Comparison of Pilot Scale Bioremediation of PAH Contaminated Construction Rubble with Laboratory Tests

B. Gemende, A. Gerbeth (University of Applied Sciences Zwickau)
G. Müller, C. Höse, J. Seidel (P-D Industriegesellschaft)
R. Lange (Dresden University of Technology)
R. H. Müller (UFZ Centre for Environmental Research)

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Content

Introduction

- Experiences in bioremediation of herbicide and PHC contaminated building rubble
- At various sites (gas works, coking plants ...) major or cross-contaminants are PAH

Introduction

Characteristics of Contaminated Material

- Usually high pH values in eluate
  → varying from 9 up to 12
- Low water holding capacity
  → usually between 10 and 30 % of dry mass content
- Low content of nutrients

And:

- High diversity of materials (bricks, concrete, wood, metals etc.)
- High inhomogeneity of contamination ("hot spots")

Introduction

Characteristics of Contaminated Material

Properties of the used building rubble:

- Originated from a former gaswork plant
- Total content of 16 EPA-PAH:
  - 355…430 mg/kg in the original charge
  - 495…790 mg/kg in the charges for laboratory scale tests
- Content of petroleum hydrocarbons 1,655…3,535 mg/kg
- pH value of eluate 8.1…9.4
- No definable nutrient concentration
- No (known) cross-contamination

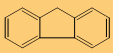
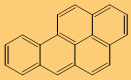
Introduction

Properties of the Relevant Pollutants

PAH = Polycyclic Aromatic Hydrocarbons

- Compounds consisting of 2 or more condensed benzene ring structures (more than 100 different substances – 16 of them are listed by US-EPA as “priority pollutants“)
- Occurring in all parts of environment
- Partly known or supposed to be cancerogenic and/or mutagenic

Physical and chemical properties of selected PAH:

Name	Mole-cular weight	Chemical structure	Vapour pressure at 25 °C (mPa)	Water solubility at 20 °C (mg/l)	lg K_{OW}
Naphthalene	128		10.8×10^{3}	30.00	3.37
Fluorene	166		4.5×10^{2}	1.8	4.18
Benzo(a)pyrene	252		3.8×10^{-3}	0.0038	6.04

Introduction

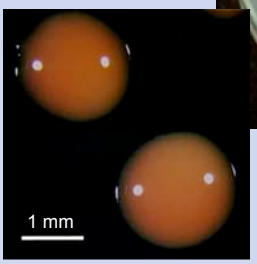
Isolation of Microorganisms

- Bacteria enrichment from PAH contaminated building rubble (former gaswork) using a percolation column
- Clean up and isolation of strains on PYE agar plates
- Isolation and selection of PAH degrading strains on PAH coated agar plates

Selection criteria:

- Broad degradation spectra (different PAH)
- Special degradation abilities (e. g. high pH tolerance)

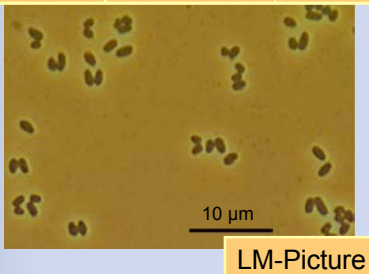
Strain SK3 on PYE



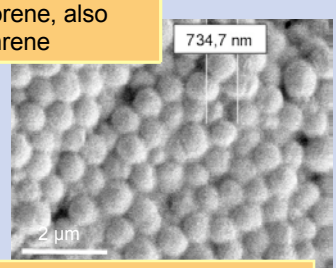
Introduction

Selected Bacterial Strains

Strain	Taxonomy	Degradation abilities
SK3	*Dietzia* sp.	Fluorene und Anthracene, also Phenanthrene und Pyrene
KB-K2	*Micrococcus* sp.	Especially Phenanthrene, conditionally also Fluorene
KB-K5	*Micrococcus* sp.	Especially Phenanthrene and Anthracene, conditionally also Fluorene
KB-F8	*Rhodococcus* sp.	Especially Fluorene, also Phenanthrene



LM-Picture of SK3



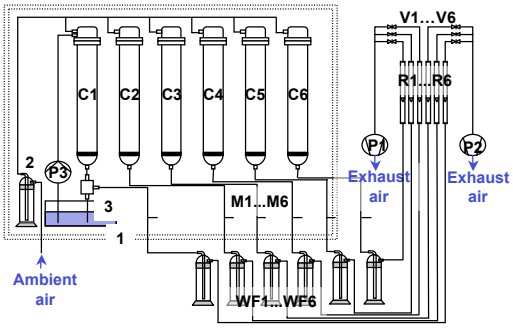
SEM-Picture of KB-K5

Introduction

Configuration of Laboratory Test Columns

Experimental Work

- 1.5 kg rubble (dry substance)
- 10...270 ml biomass suspension
- 1…2 g fertilizer
- 16…20 % moisture
- 5 l/h air flow

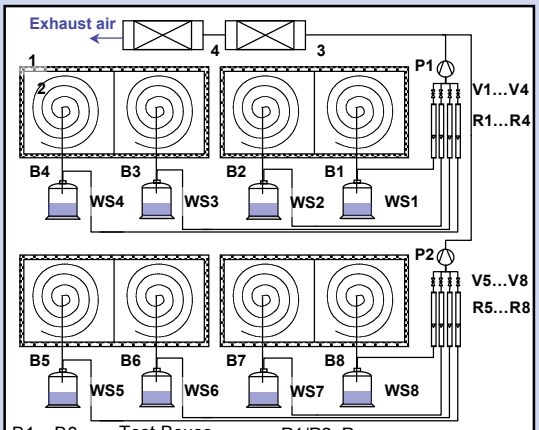


C1...C6	Glass columns	P1...P2	Swash plate pumps
M1...M6	Measuring points for exhaust air	P3	Circulating pump for percolation liquid
WF1...WF6	Flasks for condensed water	1	Insulation
		2	Humidification of air
V1...V6	Valves	3	Reservoir for percolation liquid
R1...R6	Rotameters		

Configuration of Pilot Scale Test Boxes

Experimental Work

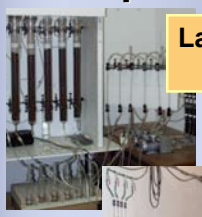
- 500...900 kg rubble (original substance)
- 1.2...5 l biomass suspension
- 0.36…1.44 kg N-P-K fertilizer
- 25...70 l water (8…15 % moisture)
- 400 l/h air flow



B1…B8	Test Boxes	P1/P2	Pumps
WS1…WS8	Separators for condensing water	1	Insulation
		2	Drainage tubes
V1…V8	Valves	3	Biofilter
R1…R8	Rotameters	4	Activated carbon filter

Scale-up to Windrows

Experimental Work



Laboratory Scale Tests
1.5 kg rubble

Scale-up factor: 300…400

Pilot Scale Tests
ca. 500…600 kg rubble

Technical Scale Windrow
ca. 500…1,000 t rubble

Scale-up factor:
1,000…2,000

Sampling and Analysis

Experimental Work

Sample

Crushing

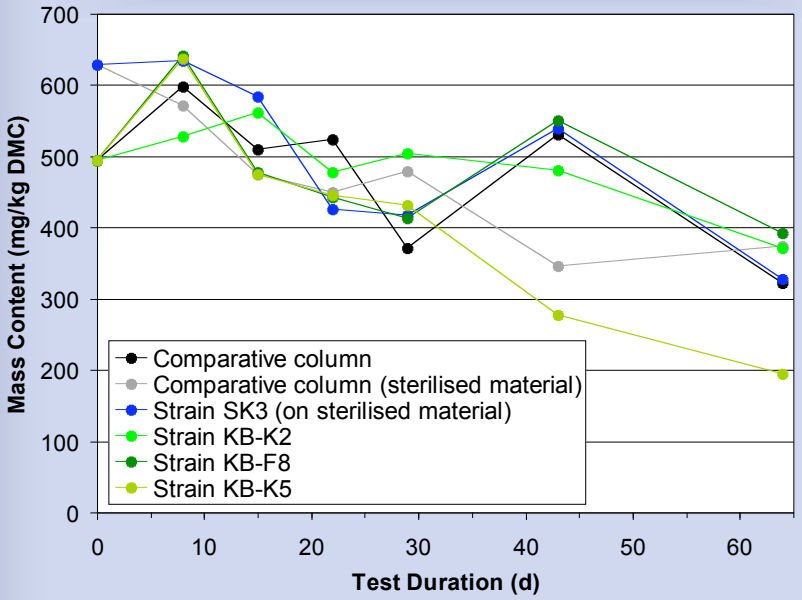
Homogenising / Splitting

Drying

PHC-Analysis	**PAH-Analysis**	Further Analysis
▪ Extraction ▪ Drying and clean up of the extract ▪ Analysis with IR-Analyser	▪ Extraction ▪ Clean up of the extract using SPE ▪ Analysis with HPLC-PDA	▪ Elution and measurement of pH value and conductivity ▪ Determination of dry mass content (DMC)

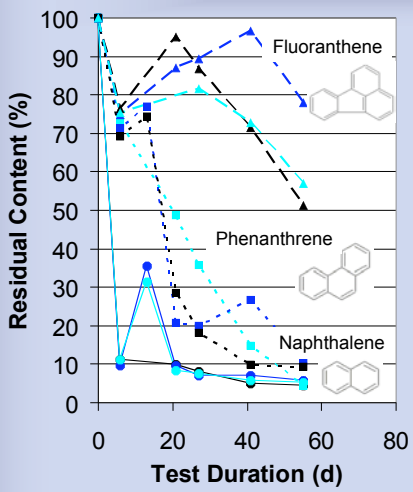
Laboratory Scale Test Results (Total PAH)

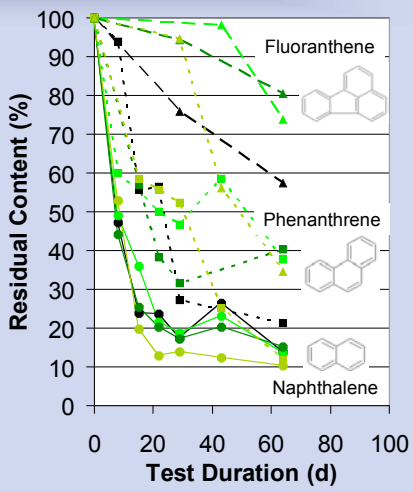
Results and Discussion



Laboratory Scale Test Results (3 PAH)

Results and Discussion

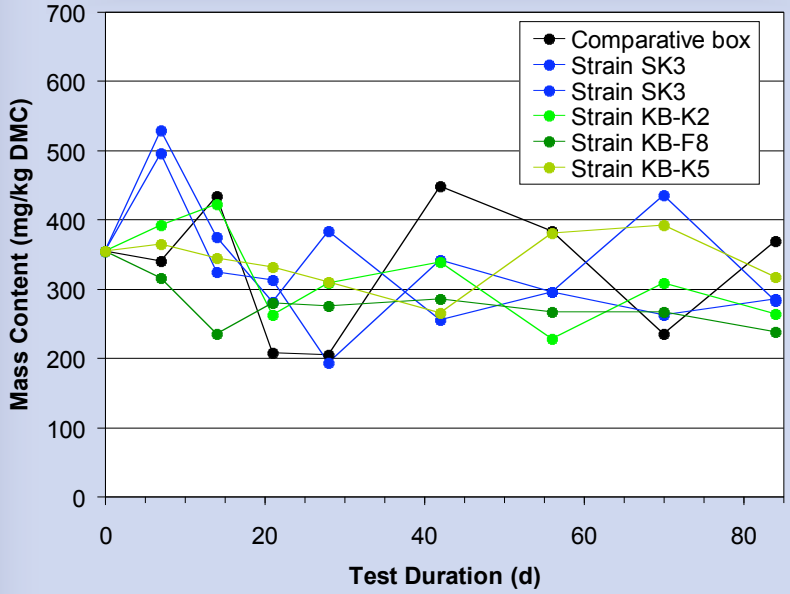




— Comparative Column
— Strain SK3
— Strain SK3 with surfactant
— Strain KB-K2
— Strain KB-F8
— Strain KB-K5

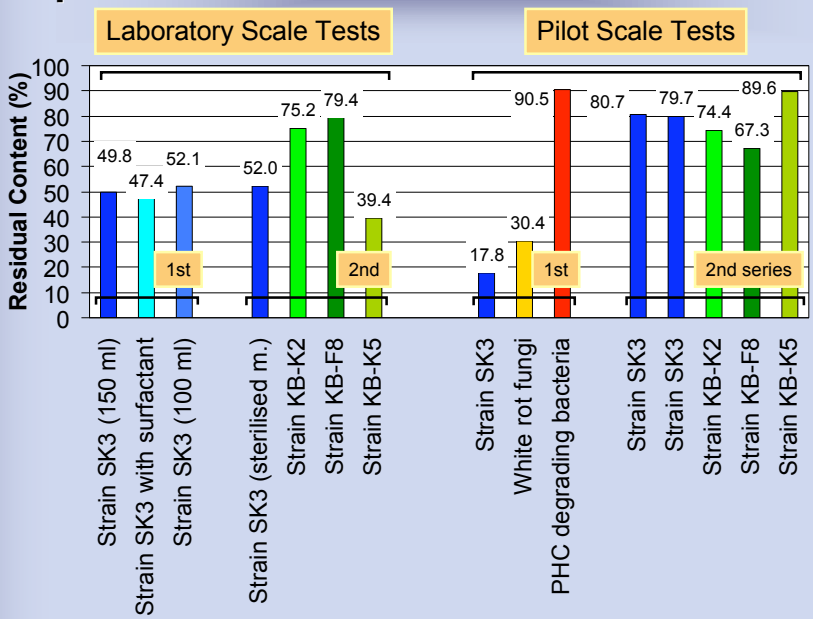
Pilot Scale Test Results (Total PAH)

Results and Discussion



Comparison of Results

Results and Discussion



Summary

- Alkaliphilic strains (*Dietzia* sp., *Rhodococcus* sp.) used for PAH degradation on building rubble
- Degradation rates:
  - ≈ 10 % for benzo(ghi)perylene (6 rings)
  - ≈ 30 % for benzo(a)pyrene (5 rings)
  - ≈ 90 % for naphthalene (2 rings)

Problems:

- Degradation not clearly attributed to allochthone strains
- Lower degradation rates in pilot scale
- Further studies for scale-up

Summary