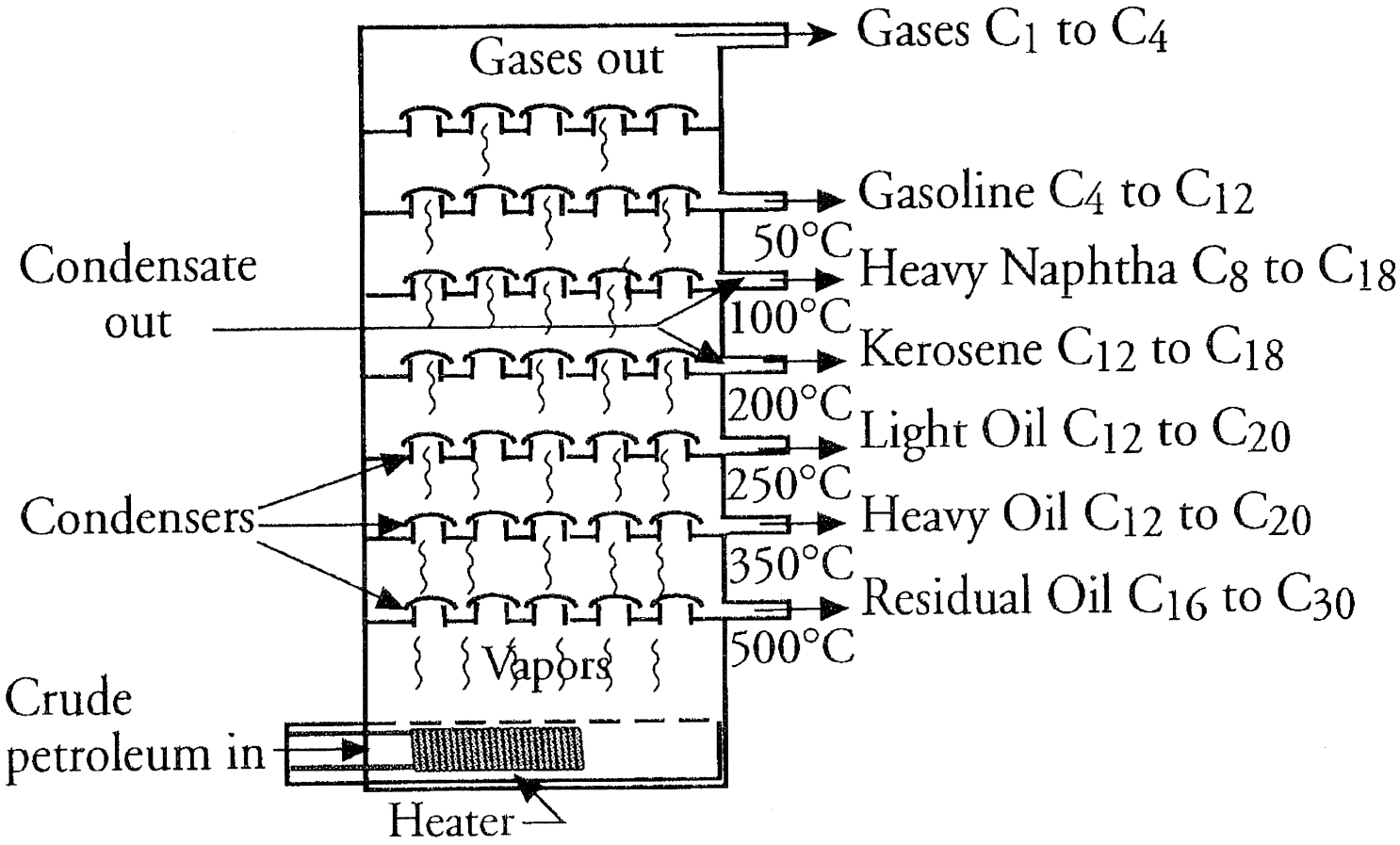
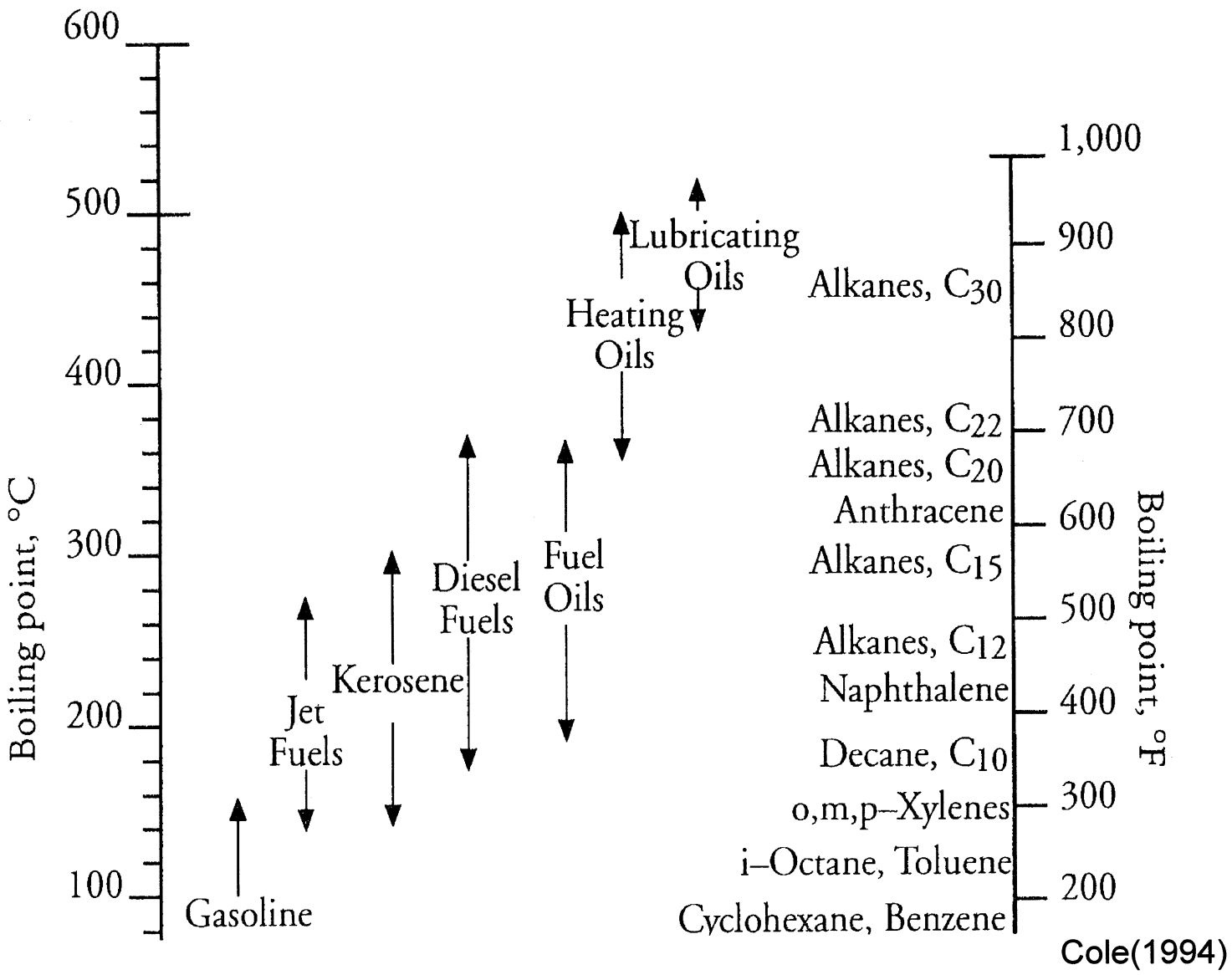
モニタリング技術

- 沈没廃井などの汚染源の探査技術
  - リモート・センシング
  - 物理探査・地化学探査
- 設備撤去後跡地や施設地下の汚染状況の探査技術
  - 地表調査・現地簡易分析
  - ボーリング
  - 物理探査（地中レーダー）・地化学探査

原油精製過程における各種石油物質の分離

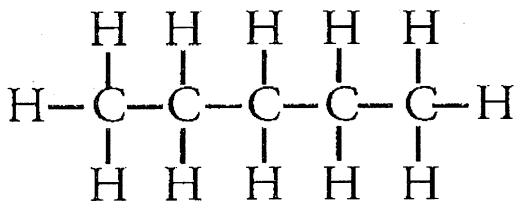



600
500
400
300
200
100
Boiling point, °C
Gasoline
Jet Fuels
Kerosene
Diesel Fuels
Fuel Oils
Heating Oils
Lubricating Oils
1,000
900
800
700
600
500
400
300
200
Boiling point, °F
Alkanes, C30
Alkanes, C22
Alkanes, C20
Anthracene
Alkanes, C15
Alkanes, C12
Naphthalene
Decane, C10
o,m,p–Xylenes
i–Octane, Toluene
Cyclohexane, Benzene
Cole(1994)

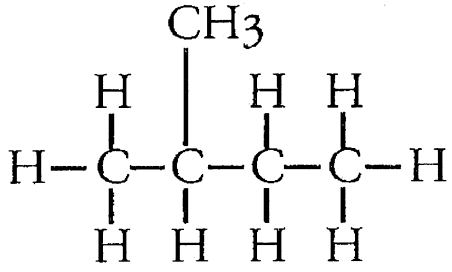
Alkane：パラフィン族

Name	Formula	Structure
Methane	CH_4	CH_4
Ethane	C_2H_6	CH_3CH_3
Propane	C_3H_8	$CH_3CH_2CH_3$
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$
Heptane	C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
Octane	C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Nonane	C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Decane	$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

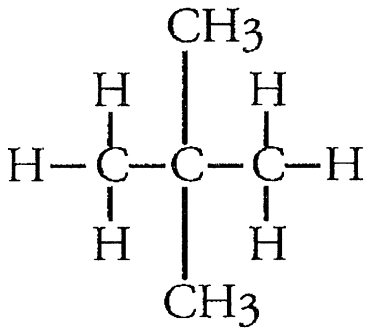
Isomeric Hydrocarbons



normal–Pentane
C_5H_{12}

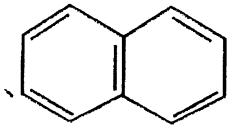


iso–Pentane
C_5H_{12}

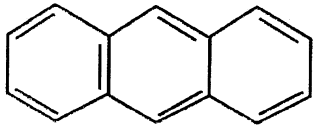


"neo–Pentane"
2,2–Dimethylpropane
C_5H_{12}

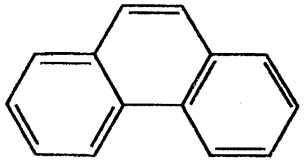
PAHs：多環芳香族



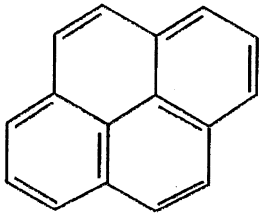
Naphthalene
$C_{10}H_{10}$



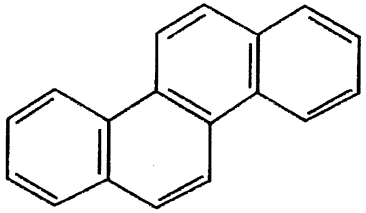
Anthracene
$C_{14}H_{10}$



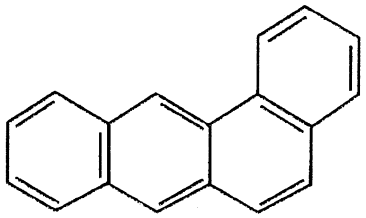
Phenanthrene
$C_{14}H_{10}$



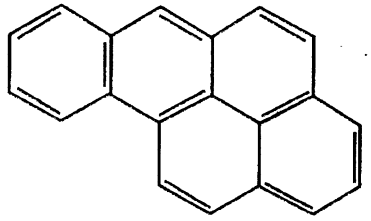
Pyrene
$C_{16}H_{10}$



Chrysene
$C_{18}H_{12}$



Benz(a)anthracene
$C_{18}H_{12}$



Benzo(a)pyrene
$C_{20}H_{12}$

Hydrocarbon	% by weight		Hazardous Substance[a]	CAS Number[b]
	Unleaded	Premium Unleaded		
n-, i-Pentane	9	13	No	
n-Hexane	11	6	No	
2-Pentane	7	3	No	
2-Methylpentane	5	4	No	
n-Octane	1	1	No	
i-Octane	2	4	No	
Benzene	4	5	Yes	71432
Toluene	4	7	Yes	108883
Ethylbenzene	2	2	Yes	100414
Xylenes	6	6	Yes	1330207[c]
Cumene	1	2	Yes	98828
MTBE, methanol, or ethanol	11 – 15	11 – 15	Yes[d]	67561[d]

[a] "Yes" means the hydrocarbon is a listed hazardous substance under Subtitle C of RCRA.

[b] Chemical Abstract Service number; useful for looking up further information.

[c] For mixed isomers of xylene.

[d] For methanol; MTBE and ethanol are not hazardous substances.

Cole(1994)

Product	Compound	TLV[1]	Potential Health Effects
Gasoline	Benzene	10	Nausea, vomiting, known human carcinogen
	Toluene	100	CNS depression, fatigue, weakness, eye irritant
	Xylenes	100	CNS depression, nausea, vomiting, skin irritant
	Ethylbenzene	100	CNS depression, nausea, vomiting, liver/kidney damage
	n–Hexane	50	Nausea, dizziness, vomiting, severe but reversible paralysis
	Other hexane isomers	500	Skin, mucous membrane irritant
	Octane	300	Weakness, fatigue, headache, nausea, vomiting, anorexia, diarrhea
	Ethylene dibromide, EDB	0[6]	Probable human carcinogens
	Ethylene dichloride, EDC[2]	10	
	Tetraethyllead, TEL	0.1[4]	Weakness, fatigue, headache, nausea,
	Tetramethyllead, TML[3]	0.15[4]	vomiting, anorexia, diarrhea
Middle Distillates	PAHs		
	Naphthalene	10	Weakness, tremors, dizziness, vomiting
	Benzo(a)anthracene	0	Probable human carcinogens
	Benzo(a)pyrene	0	Probable human carcinogens
	Cresols and Phenols	5	Skin, eye, mucous membrane irritant
	N,N–dimethylformamide	10	Skin, eye, mucous membrane irritant
	Manganese compounds[5]	0.1	CNS affected, non–specific
Residual Fuels	PAHs		
	Benzo(a)anthracene	0	Probable human carcinogens
	Benzo(a)pyrene	0	Probable human carcinogens
	Crysene	0	Possible human carcinogens

1 Threshold Limit Values; Values are time–weighted average exposures in ppm for vapors. STELs, Short Term Exposure Limits, are usually higher.

2 Additives in leaded regular gasolines.

3 Legal limit for lead in gasoline is 13 mg/liter of gasoline.

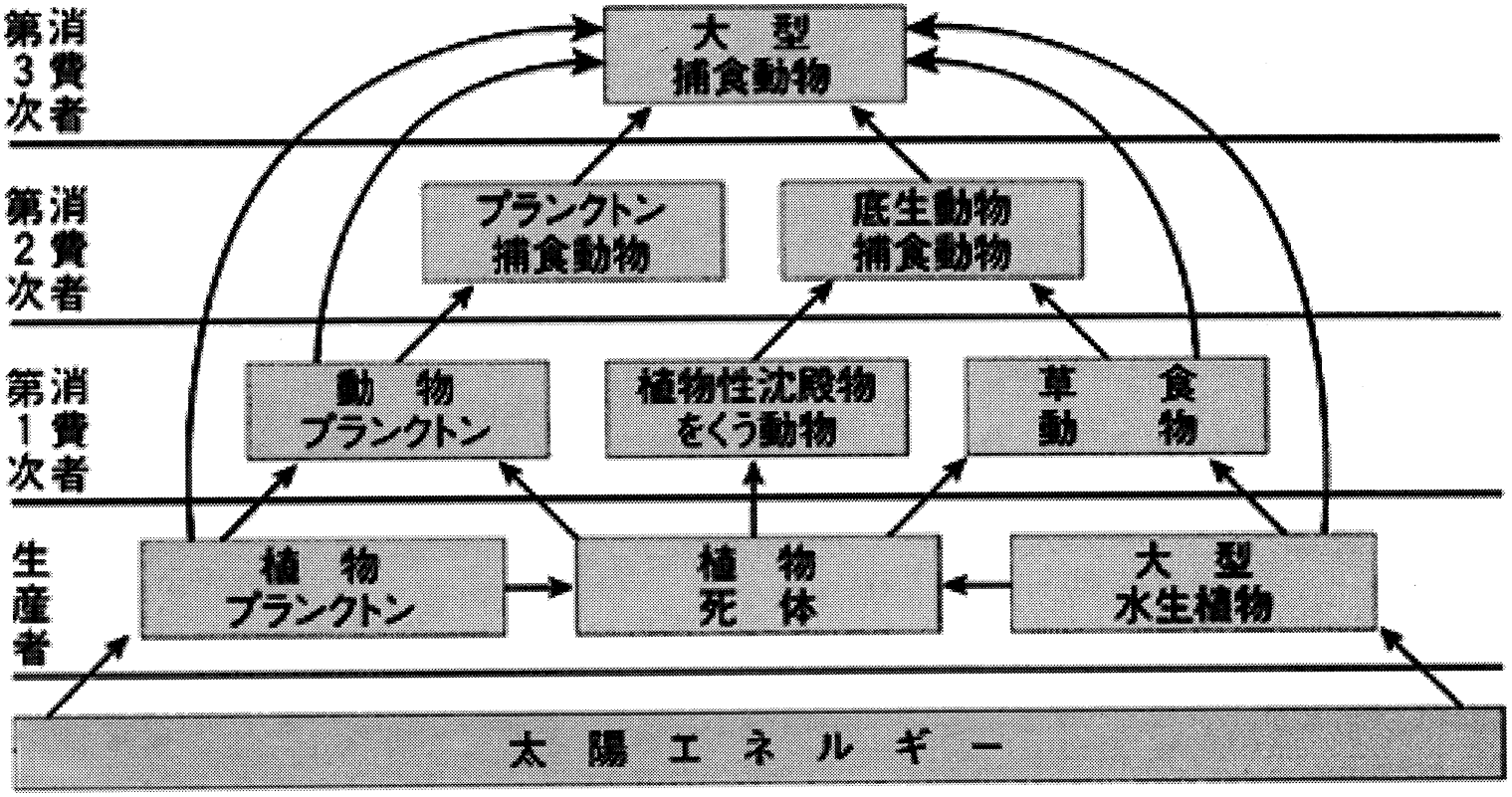
4 In mg/m^3 for skin absorption.

5 For the compound manganese cyclopentadienyl tricarbonyl which has been used as an additive in regular gasolines.

6 A value of zero means there is no acceptable exposure level.

Cole(1994)

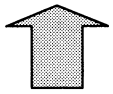
石油汚染によって正常な食物連鎖・物質環境系が崩れ、汚染海域が漁場として価値を喪失



財団法人 漁場油濁被害救済基金,2004

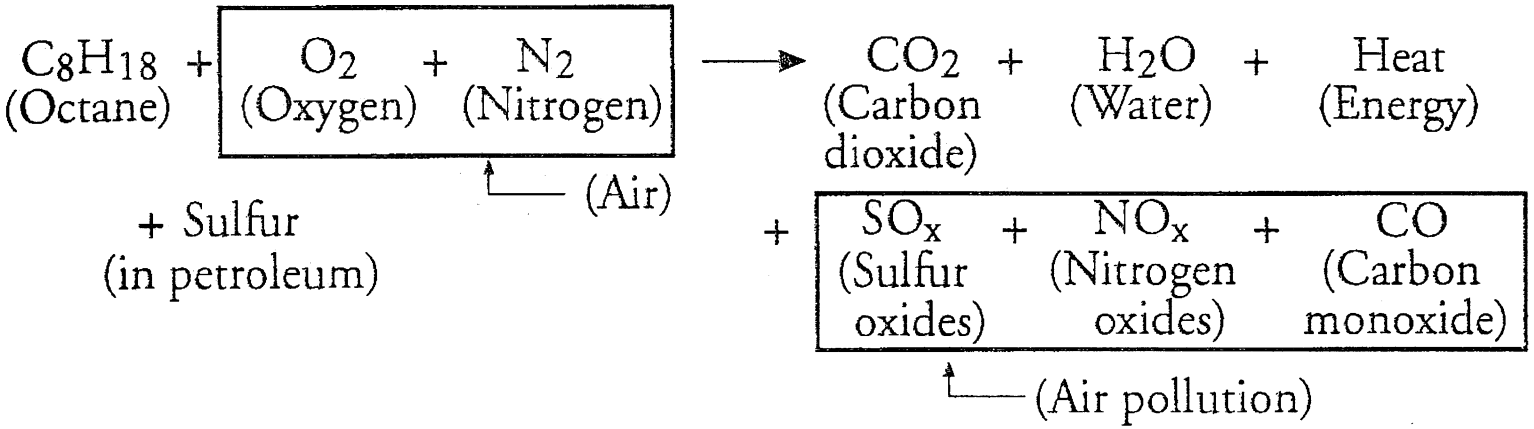
分析技術

- 石油系化学物質の同定
- 濃度の定量



- 前提条件
  - 分析プロトコール
  - 環境基準・排出基準・浄化基準
  - 分析体制

燃焼によるSOxとNOxの発生
有害微量元素の放出



+ Sulfides of Trace Metals ⟶ Particulates containing Trace Metals (Mo *etc*)

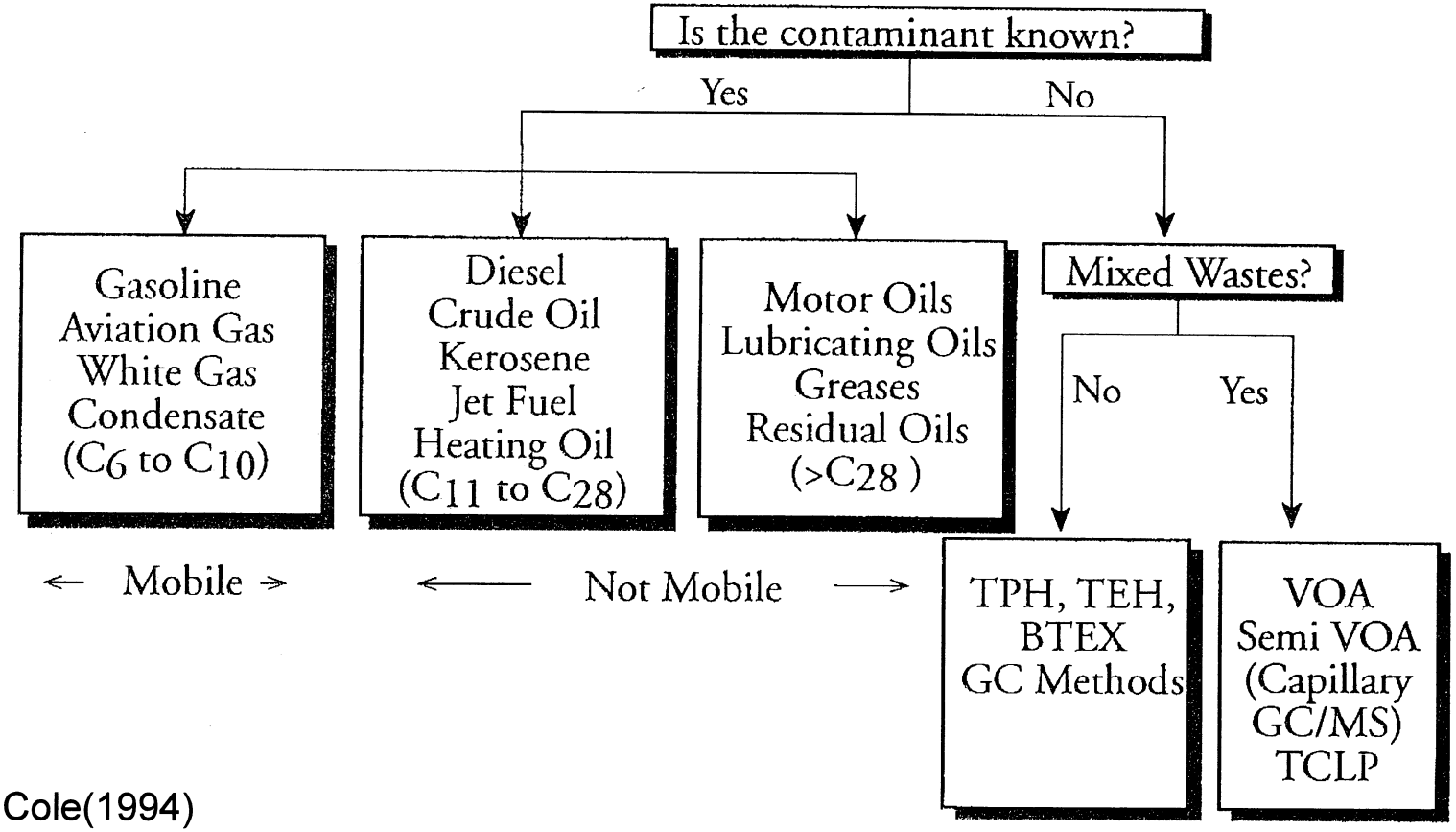
分析手法

IR
GC
GC/MS

Cole(1994)

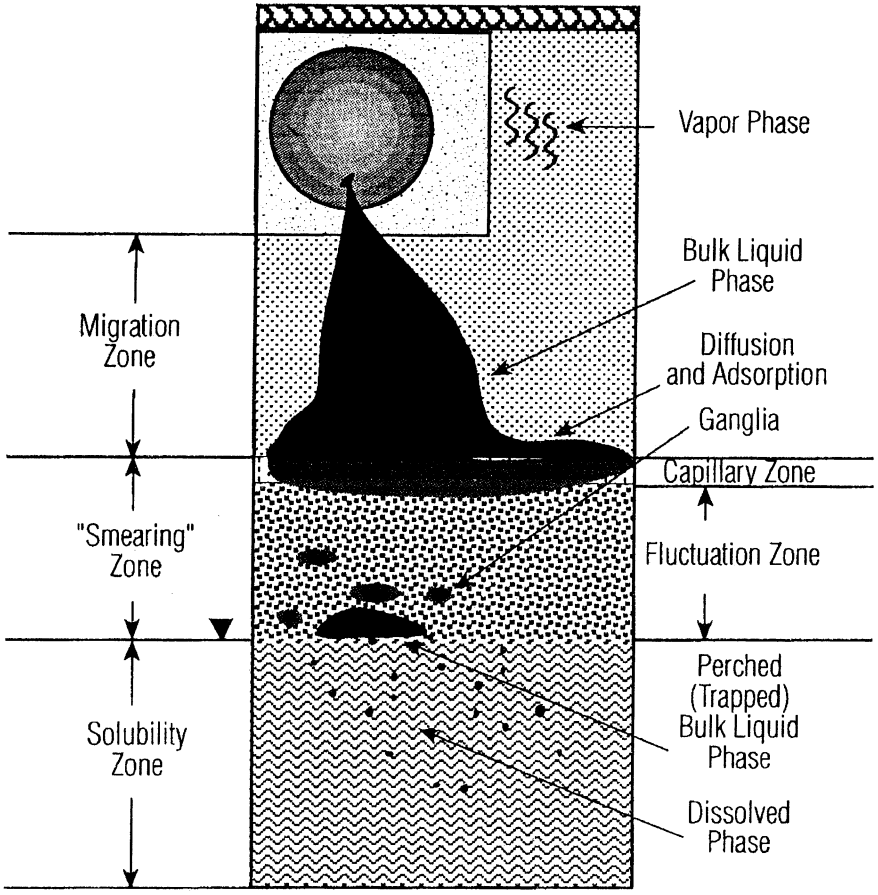
Analysis	Contaminant	Matrix	By	Method	Cost
Group Methods					
TPH	Petroleum	Soil	IR	418.1	$65
TVPH	Gasoline	Soil	GC	8015 M	65
TEPH	Diesel	Soil	GC	8020	45
TRPH	Heavy oils	Soil	IR	413.1	45
BTEX	Aromatics	Soil	GC	8015	85
TPH	Petroleum	Water	GC/MS	620	90
TVPH	Gasoline	Water	IR	8270	90
TEPH	Diesel	Water	GC	625	90
TRPH	Heavy oils	Water	GC	8015	90
BTEX	Aromatics	Water	GC/MS	624	90
VOCs	Volatiles	Soil	GC/MS	8240	225
VOCs	Volatiles	Water	GC/MS	624	225
Individual compounds					
MTBE	In gasoline	Water	GC/MS	8240	125
Ethylene glycol	Waste oil	Soil	GC	8240	75
EDB, EDC	In leaded gasoline	Soil	GC/MS	8240	125
TML, TEL	In leaded gasoline	Soil	GC/MS	8240	125

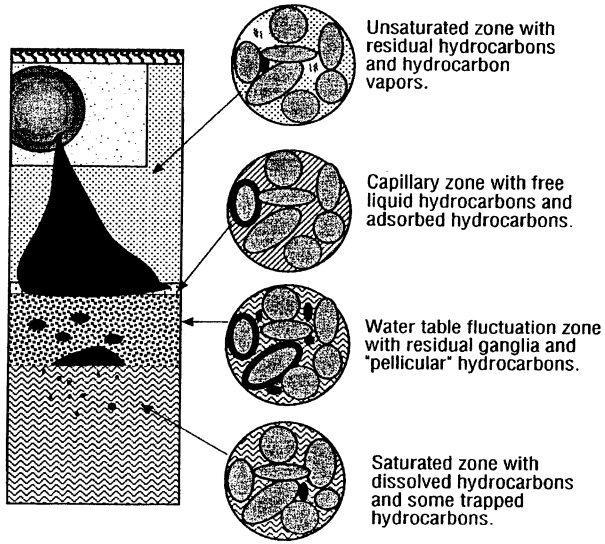
汚染サイトの評価



Cole(1994)

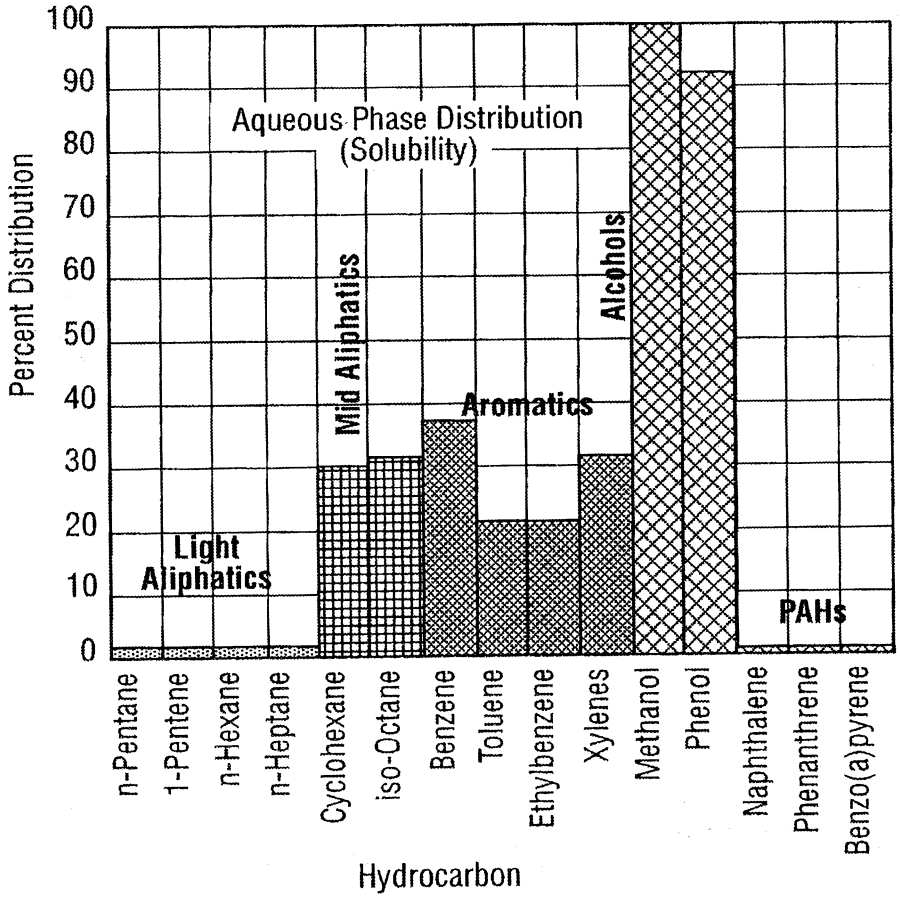
石油漏出による土壌・堆積物汚染





Cole(1994)

炭化水素の溶出



Cole(1994)

浄化処理(Site Remediation)技術

―技術選択は汚染の種類、現場条件、コストによる―

- ばっ気・気化　Volatilization (Soil Venting)
- 低温分離・分解　Low Temperature Thermal Stripping
- 高温分離・分解　High Temperature Thermal Stripping
- 溶融ガラス化　In situ Vitrification

熱処理

- 分離抽出　Leaching and Chemical Extraction
- 固化・不溶化　Solidification and Stabilization
- アスファルト固化　Asphalt Incorporation & Treatment

化学処理

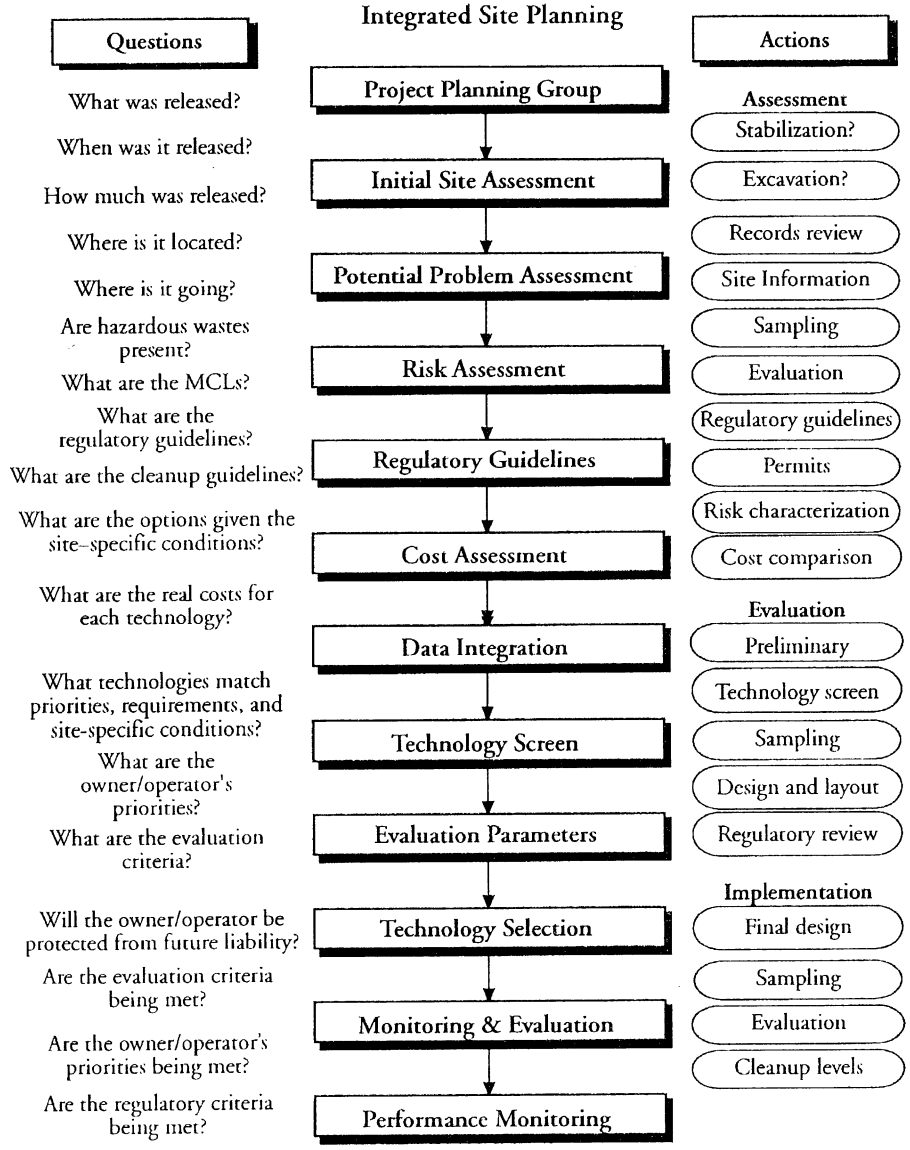
- 現地活性化生物処理　In situ Bioremediation
- 現地受動的生物処理　Passive Bioremediation
- 掘削生物処理　Landfarming (Non-In situ Bioremediation)

生物処理

- 閉鎖・封入　Isolation and Containment
- 掘削・安全埋立　Excavation and Landfilling

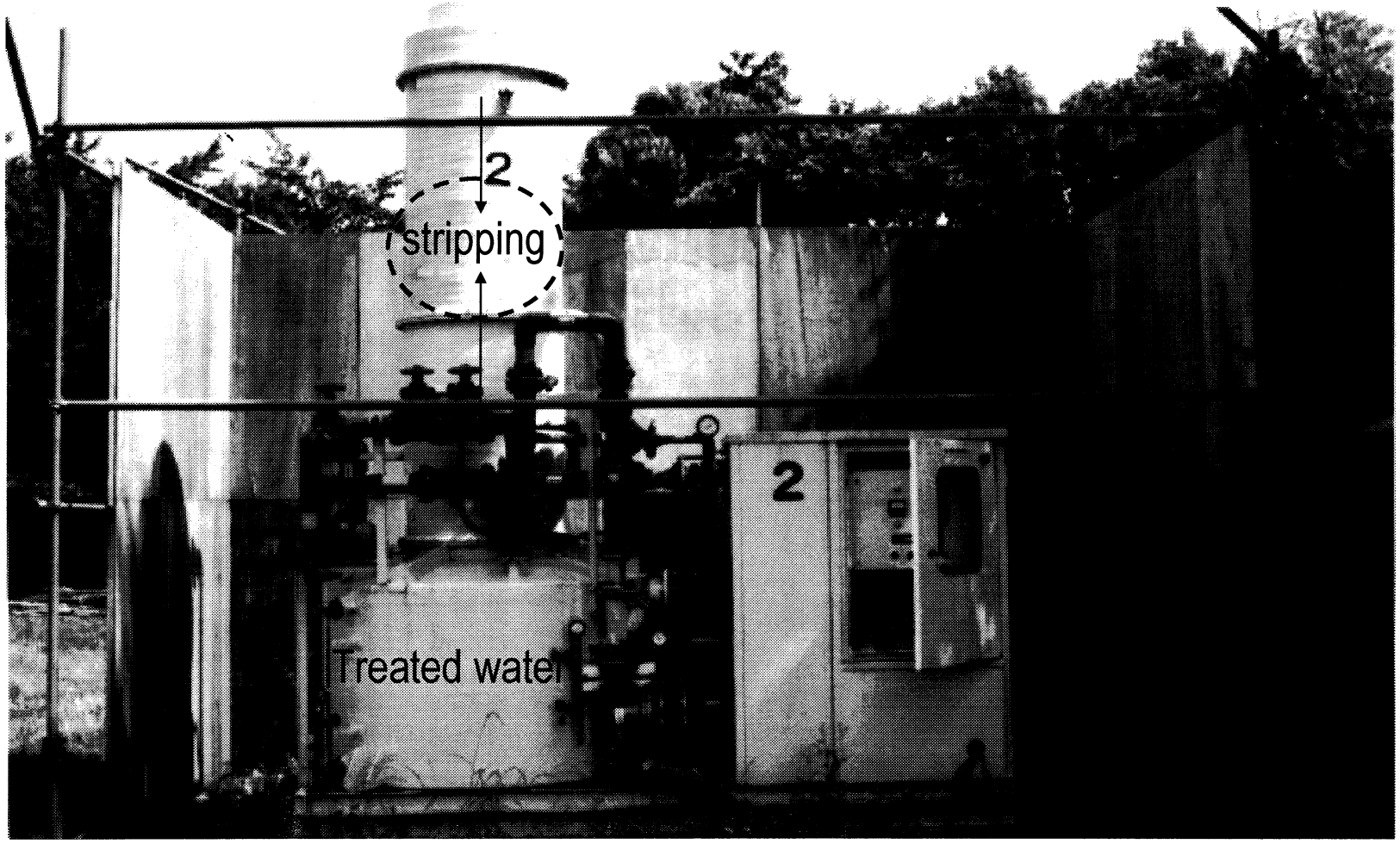
無処理遮蔽

リスク評価プロセス

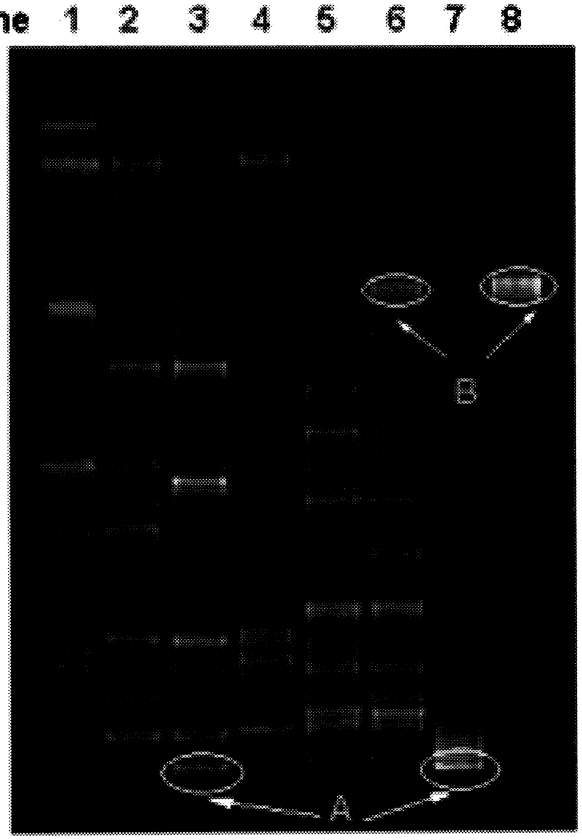


Cole(1994)

P&T: Air Stripping Tower

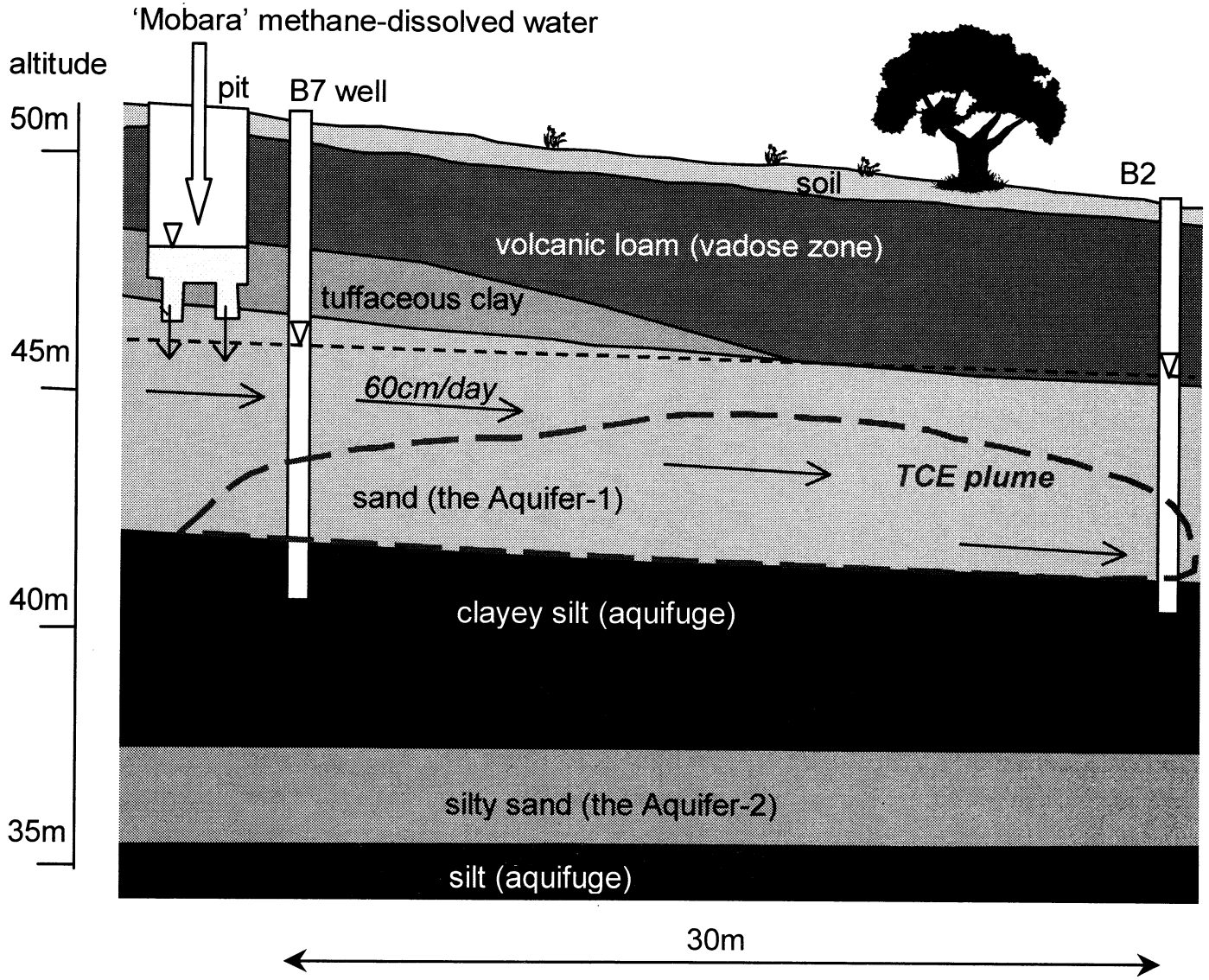


PCR-DGGE法による石油汚染土壌の微生物群集構造解析

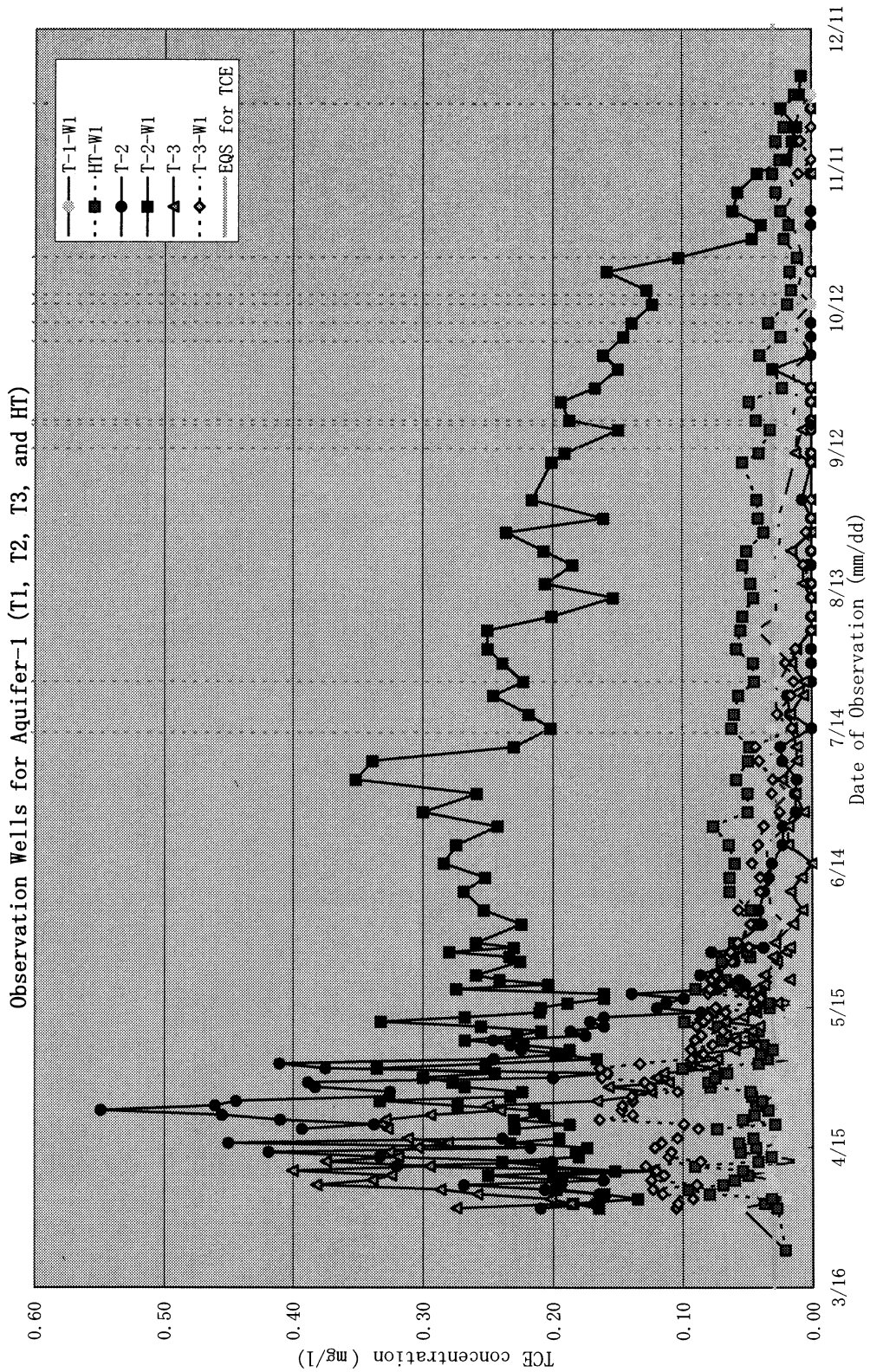


1. I 土壌
2. I 土壌 control 系
3. I 土壌 原油集積培養系
4. II 土壌
5. II 土壌 control 系
6. II 土壌 原油集積培養系
7. 石油分解菌 A
8. 石油分解菌 B

Ebara Research Co., Ltd., 2004



- modified from Takeuchi et al.(1999)


Observation Wells for Aquifer-1 (T1, T2, T3, and HT)
T-1-W1
HT-W1
T-2
T-2-W1
T-3
T-3-W1
EQS for TCE
TCE concentration (mg/l)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3/16
4/15
5/15
6/14
7/14
8/13
9/12
10/12
11/11
12/11
Date of Observation (mm/dd)

まとめ
環境管理・環境影響評価分野の協力課題

- 石油汚染に関わる法制度・環境基準・組織体制のシステム整備への協力
- モニタリング（沈没廃井や汚染源の探査、汚染状況の把握）への協力
- 分析・評価・技術選択への協力
- 汚染対策、浄化技術の技術移転と指導
- これらをになう人材育成を含めたキャパシティ・ビルディングのための協力