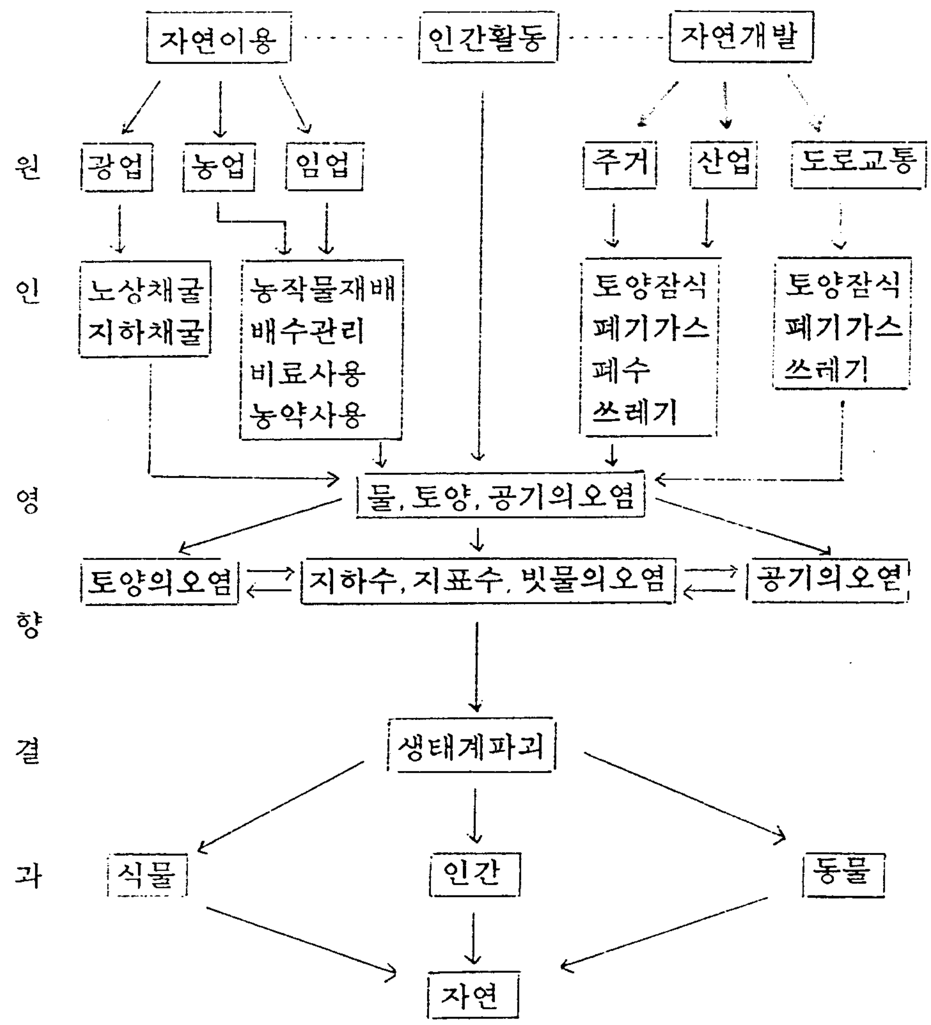
표 1: 인간활동과 생태계와의 관계



오염토양의 문제점

○ 직접접촉
오염토양의 직접적인 섭취에 의한 위해성(특히 어린이)

○ 흡입
위해성 가스나 분진의 흡입에 의한 위해성

○ 지하수
지하수, 식수의 오염

○ 지표수
먹이사슬에 의한 오염 (어류)

○ 식물
식물오염 및 생산성저하

○ 식품 및 사료
동 · 식물제품의 오염

○ 토양
자정력 장애, 자연생산성 (지력) 약화, 생명공동체 유지기능 약화

○ 건축물
부식을 통한 훼손

○ 발화/폭발위험
매립지 Gas배출로 인한 오염

○ 인간
급성 또는 만성적 위해

Methods of soil remediation

- **In-situ decontamination (Methods requiring no excavation)**

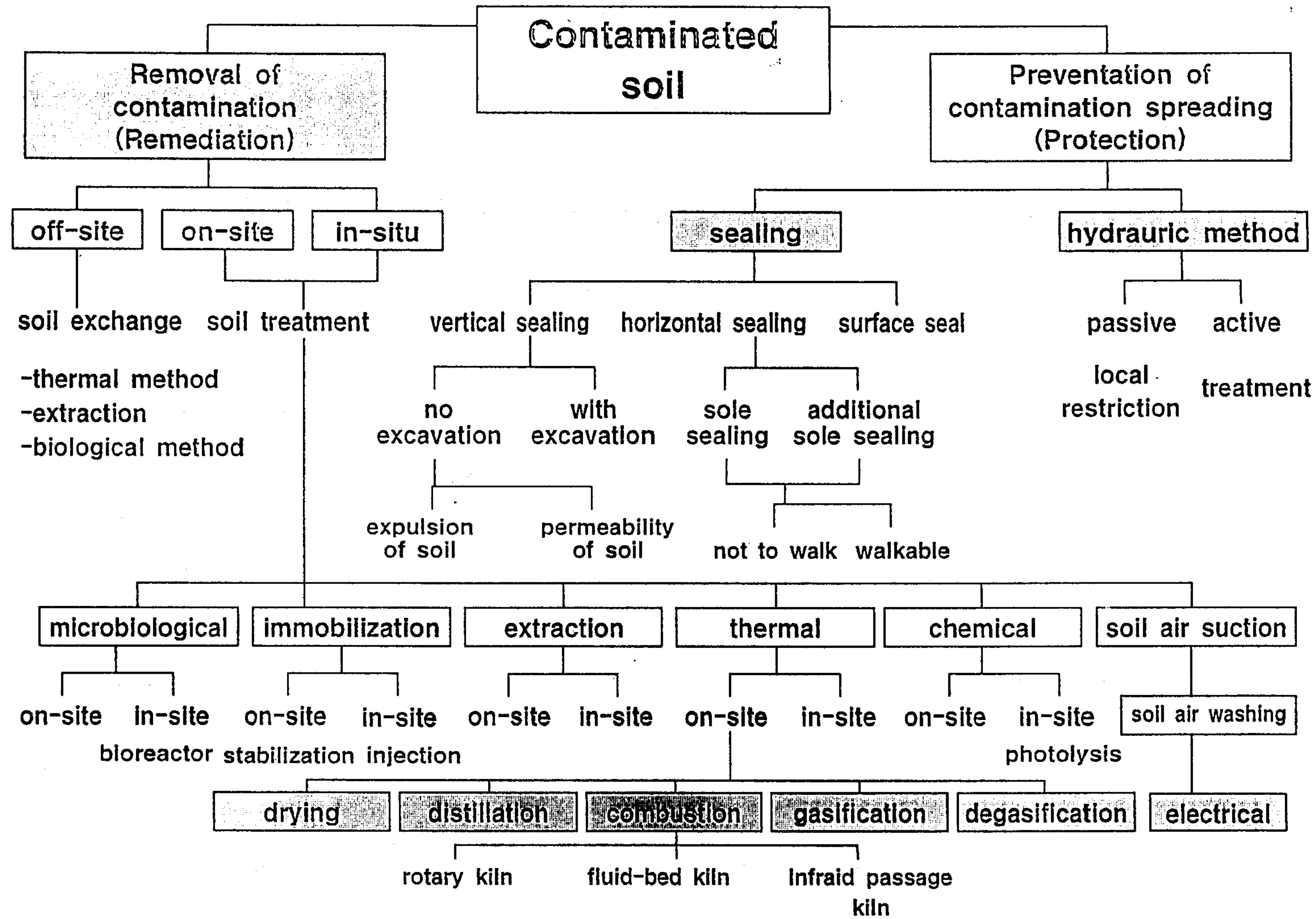
  Contamination are removed from the subsurface by extraction or trasformation

- **On-site technologies (Methods with excavation)**

  The excavated soil is treated at the contaminated site

- **Off-site technologies (Methods with excavation)**

  The excavated soil is transported to a treatment plant



Remediation of soil

토양의 종류에 따른 처리기술

기술명 \ 토양의 종류		입자가 큰 모래땅	비옥한 모래땅	점토질 땅	유기질 땅	불균일한 땅
토양공기흡입법 (soil vapor extraction)		0	0	X	?	?
열처리법 (thermal treatment)	고온처리와 폐기가스소각법 (high temperature and waste gas incineration)	0	0	0	?	0
	저온처리와 폐기가스소각법 (low temperature and waste gas incineration)	0	0	0	?	0
추출 또는 세척법 (extraction/soil washing)		0	?	X	?	?
생물학적 방법 (mikrobiological treatment)		0	0	?	0	0

적합: 0
조건적 사용가능 또는 불규명: ?
부적합: X

오염물질에 따른 처리기술

기술명 \ 오염물질		중금속	시안화합물	탄화수소 광유	다환 방향족탄화수소	휘발성 염소화탄화수소	할로겐 유기화합물
토양공기흡입법 (soil vapor extraction)		X	X	X	X	0	X
열처리법 (thermal treatment)	고온처리와 폐기가스소각법 (high temperature and waste gas incineration)	?	0	0	0	0	0
	저온처리와 폐기가스소각법 (low temperature and waste gas incineration)	X	0	0	?	0	X
추출 또는 세척법 (extraktions/soil washing)		0	0	0	0	0	?
생물학적 방법 (microbiological treatment)		X	?	0	0	?	0

적합: 0　　조건적 사용가능 또는 불규명: ?　　부적합: X

물리화학적 처리기술
(physical-chemical treatment techniques)

1. Soil Flushing (Soil Washing)

   - Aqueous
   - Surfactant
   - Solvent

2. Soil Vapor Extraction (SVE)

3. 기타 처리기술

   - Air Sparging
   - Air Stripping
   - 활성탄흡착
   - 이온교환
   - Critical Fluid (초임계유체)

토양세척시 사용되는 첨가제

1. 계면활성제 (surfactant)

2. complexing agent

3. 산 (acid)

4. 알카리 (alkali)

토양세척의 주요공정

1. 오염토양의 전처리공정
   (분쇄기, 크기선별기)

2. 토양세척공정
   (첨가제 및 기계적 에너지이용)

3. 정화된 토양의 분리공정
   (침전, 부유, hydrocyclone, de-emulsification)

4. 세척용액의 처리공정
   (세척액 처리장치)

5. 배기가스 처리공정
   (대기오염 방지장치)

표 8: 물리화학적 처리법의 개요

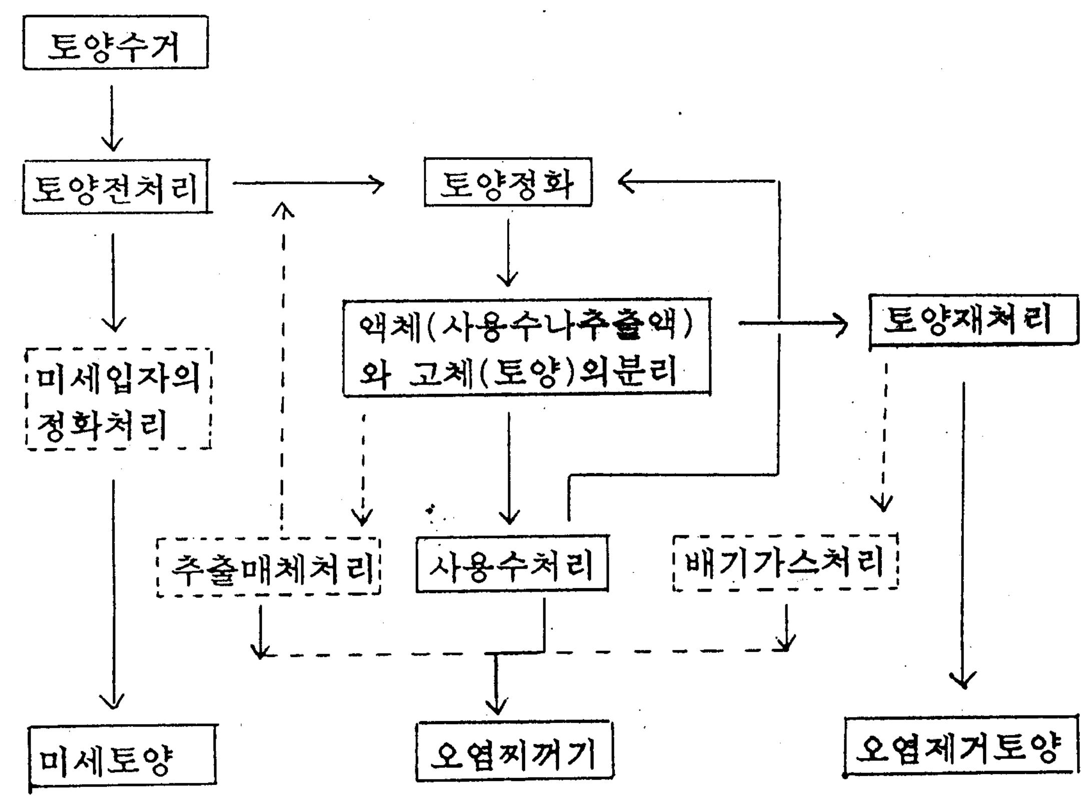
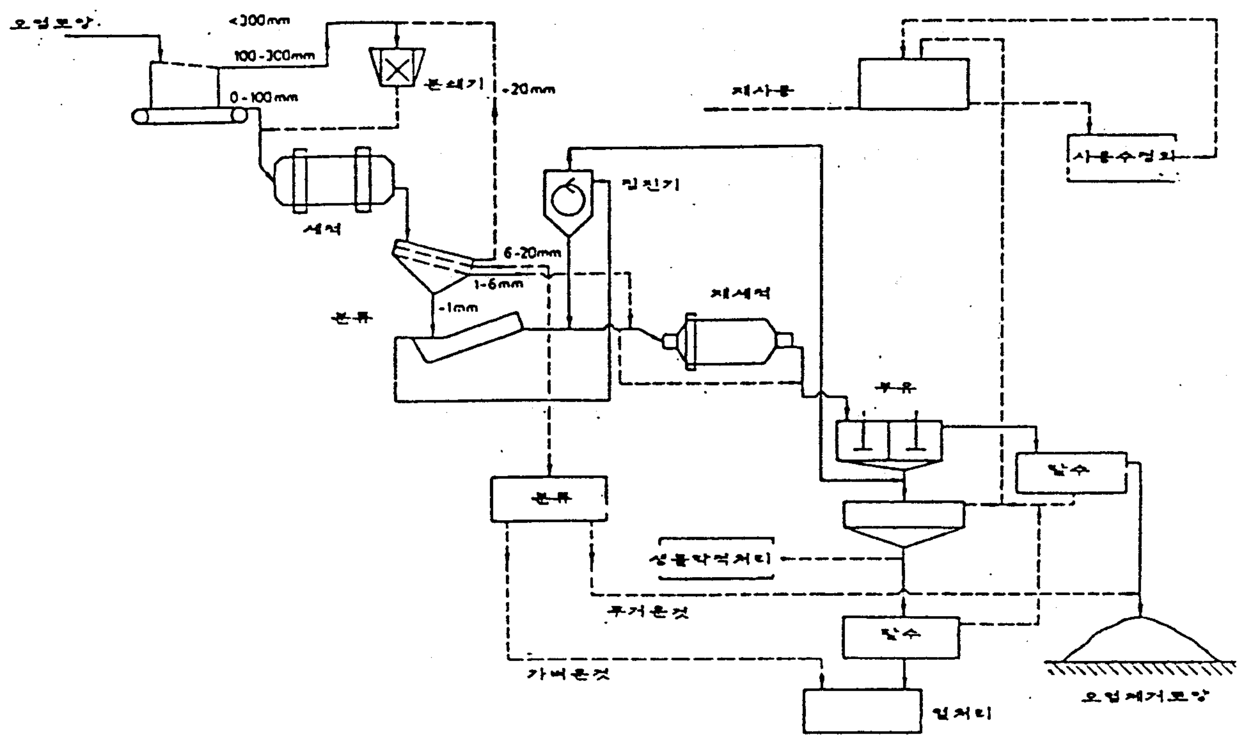


그림 4: 토양세척법

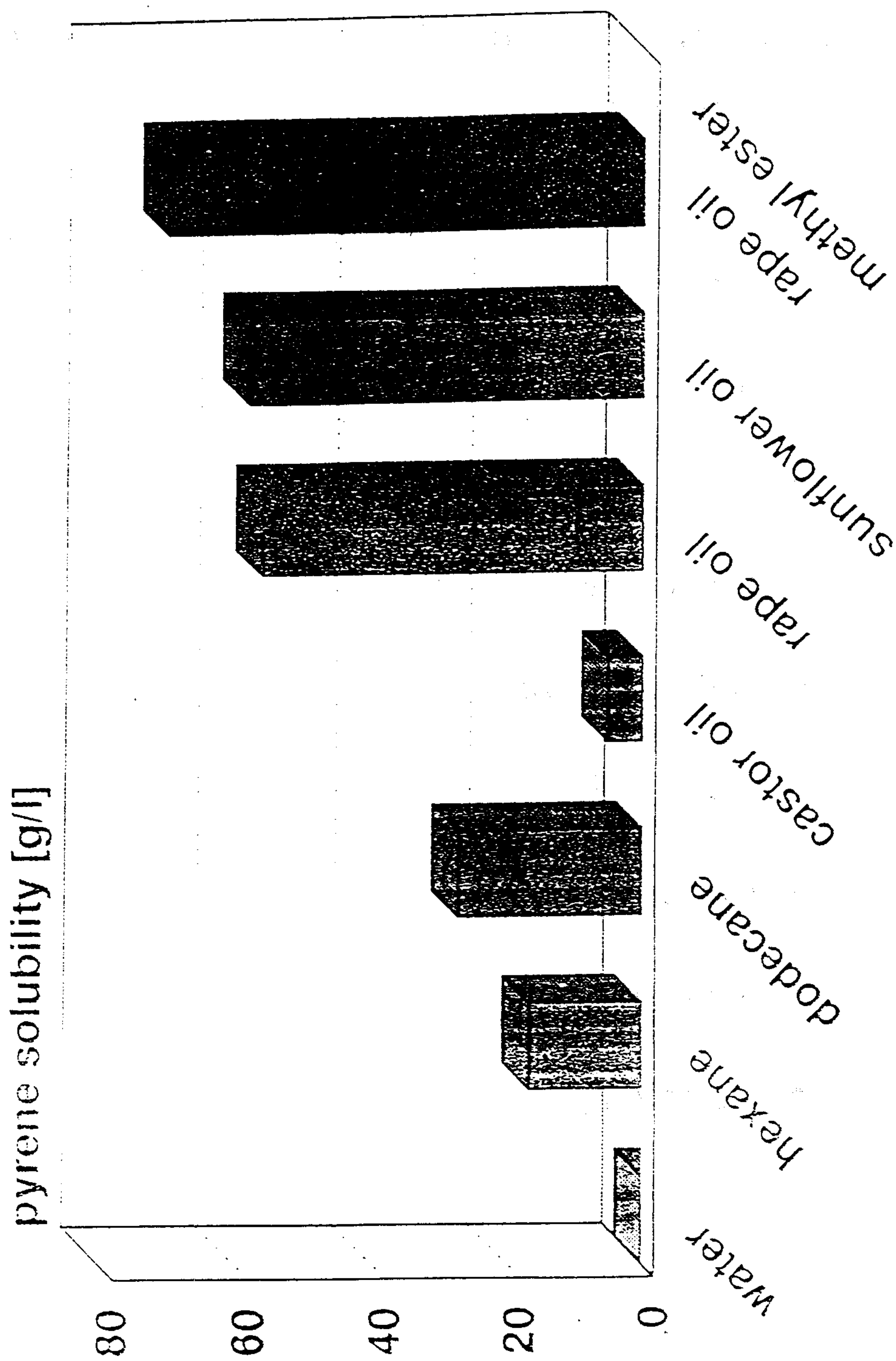

오염토양
<300mm
100-300mm
0-100mm
분쇄기
+20mm
세척
6-20mm
1-6mm
-1mm
분류
집진기
재세척
재사용
사용수정화
부유
탈수
분류
생물학적처리
무거운것
가벼운것
탈수
열처리
오염제거토양

Function of surfactants in the soil remediation

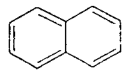
- Sorption barrier
- Floatation and coagulation auxilary
- Mobilization of pollutants
- Solubilization of pollutants
- Support of biological degradation of pollutants

Important parameters for the soil remediation

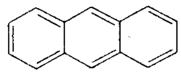
- Wetting
- Interfacial tension
- Surface tension and CMC
- Viscosity
- Solubilization
- Absorption
- Desorption
- Precipitation
- Recovery


pyrene solubility [g/l]
80
60
40
20
0
water
hexane
dodecane
castor oil
rape oil
sunflower oil
rape oil
methyl ester

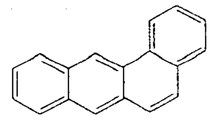
PAK nach EPA und TVO



Naphthalin

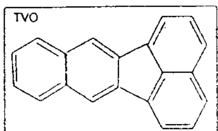


Anthracen

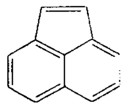


Benz[a]anthracen

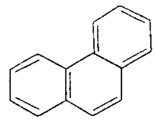
TVO



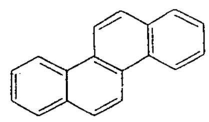
Benzo[k]fluoranthen



Acenaphthylen

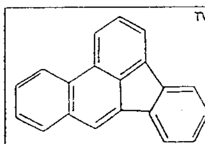


Phenanthren

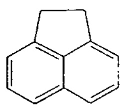


Chrysen

TVO

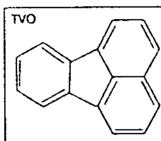


Benzo[b]fluoranthen



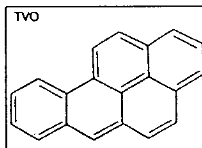
Acenaphthen

TVO



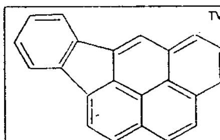
Fluoranthen

TVO

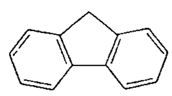


Benzo[a]pyren

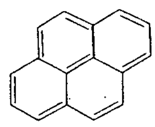
TVO



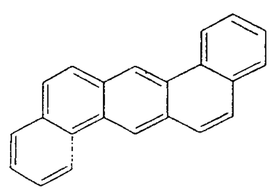
Indeno[1,2,3-cd]pyren



Fluoren

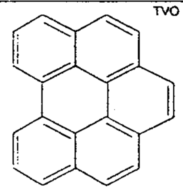


Pyren



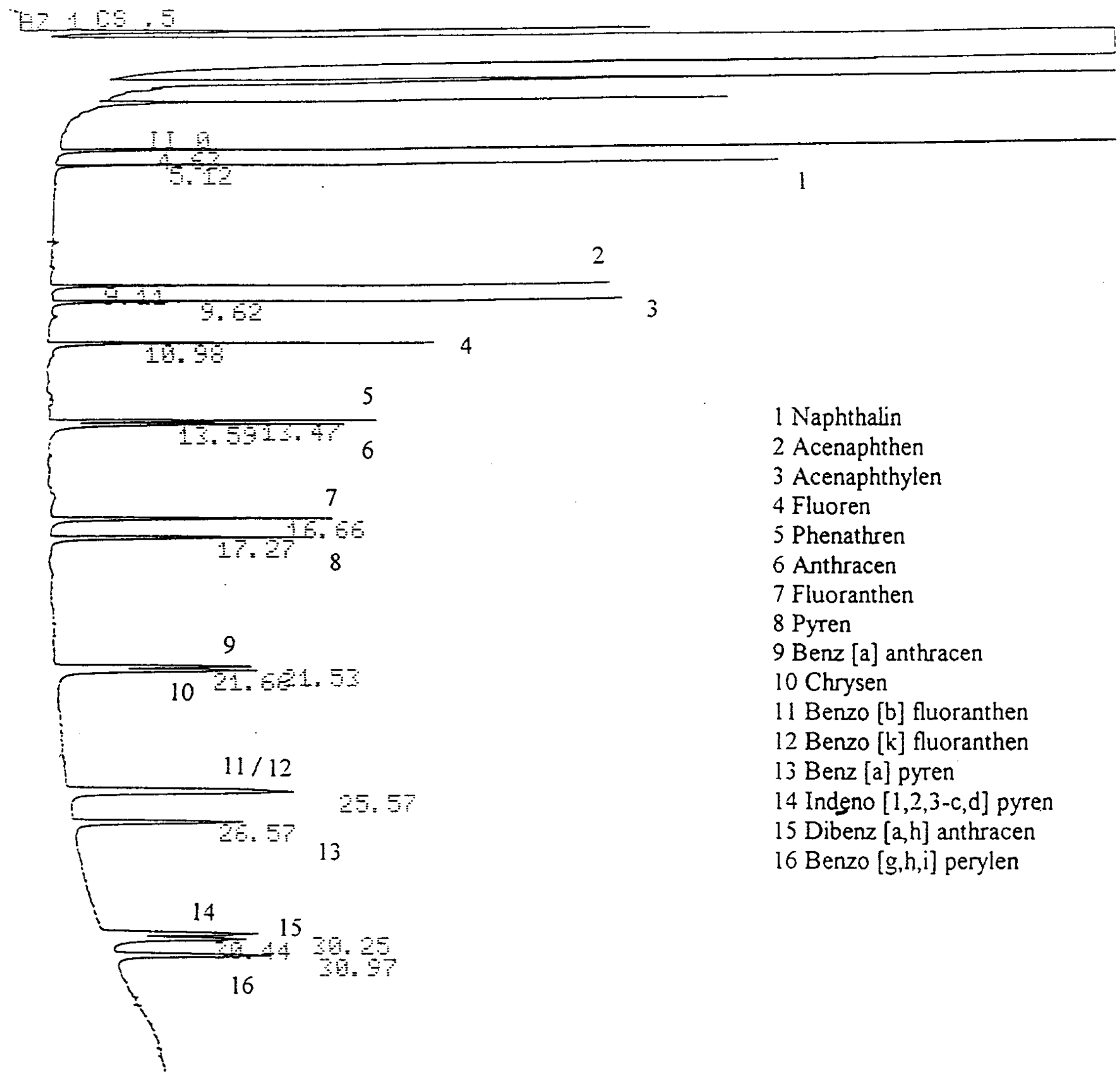
Dibenz[ah]anthracen

TVO



Benzo[ghi]perylen

Abb. 1 : Gaschromatogramm einer Standardlösung (16 EPA PAK´s)



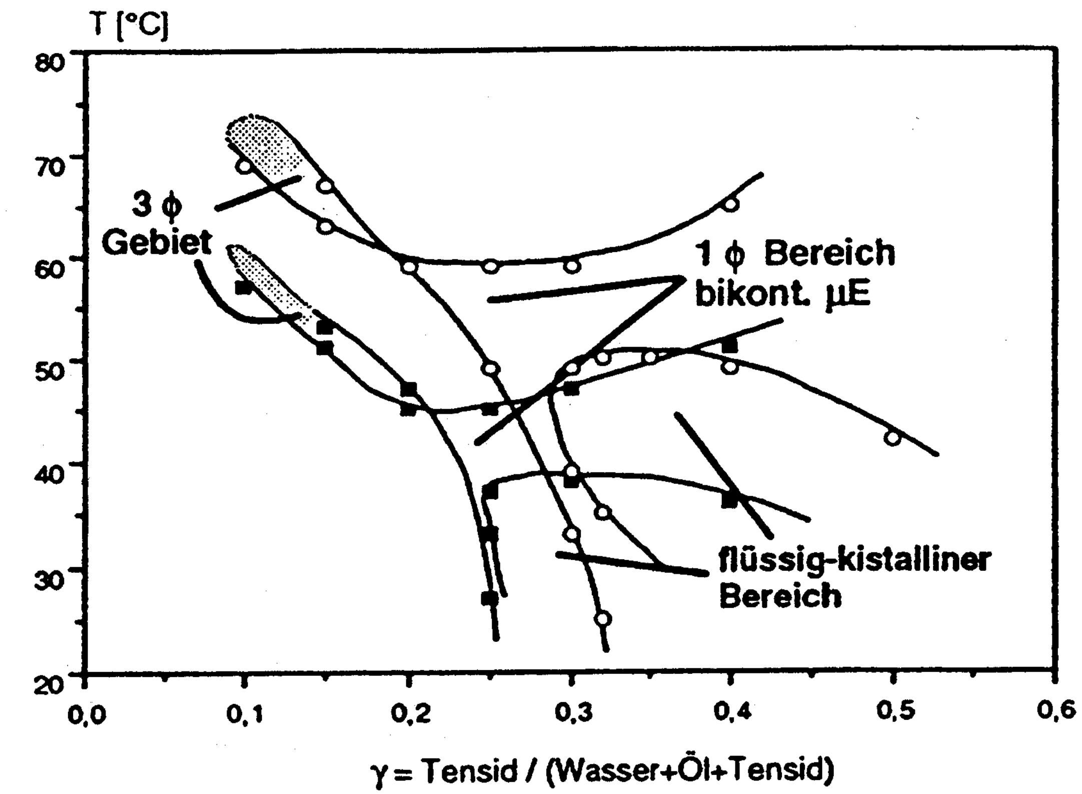


Bild 3: Phasendiagramm der Systeme $C_{9/11}E_4$ bzw. $C_{9/11}E_5$ mit RME

Tabelle 1: Verteilungsgleichgewicht von Pyren zwischen der wäßrigen $^{(w)}$ und der ölreichen $^{(o)}$ Phase für das System $C_{9/11}E_4$/RME/Wasser. Die Extraktion fand bei 43°C statt, das Lsg./ Boden-Verhältnis war 6/1

α	γ	T_{sp} in [°C]	V^o / V_0^o	$c_{Pyr.}^o / c_{Pyr.}^w$	$m_{Pyr.}^o / m_{Pyr.}^w$	% Pyren-abtrennung
0,3	0,17	30	0,32	3,06	0,29	22
0,3	0,17	22	0,56	4,14	0,74	43
0,3	0,17	16	0,67	4,76	1,04	51
0,3	0,17	10	0,73	5,27	1,26	56
0,5	0,22	34	0,38	2,02	0,38	28
0,5	0,22	26	0,57	2,60	0,81	45
0,5	0,22	20	0,66	2,98	1,08	52
0,5	0,22	16	0,69	3,06	1,20	55

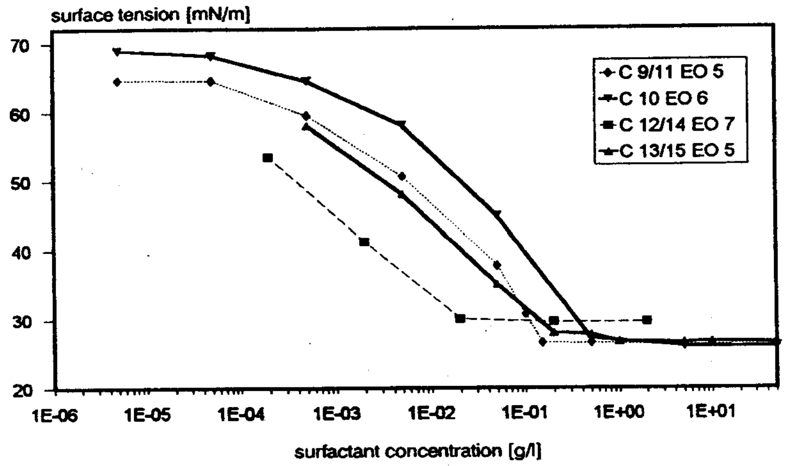


Figure 1. **c.m.c. for different nonionic surfactants**

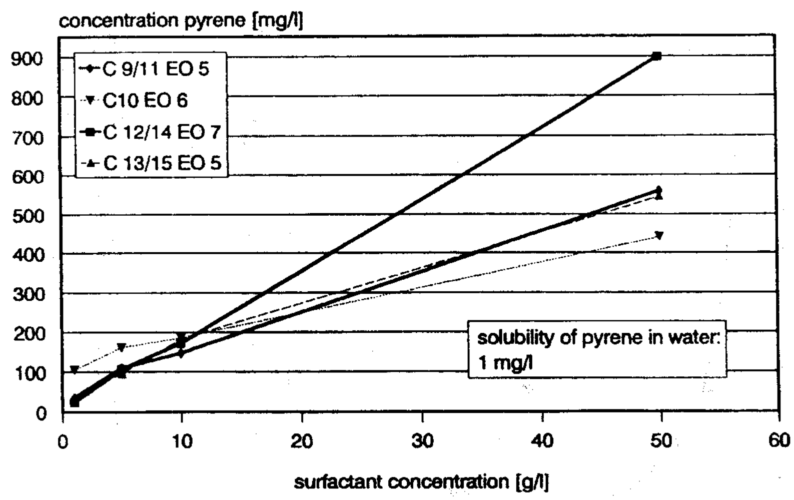


Figure 2. **Solubilization capacity of pyrene in various surfactant systems**

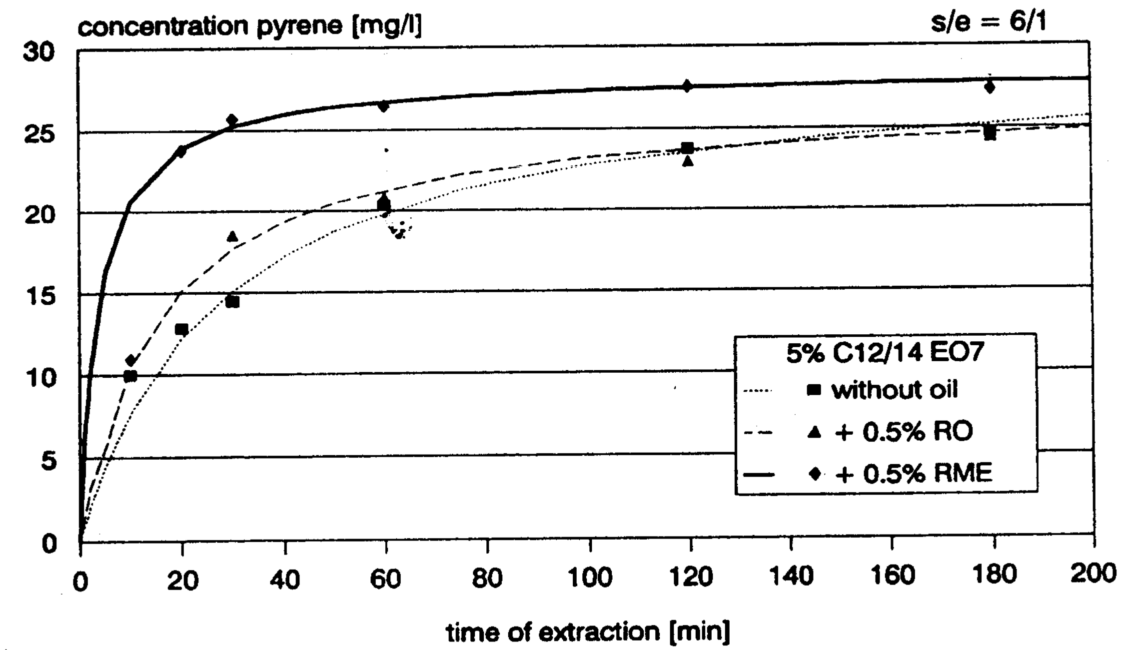


Figure 3. **Kinetics of the pyrene uptake from a fine soil fraction with pure surfactant and o/w microemulsion systems**

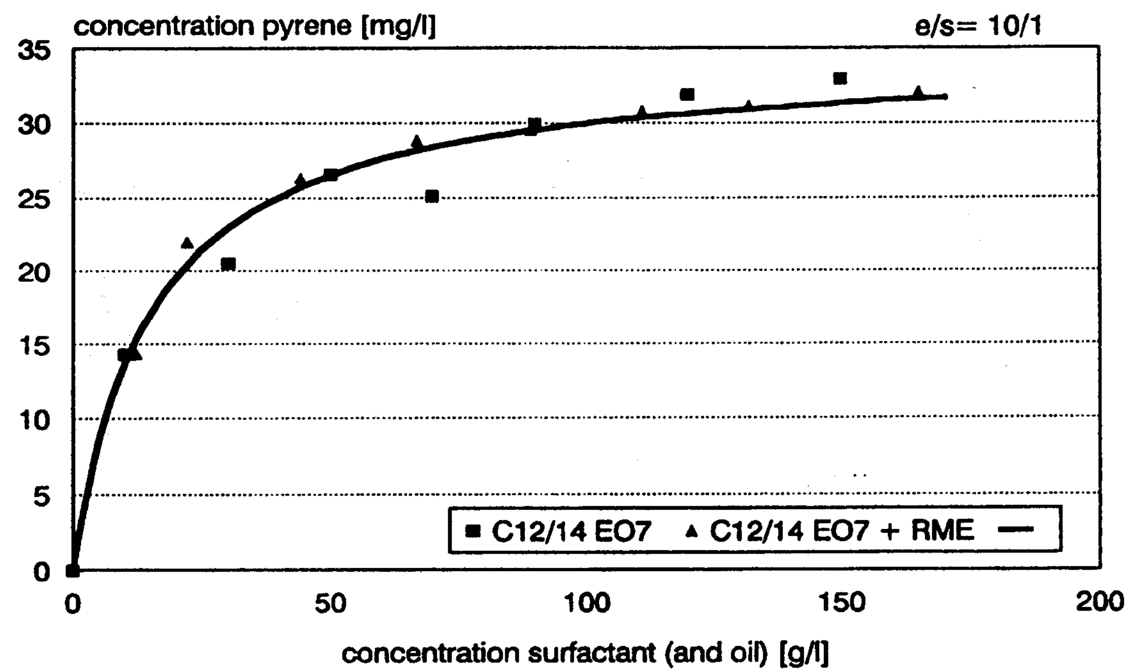


Figure 4. **Pyrene uptake from fine soil fraction as a function of surfactant (surfactant + oil) concentration**

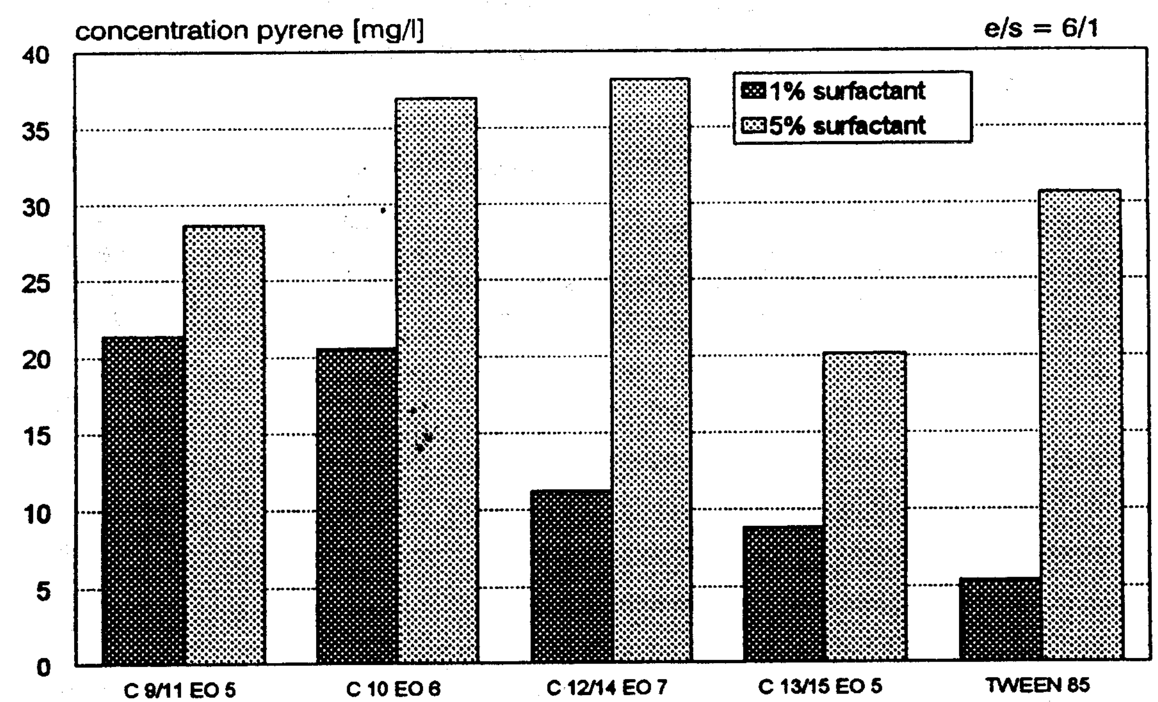


Figure 5. **Pyrene extraction with surfactant solutions**

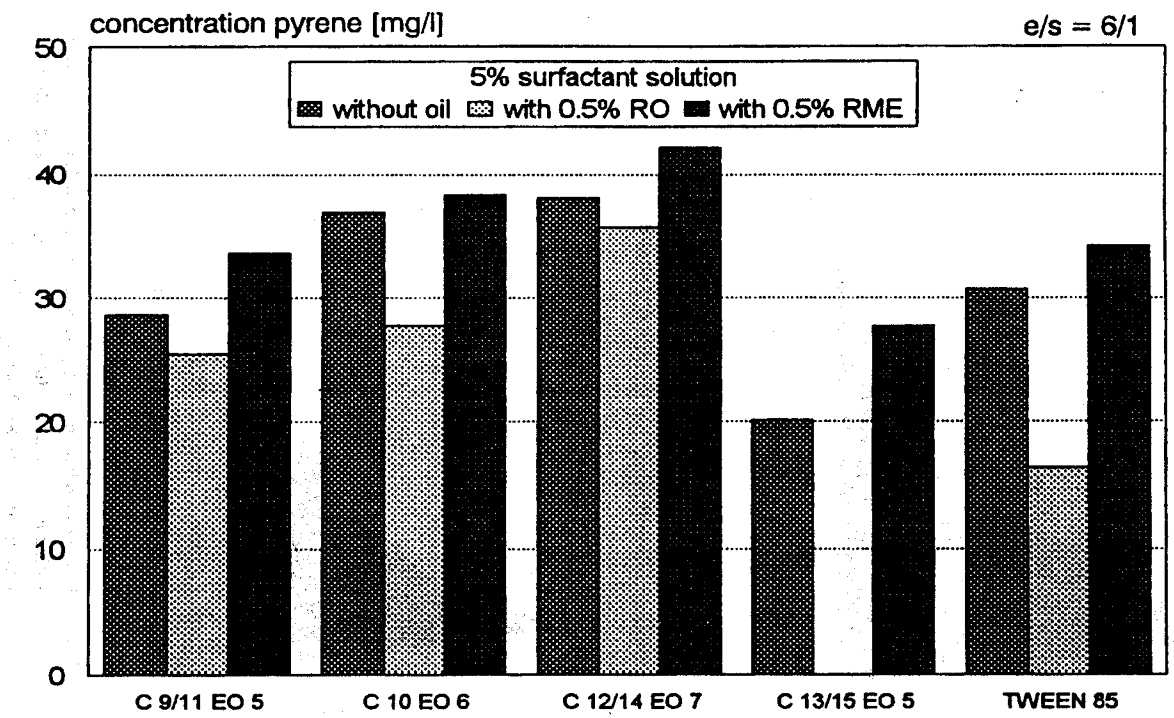
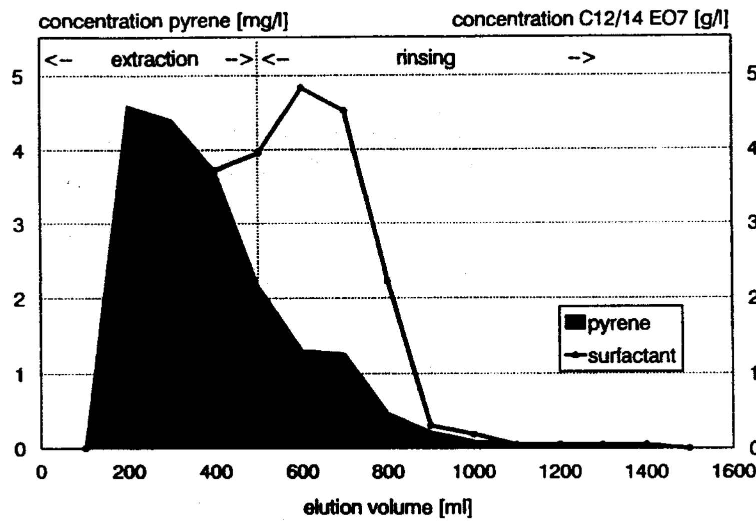


Figure 6. **Pyrene extraction with surfactant solutions and o/w microemulsions**

a)



b)

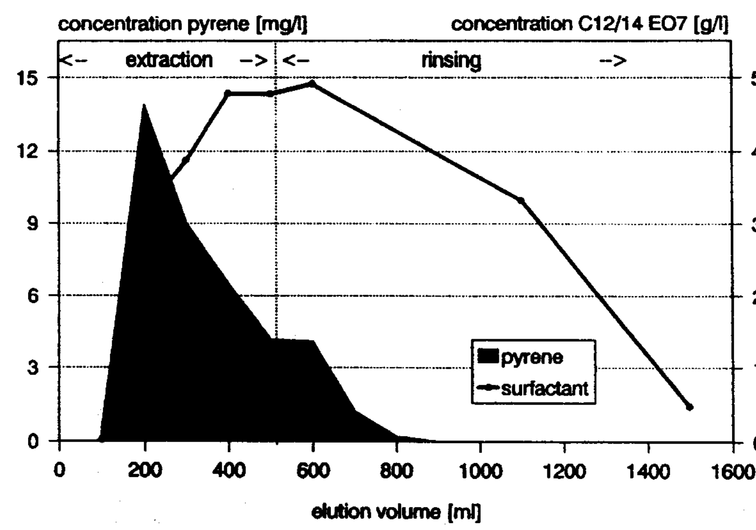


Figure 7 a) and b). **Comparison between the pyrene extraction of filled soil columns with pure surfactant solution (5% $C_{12/14}$ EO_7) and with an o/w microemulsion (5% $C_{12/14}$ EO_7 + 0.5% RME)**

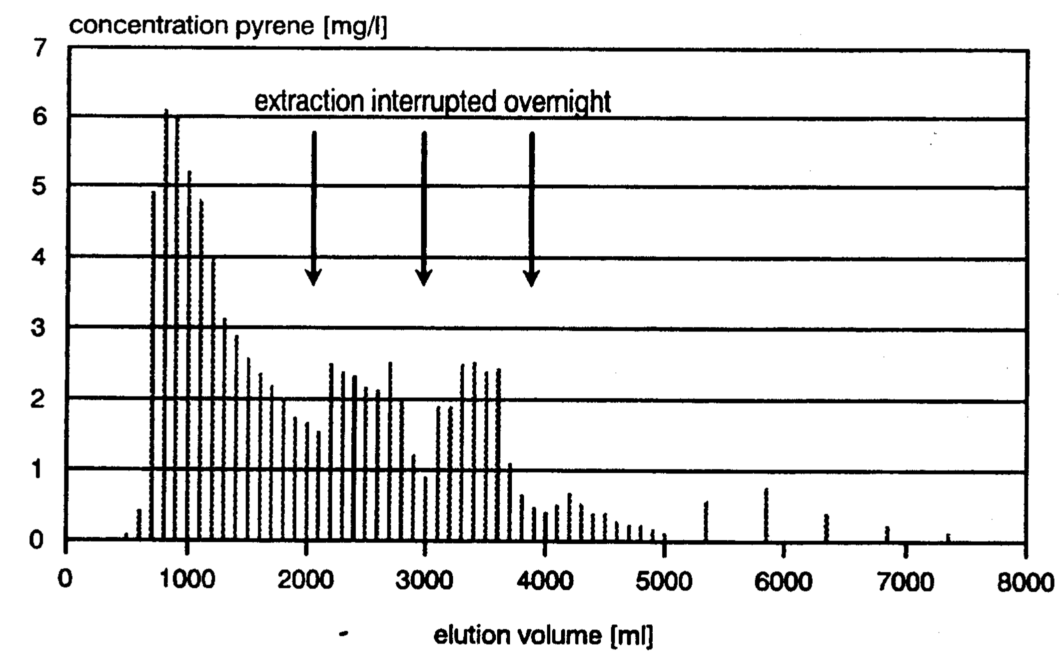


Figure 8. **Pyrene concentration of single eluate samples of the extraction of a bore sample with an o/w microemulsion** *(5% $C_{12/14}EO_7$ + 0.5% RME)*

Tabelle 2: Substratzusammensetzung und Abbauraten

Reaktortyp	Rührkessel **(Ortmann 1995)**				
	Versuch #1		Versuch #2		
Substrat	Konz. im Zulauf [mg/l]	Umsatz [%]	Konz. im Zulauf [mg/l]	Umsatz [%]	Umsatz mit HMN [%]
Acenaphthen/Fluoren	43,8	75,7	8,8	70,5	95,7
Phenanthren	50,0	75,2	10,0	59,2	96,2
Fluoranthen	18,8	61,5	3,8	51,7	89,2
Pyren	12,5	73,4	2,5	54,8	69,4
Σ PAK	125,0	75,9	25	60,8	92,4
RME	2275,0	99,2	935,0	98,5	99,4

Reaktortyp	Wirbelschicht	
	Versuch #3	
Substrat	Konz. im Zulauf [mg/l]	Umsatz [%]
Acenaphthen/Fluoren	21,9	
Phenanthren	25,0	
Fluoranthen	9,4	
Pyren	6,3	
Σ PAK	62,6	98,0
RME	2338,0	99,0

Tabelle 3: Am Boden verbleibende Gehalte an Tensid, RME und PAK (Pyren und Phenanthren) nach der Extraktion mit einer O/W-Mikroemulsion.

Stoff	Ausgangsgehalt Boden bzw. Mikroemulsion	Rückstand im Boden nach Extraktion mit Mikroemulsion
Pyren	29,3 mg/kg Realboden	2,7 mg/kg 9,2 %
$C_{12/14}E_{10}$	50 g/l	3,6 g/kg 2,4 %
RME	5 g/l	1,3 g/kg 8,6 %

Stoff	Ausgangsgehalt Boden bzw. µE	Rückstand im Boden nach Extraktion mit Mikroemulsion
Phenanthren	800 mg/kg Parabraunerde	333 mg/kg 41,6 %
$C_{12/14}E_{11}$	50 g/l	2,6 g/kg 1,7 %
RME	5 g/l	0,45 g/kg 3,1 %

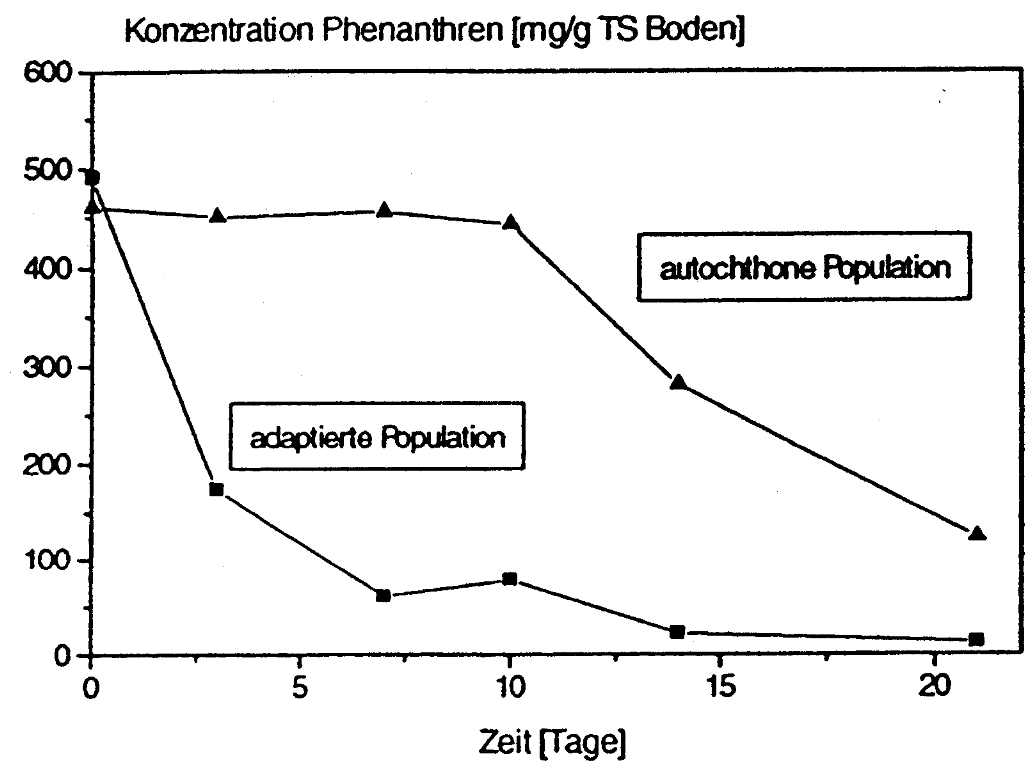


Bild 7: Abbau von Phenanthren durch die autochthone und eine voradaptierte Bakterienpopulation im Boden

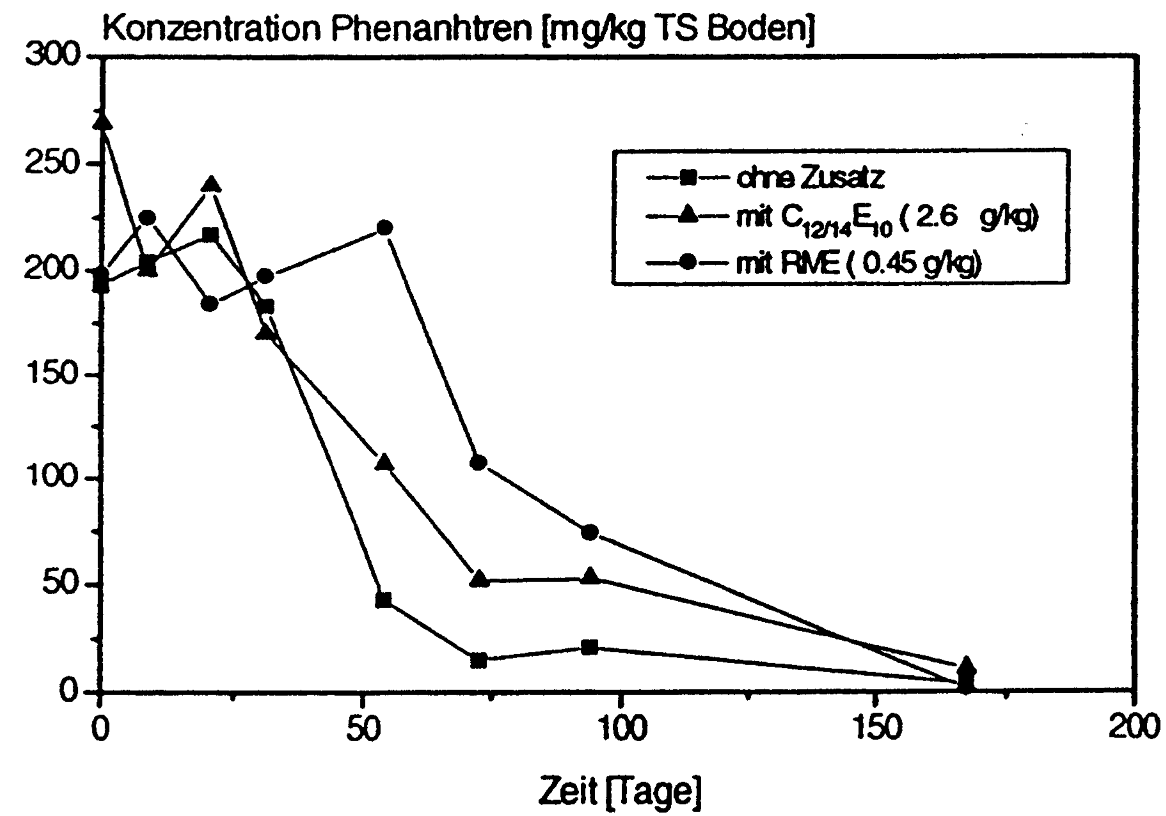


Bild 8: Verlauf des Abbaues von Phenanthren, Phe + RME und Phe + $C_{12/14}E_{11}$ im Boden