating Ground Water							
Hydrogeology	Pollutant	Mobile Dissolved(Degrades/Volatilizes)	Mobile Dissolved	Strongly Sorbed, Dissolved	Strongly Sorbed, Dissolved(Degrades/Volatilizes)	Separate Phase DNAPL ⁽¹⁾	Separate Phase DNAPL ⁽²⁾
Homogeneous, Single Layer		1	1~2	2	2~3	2~3	3
Homogeneous, Multiple Layers		1	1~2	2	2~3	2~3	3
Heterogenous, Single Layer		2	2	3	3	3	4
Heterogenous, Multiple Layers		2	2	3	3	3	4
Fractured Bedrock		3	3	3	3	4	4

) 1 : least difficult, 4 : most difficult.
 1) LNAPL : Light Non-Aqueous Phase Liquid
 2) DNAPL : Dense Non-Aqueous Phase Liquid

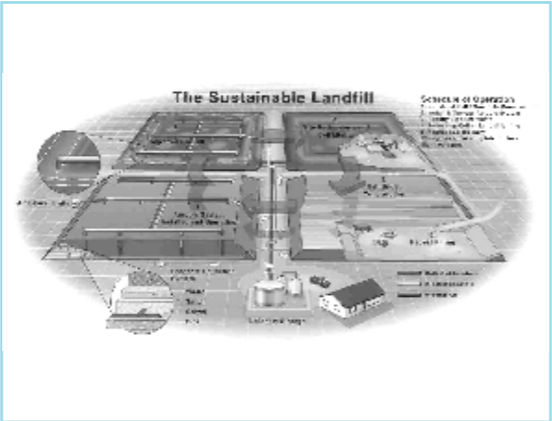
, 1995 1998가
 Full-scale
 , MNA(Monitored Natural Attenuation)
 119,000m
 1999 가 .(
 1999) , VOC
 300ton Biofarming 가
 가 . BTEX
 SVE

NA, (Phytoremedia-
 tion), PRB(Permeable Reactive Barrier)
 가
 (, ,)
 Pneumatic fracturing
 .(< 3>) , ,

5.
 5.1 .
 in-situ

G-7
 가 . 10
 (Eco-technopia 21)

- New technologies : in-situ Ground Water Remediation**
- Dual-phase extraction
 - Circulating wells (UVB)
 - Steam flushing
 - Dynamic underground stripping
 - Cosolvents/surfactants (enhanced flushing)
 - Natural attenuation of nonchlorinated compounds/hydrocarbons
 - Phytoremediation
 - Vertical barrier walls
 - Reactive treatment walls
 - in-situ oxidation (with Fenton's reagent)



[2] Sustainable landfill

가

Compost,

[2]

ECS(Environmental Control Systems, Inc.)

Sustainable landfill

Burghhof Smell well system

가

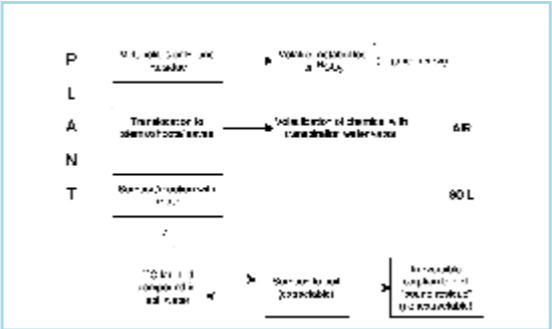
Phytoremediation

LFG(Land Fill Gas) 2 가

가,

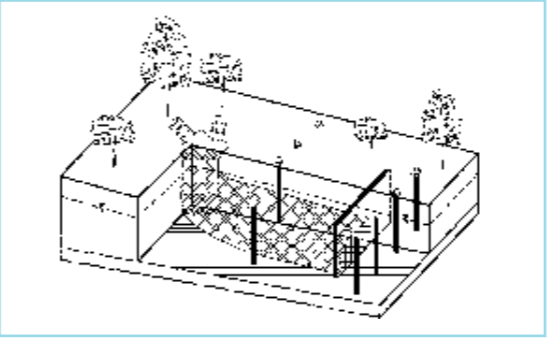
가

Phytoremediation VOC,



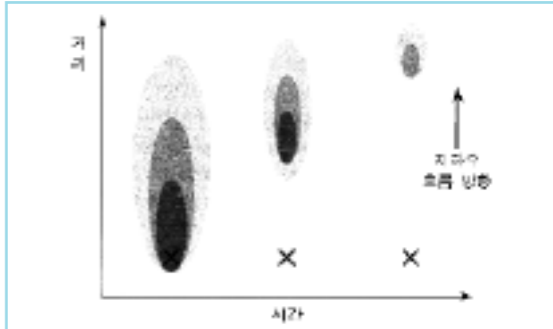
[3] Fate and transport of organic chemicals in phytoremediation (Laboratory experiments with ¹⁴C-isotopes)

가 (Permeable Reactive Barrier, PRB) 1996 가 ([4]) PRB 가



[4] PRB()

PRB (Passive system) 가



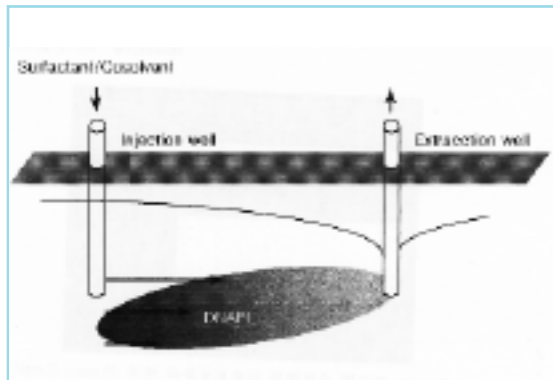
[5]

Monitoring well PRB

가 dithionite, zeolite, surfactant modified silicates, organobentonites hydroxyapatite

(Natural Attenuation, NA)

Superfund NA NA , EPA



[6] Surfactant and Cosolvent Flushing

Cosolvent Flushing
가 , Pump-and-
treat system

Surfactant 가

5.3

Surfactant and Cosolvent Flushing

Injection well Surfactant

Cosolvent , Surfactant

NAPL , Cosolvent NAPL
VOC,

PCB(Poly Chlorinated Biphenyl),
가 . Surfactant and

D/B

D/B < 4>

RemScreen EPA (US EPA,
1994) 5가 /

가,
가) 가

PC

RemScreen

< 4> D/B

	D/B program
	- Vendor Field Analytical Characterization Technology System (VendorFACTS) - Vendor Information System for Innovative Treatment Technologies (VISITT), Ver. 5.0 - Innovative Treatment Technologies Database (ITT), Ver. 2.0 - Bioremediation in the Field Search System (BFSS), Ver. 2.1
	RemScreen Ver. 1.0

) , pp. -1 30, 1998

) RemScreen , (http://club.hanyang.ac.kr/~ wastelab)

, in-situ SVE가 가
Bioventing, (NA) .([7])
가 , Bioventing
SVE Thermally
enhanced SVE가 가 . ex-situ
Composting .S



[7] RemScreen 가

6.

Biosphere ,

21 가
(2011

20 ,),

가

1. U.S. EPA, Treatment Technologies for Site Cleanup: Annual Status Report(9th Ed.), 1998.
2. U.S. EPA, Remediation Technologies Screening Matrix and Reference Guide, 1994.
3. , " ; 1999.
4. , " () ; 1999.
5. , " ; pp. -1 30, 1998.
6. Walter Kovalick, Innovative Ground-Water Technologies: Development Status and Trends, Advances in Innovative Ground-Water Technologies Conference, 2000. 6.