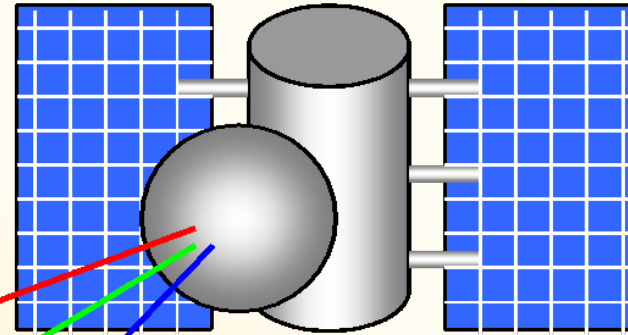


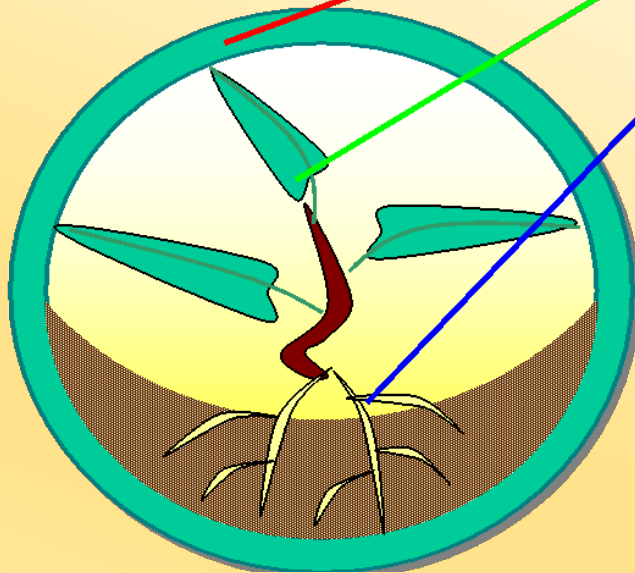
# Biological Soil Remediation


## Phytoremediation

**EUTEC**  
*Environmental Technology  
Institute Emden*

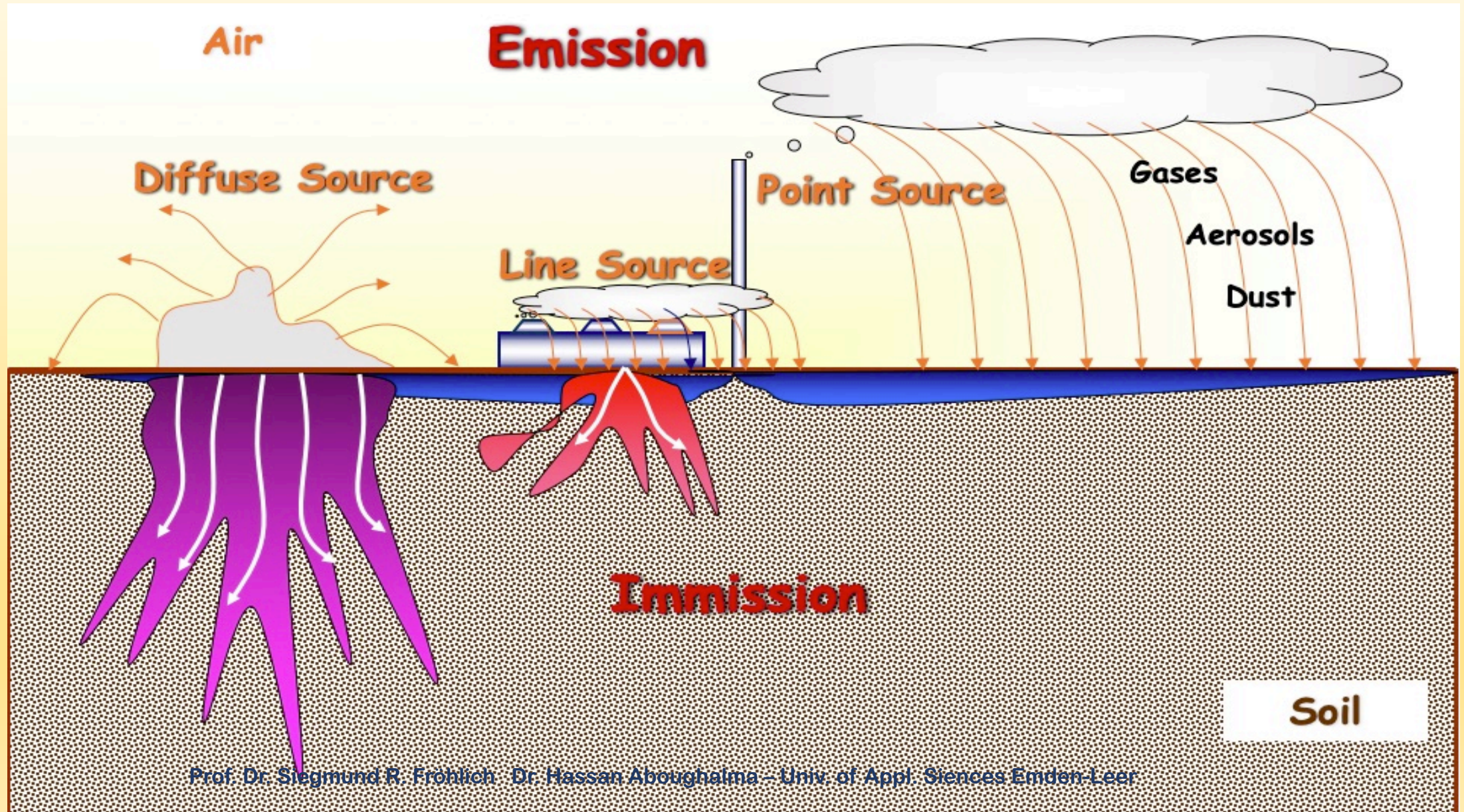


**Prof. Dr. Siegmund R. Fröhlich**  
**Dr. Hassan Aboughalma**



**IAPG**   
Institute for Applied Programmetry  
and Geoinformatics

# Emission / Immission





# Soil Pollutant Classification

## Soil - Pollutants

### Inorganic Compounds

### Organic Compounds

Heavy Metals

N-, S-  
Compounds

Acids,  
Bases

Degradable  
Organic  
Compounds

Non  
Degradable  
Org. Comp.

-Pb, Pb-org.  
-Cd, As, Hg...  
-Cu, Ni, Co...  
-Zn, Sn...  
-Radioisotopes  
...

- $SO_4^{2-}/SO_3^{2-}$ ,  
- $NO_3^-$ ,  $/NO_2^-$ ,

rather  
seldom

-Mineral Oils  
-org. Acids  
-aliph. Alcohols  
-Aldehydes  
-BTX  
-Amines  
-Phenoles

-PACs,  
-org. Halides  
-TNT,  
-Me-Org. (TBT)  
-Polyarom. PCB..  
-Tar Comp.  
...



# Biological Soil Remediation Project

## NF-Metal-Smelter Nordenham





# **Biological Soil Remediation**

## **Project Review**

### **Main Research Project „Soil Remediation“**

5-Year Project of Univ. Emden & Univ. Oldenburg – 2003 -2008

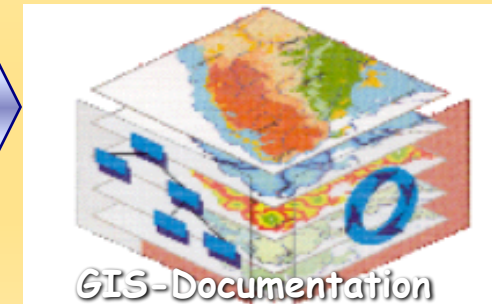
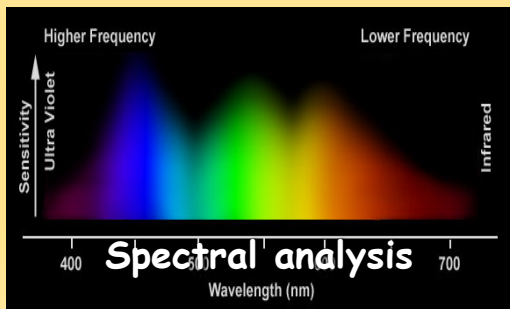
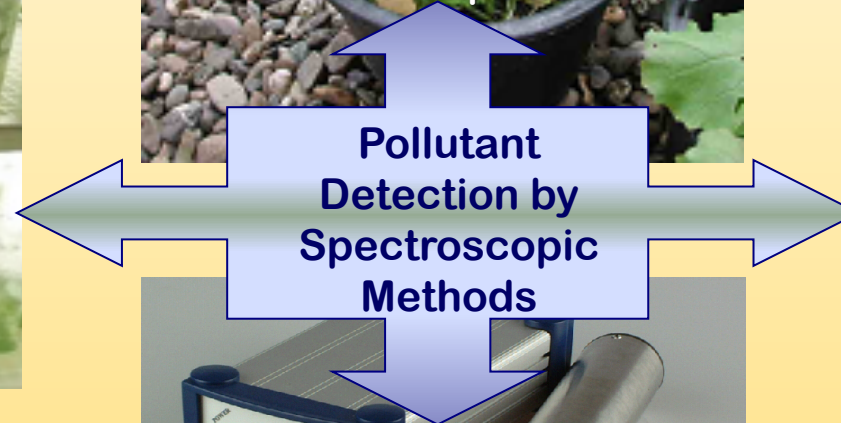
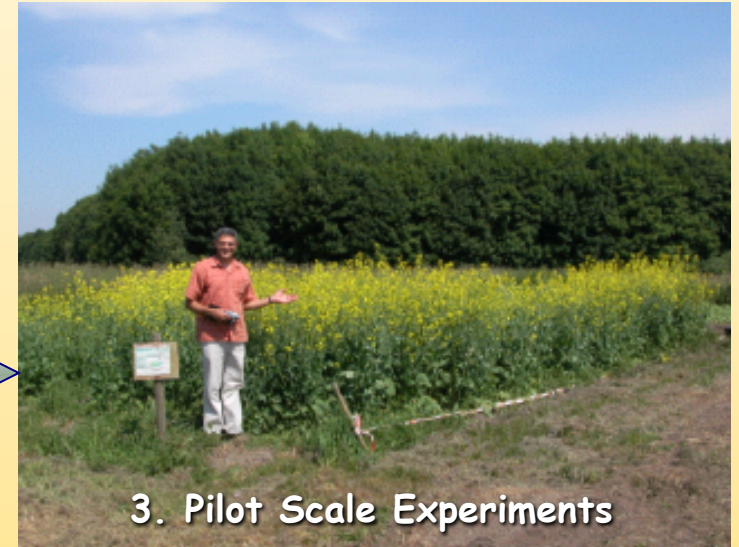
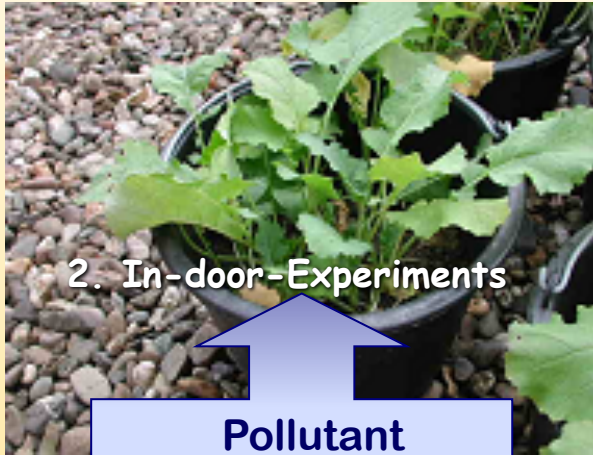
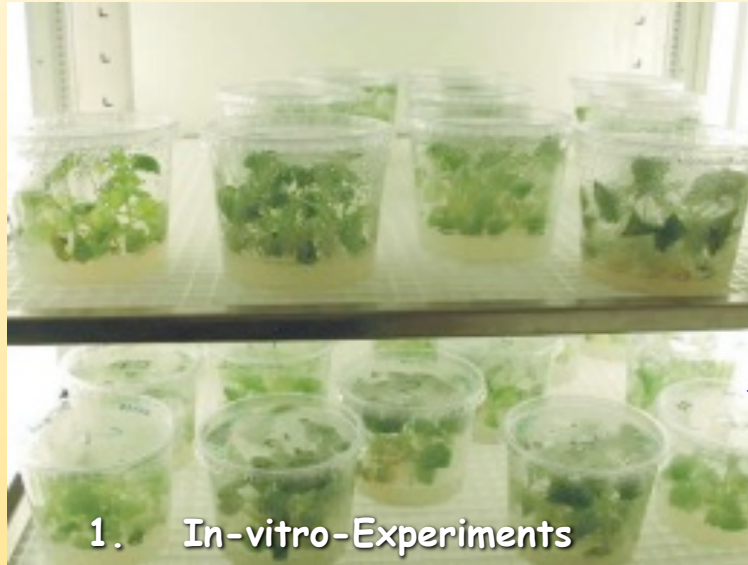
Finances: 817 000 EURO

Scientific Personnel: 4 Scientists / 5 Professors

Test Stadia: in-vitro, green house, large scale pilots

- **Verification of the phytoremediation in terms of feasibility and economic aspects**
- **Wide screening of collector plants**
- **Development of spectroscopic monitoring hardware**
- **Observability of the remediation progress**

# Biological Soil Remediation Project Scale-up

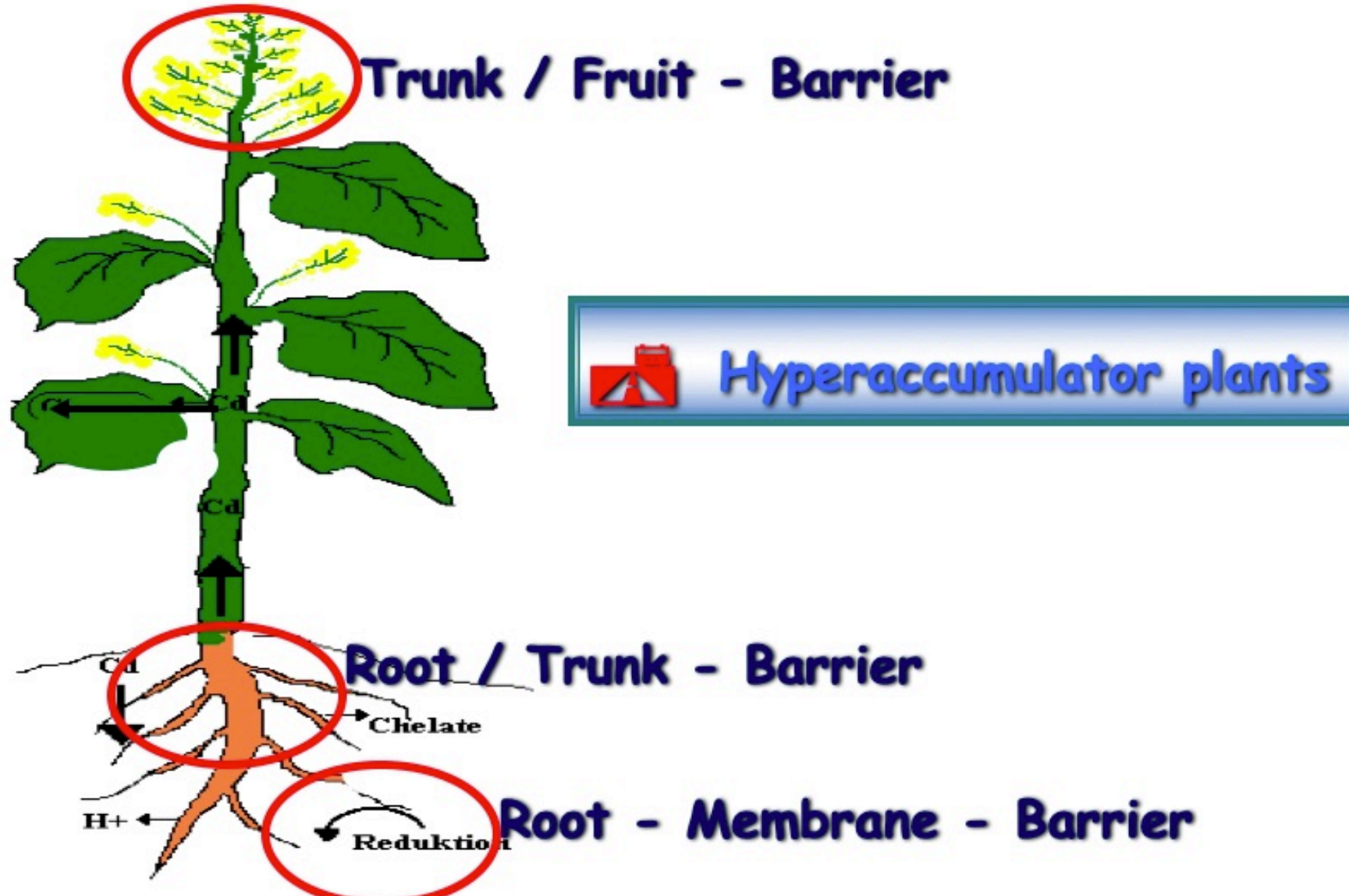




# Main Project Personnel



# Three HM-Transport Barriers





# Biological Soil Remediation

## In-vitro Plant Cultivation





# Biological Soil Remediation

## Rape Plant Pot-Pilot



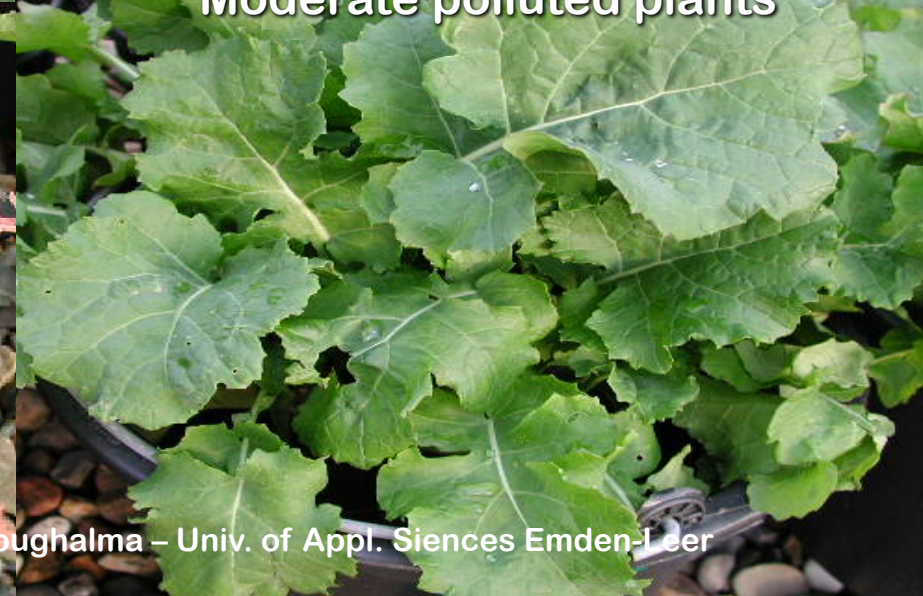
Non polluted plants



Moderate polluted plants



Strong polluted plants





# 1<sup>st</sup> Pilot Field near Smelter Feb. 2005



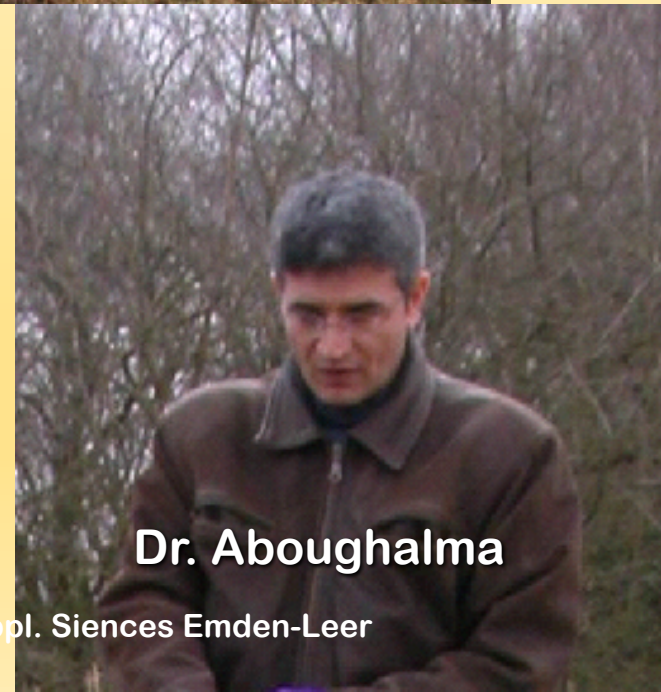
Test Yard near smelter



Prof. Dr. Siegmund R. Fröhlich



Soil Profile



Dr. Aboughalma

Dr. Hassan Aboughalma – Univ. of Appl. Sciences Emden-Leer



# Experiments with Rape

## 2<sup>nd</sup> Test Yard – Moderate Polluted



Prepared test yard



Prof. Dr. Siegmund R. Fröhlich Dr. Hassan Aboughalma – Univ. of Appl. Sciences Emden-Leer



1<sup>st</sup> Spectroscopic tests



# Experiments with Rape

## 2<sup>nd</sup> Test Yards – Moderate Polluted



Plant harvesting



Prof. Dr. Siegmund R. Fröhlich Dr. Hassan Aboughalma – Univ. of Appl. Sciences Emden-Leer



Plant preparation  
for analytics



# Experiments with Potato



Different potato plants

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# Experiments with Potato, Maize & Rape





# Experiments with Maize





# Experiments with Maize





# Experiments with Sun Flower





# Experiments with Sun Flower





# Experiments with Tobacco





# Experiments with Tobacco





# Biological Remediation

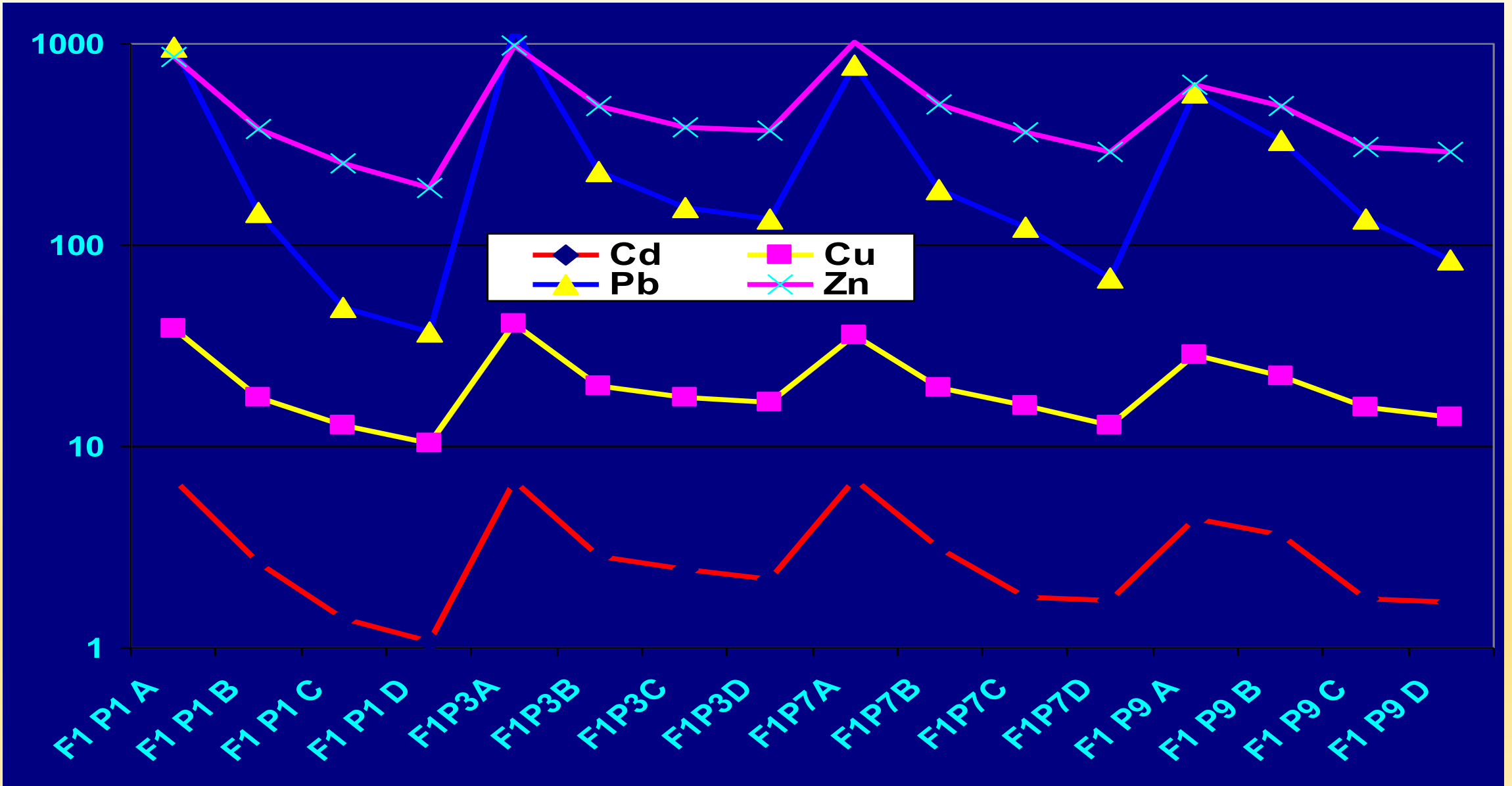
## 3<sup>rd</sup> Test Yard – Moderate Polluted



**3<sup>rd</sup> Test yard in a special prepared pond**

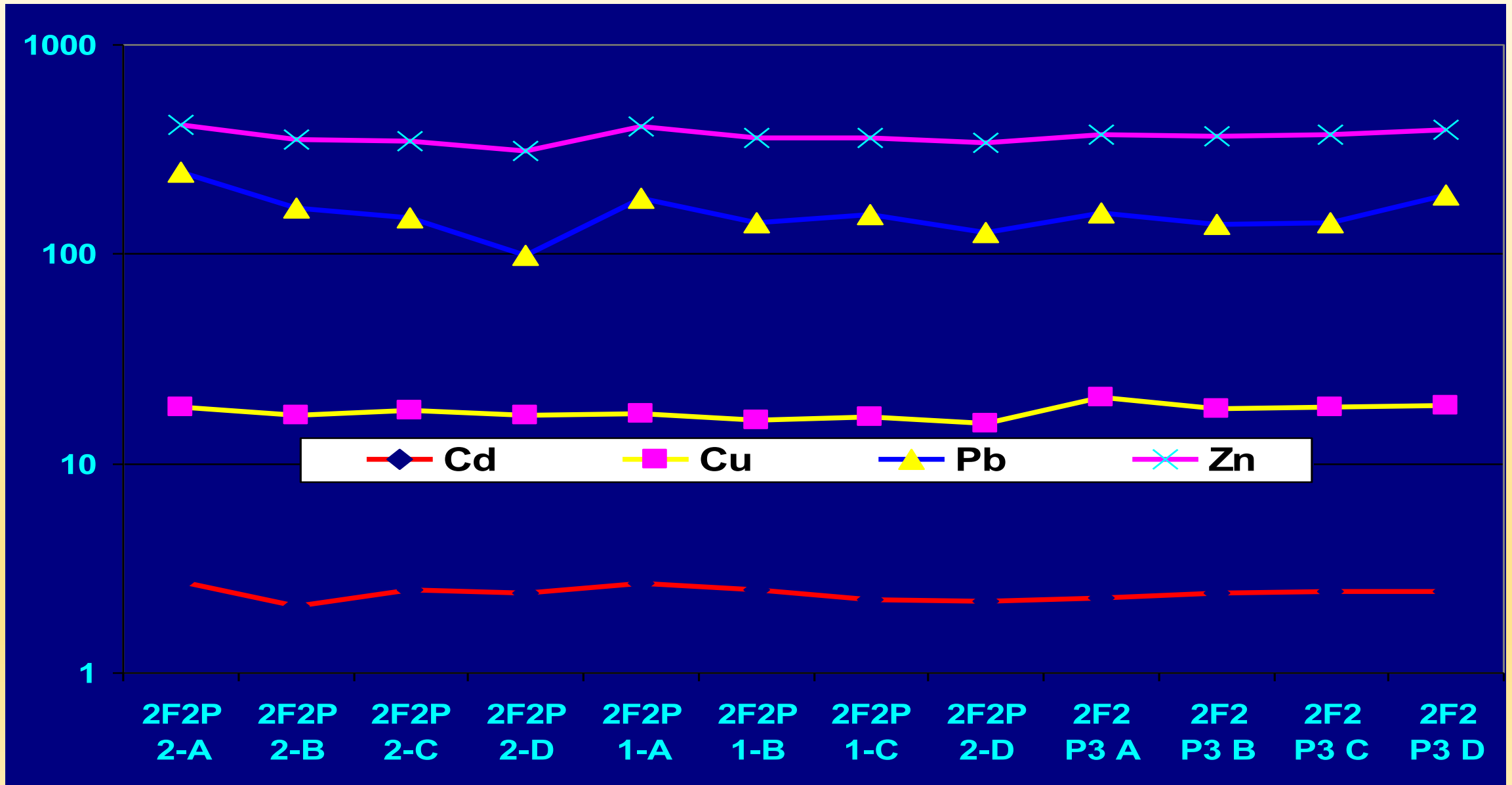


# Original Soil Profile - Before Homogenizing



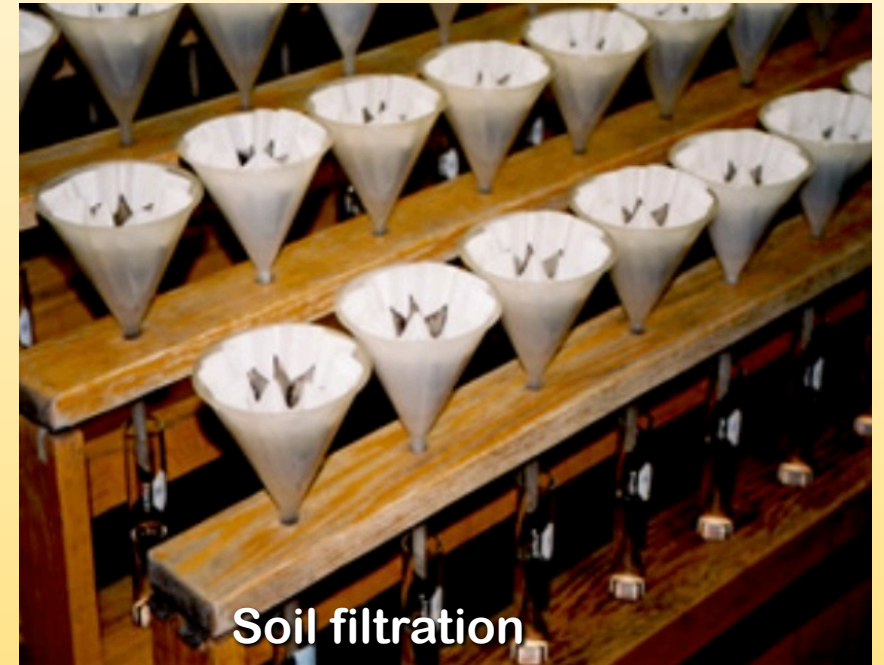
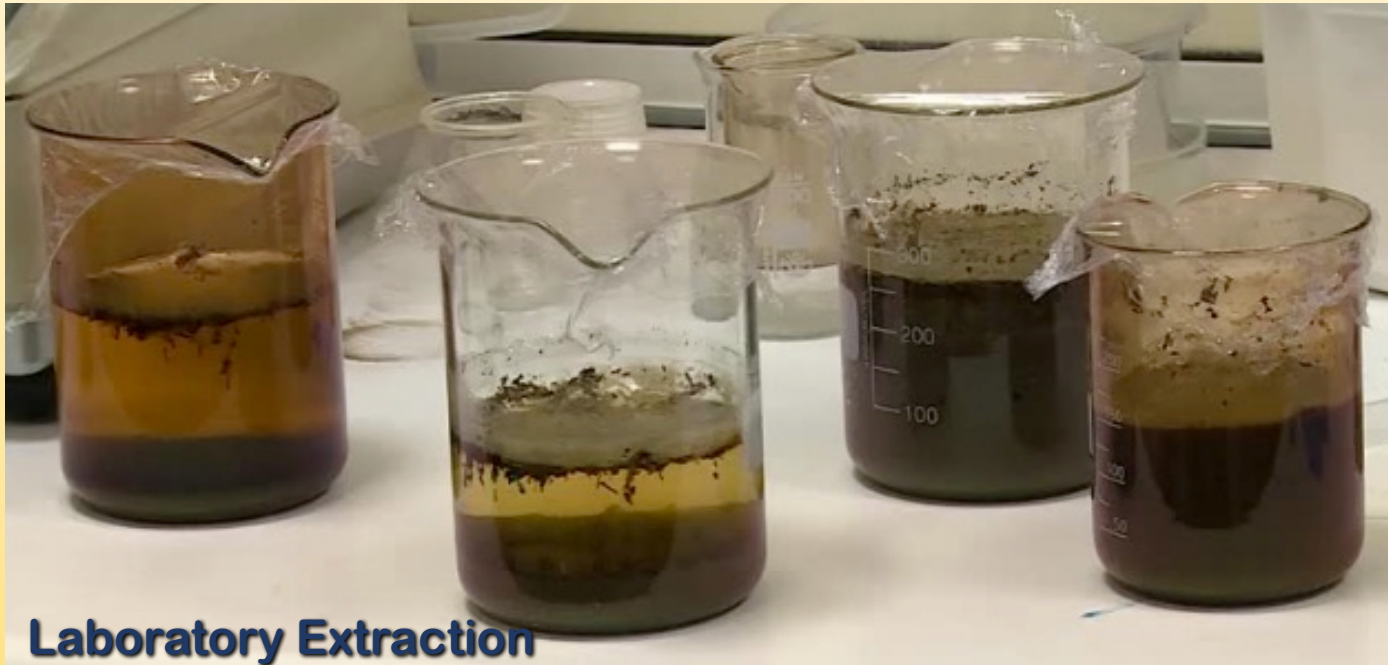


# Soil Profile - After Homogenizing










# Soil Extraction @ Mobilisation Tests





# HM-Availability by Plants @ Mobilisation Tests

- |  |  |   |
|--|--|---|
|  | 1. Fraction: Mobile Heavy Metals           | Solvent: 1 M $\text{NH}_4\text{NO}_3$                                   |
|  | 2. Fraction: Simple to deliver HM          | Solvent: 1 M $\text{NH}_4\text{OAc}$                                    |
|  | 3. Fraction: HM fixed @ Metall-Oxides      | Solvent: 0.1 M $\text{NH}_2\text{OH-HCl}$ + 1 M $\text{NH}_4\text{OAc}$ |
|  | 4. Fraction: HM fixed @ Organic Matter     | Solvent: 0.025 M $\text{NH}_4\text{-EDTA}$                              |
|  | 5. Fraction: HM fixed @ Cristalline Fe-Ox. | Solvent: 0.2 M $\text{NH}_4\text{-Oxalate}$ (pH 3.2)                    |

Sequential extraction was conducted on six samples each



# Soil Contamination @ Mobilisation Tests

Sample depth	0-30 cm	30-60 cm	60-90 cm
Number of samples	20	10	5
Cd* (mg/kg TS)	< 5 - 28	< 5 - 8,3	2,3 – 8,6
Pb* (mg/kg TS)	86 - 830	110 – 750	78 - 430
Zn* (mg/kg TS)	280 - 1900	150 – 990	210 - 840

\* Concentration @ aqua regia dissolution



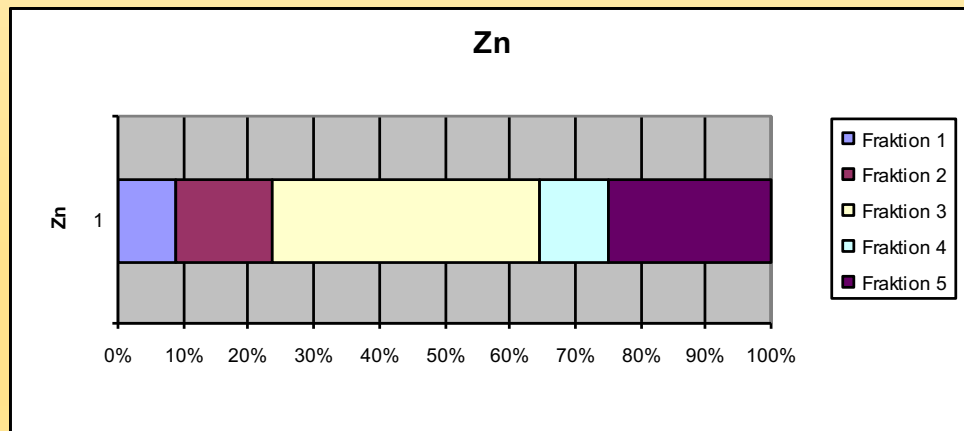
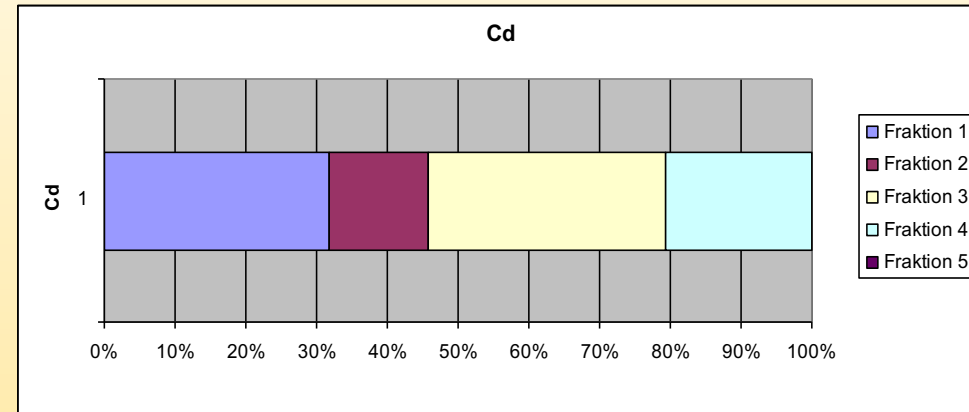
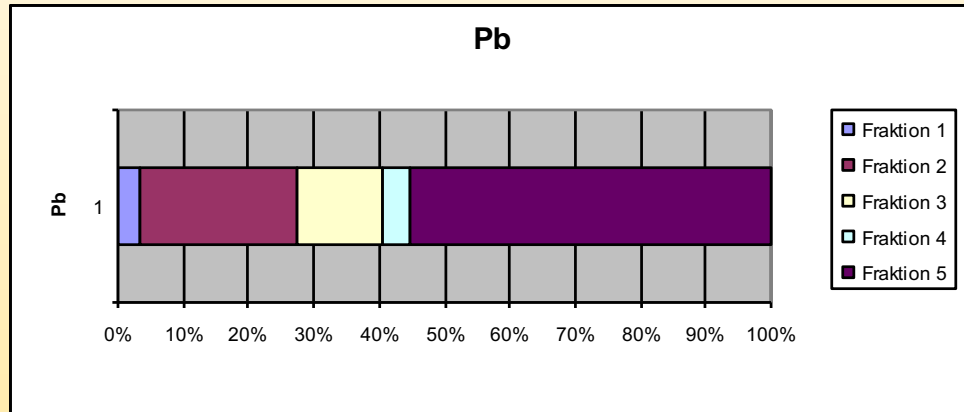
# Heavy Metal Concentrations In Homogenized Soil






Heavy metal	Mean concentration in soil (mg/kg <sub>dm</sub> )	Relative Uncertainty in (mg/kg <sub>dm</sub> )
Cd	5,21	11,12%
Cu	56,65	39,12%
Pb	348,81	1,26%
Zn	682,89	4,98%

\* Concentration @ aqua regia dissolution



# Different Eluated HM in Extracted Soil



-  **1. Fraction 1 M NH<sub>4</sub>NO<sub>3</sub>**
-  **2. Fraction 1 M NH<sub>4</sub>OAc**
-  **3. Fraction 0.1 M NH<sub>2</sub>OH-HCl + 1 M NH<sub>4</sub>OAc**
-  **4. Fraction 0.025 M NH<sub>4</sub>-EDTA**
-  **5. Fraction 0.2 M NH<sub>4</sub>-Oxalate (pH 3.2)**



# HM Mobilisation by Organic Acids Solution

Element	Cd (mg/l)	Cd %	Cu	Cu	Pb	Pb	Zn	Zn
			(mg/l)	%	(mg/l)	%	(mg/l)	%
Total conc./100%	2,08	100,0	24,0	100	139,6	100	272,0	100
Citric acid 2%	0,4	19,2	0,7	3,0	4,6	3,3	46,6	17,1
Citric acid 10%	0,53	25,5	1,5	6,1	12,1	8,7	49,4	18,2
Tartaric acid 2%	0,43	20,7	1,1	4,7	5,4	3,8	74,6	27,4
Tartaric acid 10%	0,66	31,7	2,6	11,0	21,7	15,6	75,3	27,7
Acetic acid 2%	0,26	12,5	0,1	0,6	0,8	0,5	21,1	7,8
Acetic acid 10%	0,35	16,8	0,3	1,1	1,9	1,3	25,2	9,3
Oxalic acid 2%	0,21	10,1	3,1	12,7	2,7	1,9	60,1	22,1
Oxalic acid 10%	0,01	0,5	1,6	6,8	0,3	0,2	14,9	5,5
dist. water	0	0,0	0,1	0,5	0,0	0,0	0,1	0,0



# Biological Remediation

## 3<sup>rd</sup> Test Yard – Moderate Polluted





# Variation of HM-Acquisition – Rape Plants

Rape Name	Flowerpot-number.	Sample	Mass g	Cu mg/kg DM	Cd mg/kg(DM)	Pb mg/kg(DM)	Zn mg/kg(DM)
Artus	0**	Leaves	0,35	9,23	0,00	0,00	54,70
Artus	1	Leaves	0,22	18,97	19,28	5,34	481,98
Artus	2	Leaves	0,26	18,96	21,50	20,75	414,10
Artus	3	Leaves	0,24	14,06	20,57	10,41	446,07
Lambada	1	Leaves	0,20	23,56	22,35	0,00	520,03
Lambada	2	Leaves	0,17	23,94	22,75	109,16	630,63
Lambada	3	Leaves	0,15	33,86	20,40	3,44	680,50
Licolly	1	Leaves	0,24	27,30	29,79	6,16	451,99
Licolly	2	Leaves	0,20	28,43	26,02	6,68	557,45
Licolly	3	Leaves	0,19	31,62	29,32	5,62	565,74
Liforum	1	Leaves	0,21	25,76	24,47	80,05	499,78
Liforum	2	Leaves	0,13	29,59	27,96	8,87	802,94
Liforum	3	Leaves	0,21	33,93	28,22	223,53	516,40
Pronto	0**	Leaves	0,24	8,47	0,10	0,55	90,31
Pronto	1	Leaves	0,18	21,14	22,30	19,22	576,96
Pronto	2	Leaves	0,22	22,43	29,18	15,81	482,26
Pronto	3	Leaves	0,28	15,16	20,75	11,59	386,06
Talent	0**	Leaves	0,19	10,22	0,06	0,00	73,13
Talent	1	Leaves	0,14	20,97	22,80	13,16	767,32
Talent	2	Leaves	0,13	19,92	19,75	20,26	803,45
Talent	3	Leaves	0,11	22,07	24,80	26,77	966,96

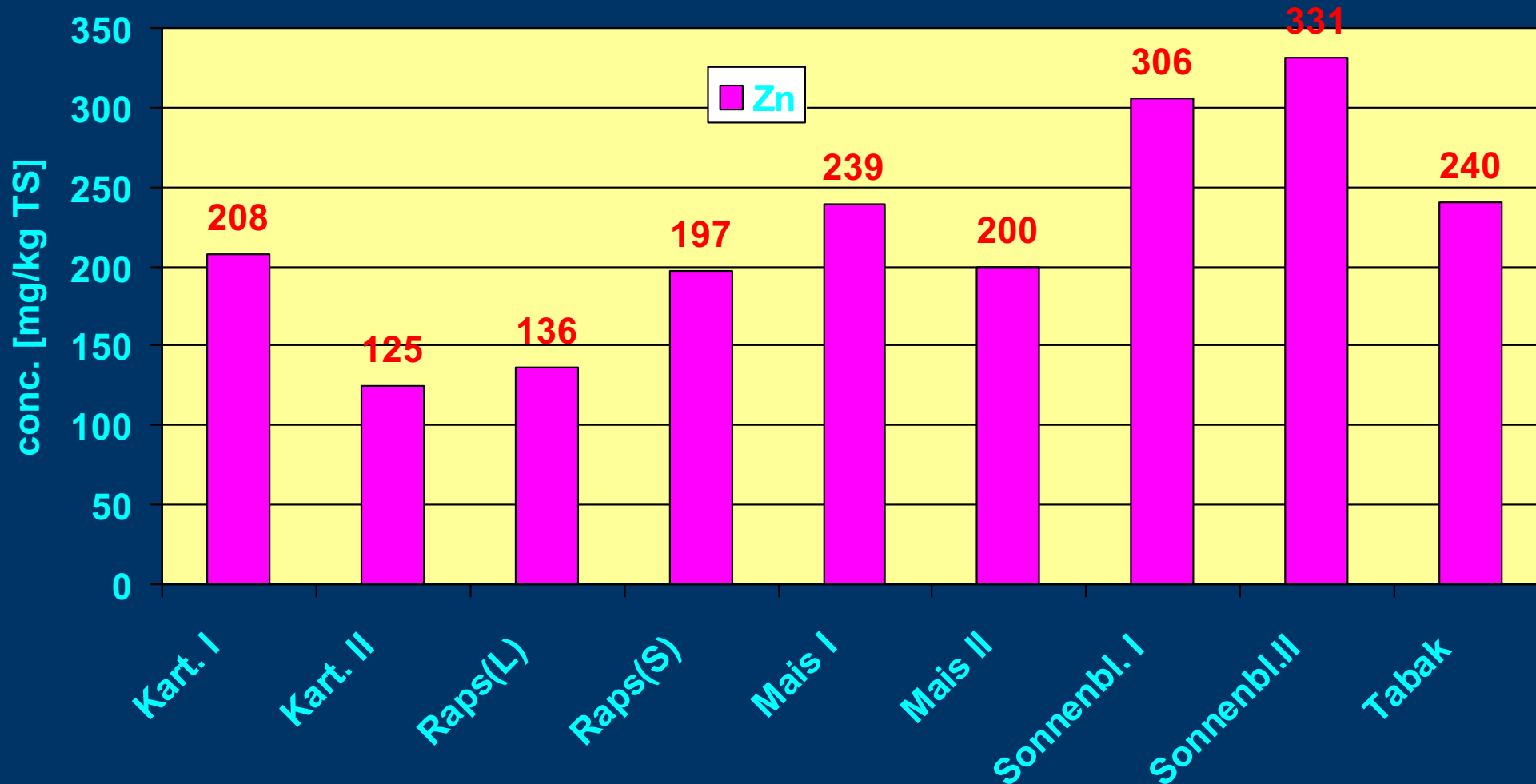


# Zn – Pollution in Plants

SF > Tob. ≈ Maize > Pot. ≈ Rape

Zinc

Pot. (n=10), Rape (n=17), Maize (n=10),  
Tob. (n=11), Sun flow.. (n=10)



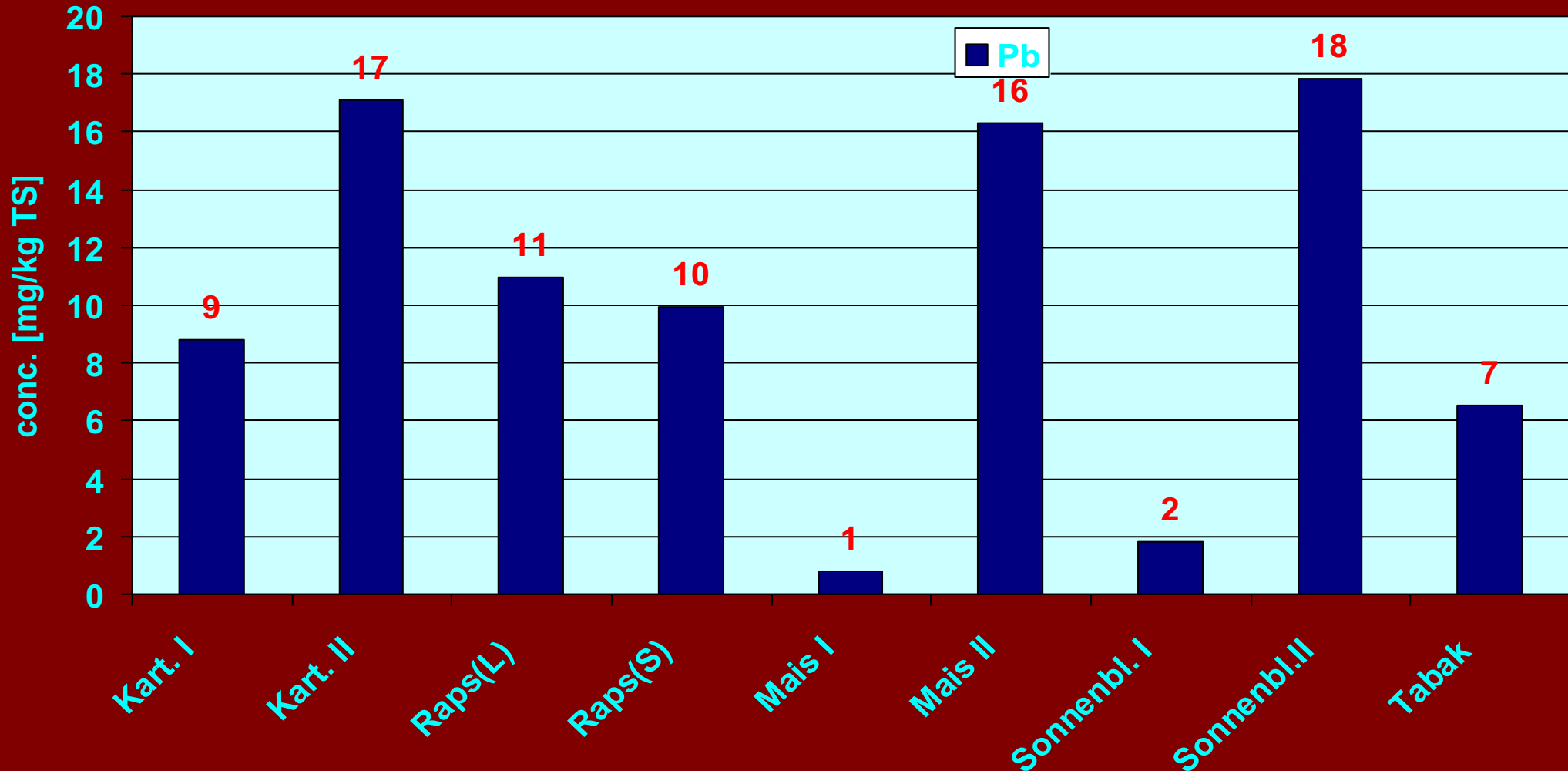


# Pb – Pollution in Plants

SF > Pot. > Maize > Rape > Tob.

Lead

Pot. (n=10), Rape (n=17), Maize (n=10),  
Tob. (n=11), Sun flow.. (n=10)

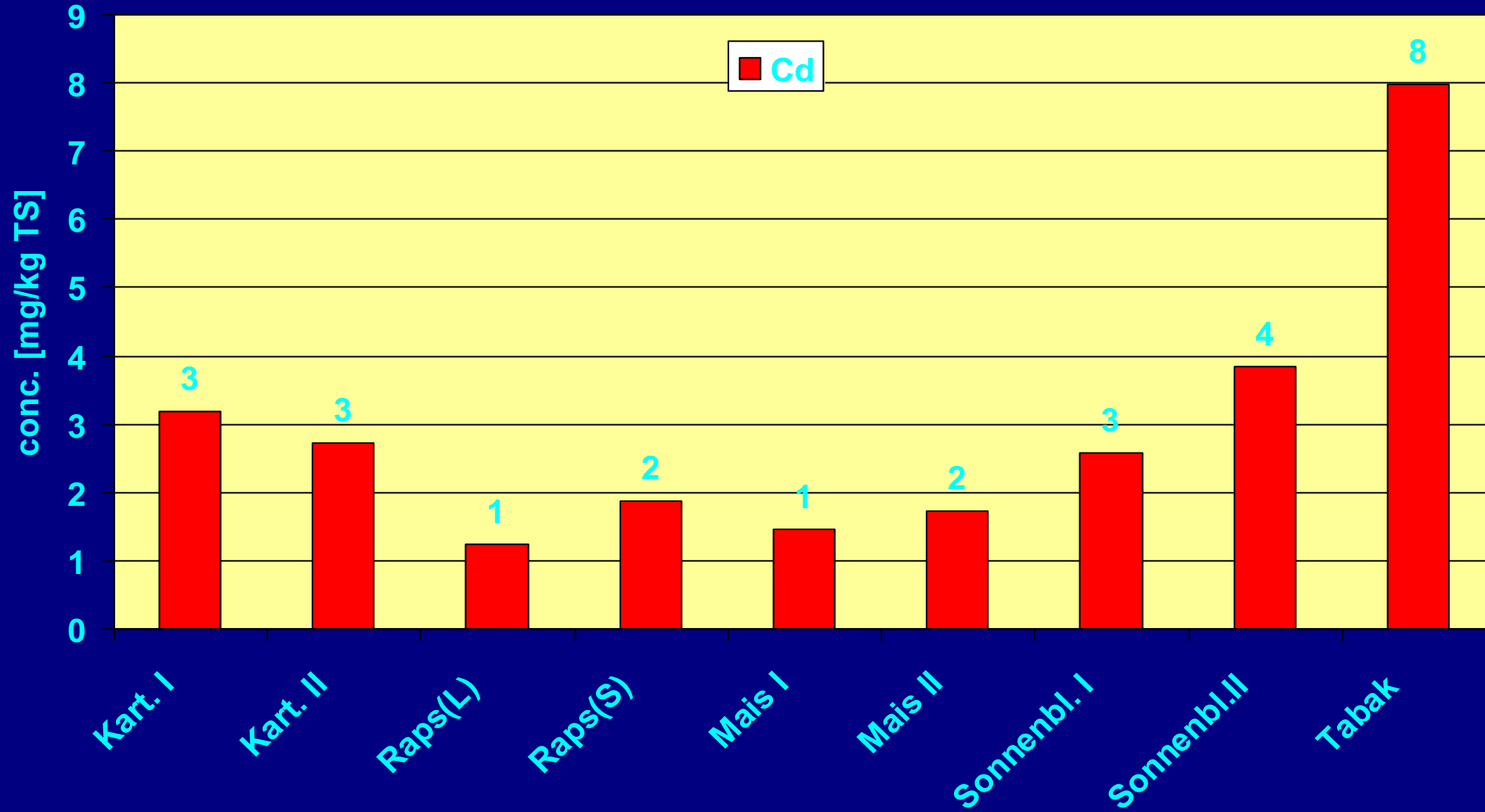




# Cd – Pollution in Plants

Tob > SF > Pot. > Rape ≈ Maize Cadmium

Pot. (n=10), Rape (n=17), Maize (n=10),  
Tob. (n=11), Sun flow.. (n=10)

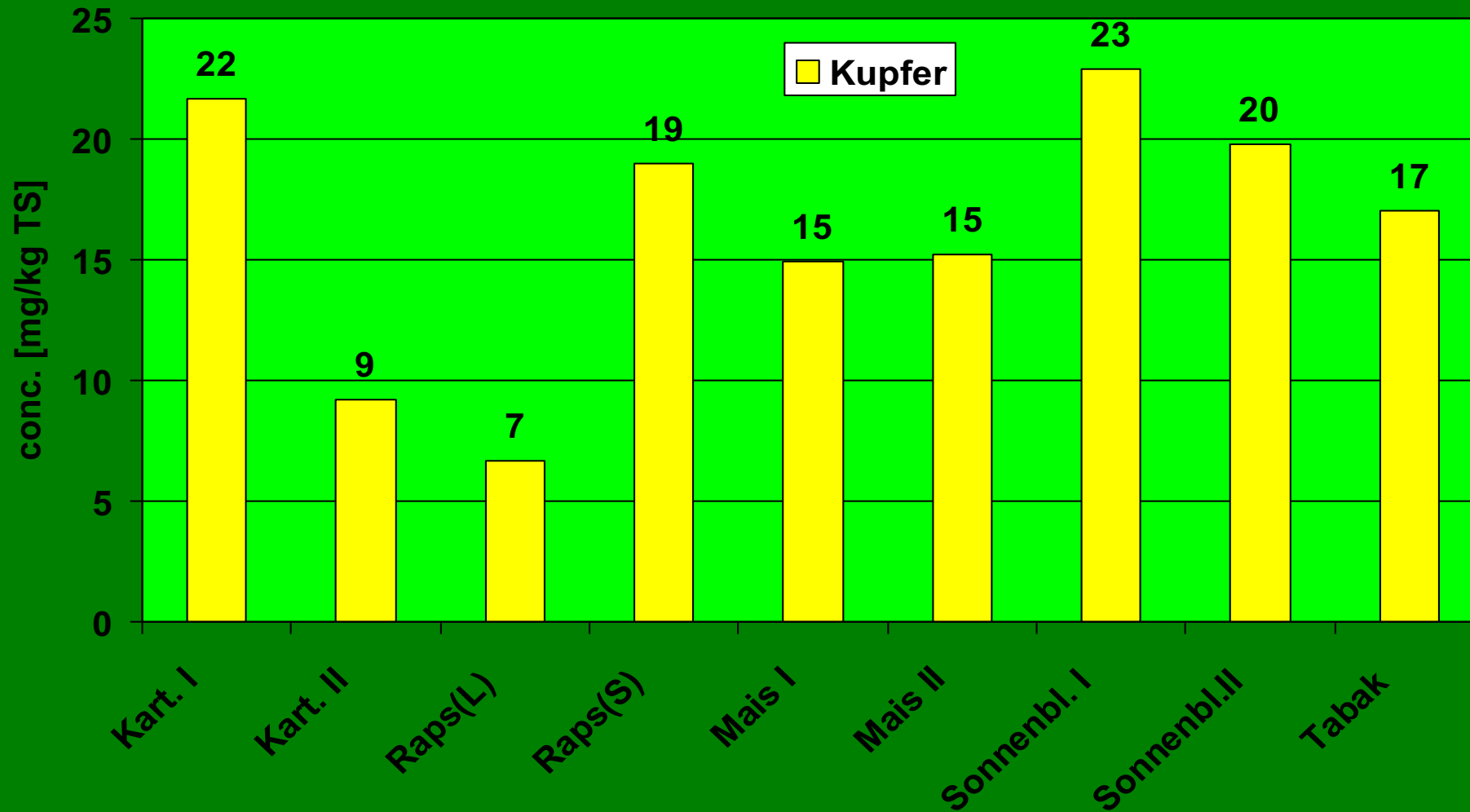




# Cu – Pollution in Plants

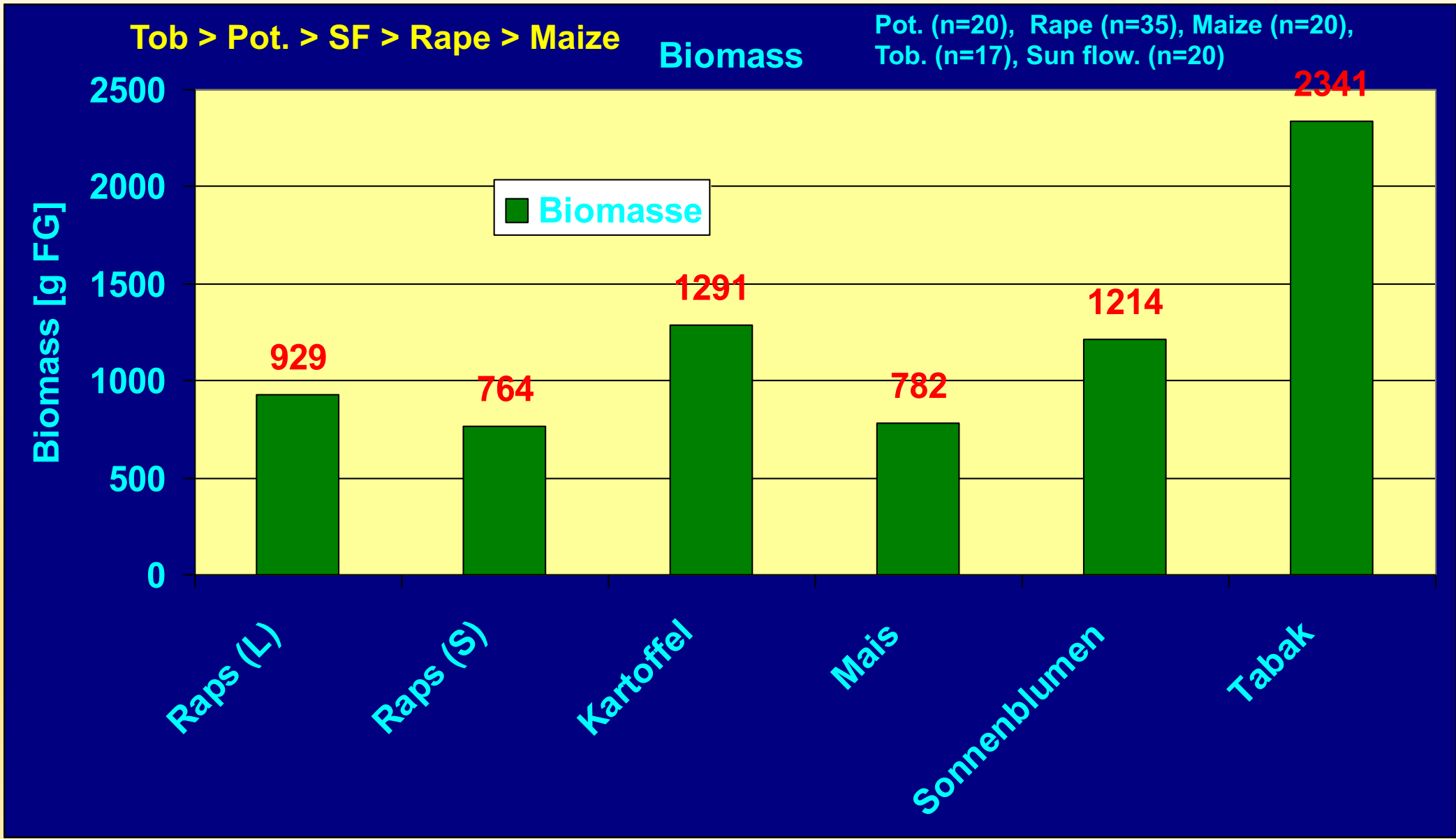
SF > Pot. > Rape (S) > Tob. > Maize Copper content

Pot. (n=10), Rape (n=17), Maize (n=10),  
Tob. (n=11), Sun flow. (n=10)





# Biomass Yield





# Conclusions

- **Cd- and Pb-Remediation by plants on moderate polluted levels is possible – Cd $\approx$ 60 mg/kg und Pb $\approx$ 3 500 mg/kg**
- **Sour clay minerals in the soil are predestined to implement Phytoremediation Processing**
- **Moderate contaminated sites could be well suited for purification by Phytoremediation in approx. 15 - 20 years**
- **Geoinformatic Monitoring-Tools are successfully approved in the practice on spectroscopic monitoring of crop pollution**

# Literature

1. **FHOOW Oldenburg 2004: „Int. Symposium Biologische Bodensanierung“; W. Adamski, C. Baum, S. Burek, G. Charles, G. Denafas, S. Fröhlich, P. Linger, R. Lösch, H. Thomas, E. Siefert, M. Weisensee**
2. **Biotechnika Hannover 2005: “Die Kraft der Pflanze: Zukunftsperspektiven der Phytoremediation und Energiegewinnung“; H. Aboughalma, S. Fröhlich**
3. **Achema 2006: Poster und Bericht “Forschungsschwerpunkt Biologische Bodensanierung” H. Aboughalma, S. Fröhlich**
4. **GAW 8 Kairo – Int. Conference on Geology of Arab World 2006: „Phytoremediation of Contaminated Sites and Energy Production“; H. Aboughalma, S. Fröhlich**
5. **FHOOW-Intern 2008: „Abschlussbericht zum Forschungsschwerpunkt Biologische Bodensanierung“; S.J. Weets, H. Aboughalma, S. Fröhlich, W. Gombler, M. Schlaak, E. Siefert**
6. **Achema 2009: Poster + Bericht „Forschungsschwerpunkt Kfz emittierte Metallfraktionen im Feinstaub“; H. Buse, H. Ernst, S. Fröhlich, W. Gombler, H. Kreitlow, E. Siefert, M. Weisensee**



A photograph of a beach at sunset. The sky is a gradient of dark red, orange, and yellow, with some wispy clouds. The horizon is a dark line. In the foreground, there is a sand dune with several clumps of tall, thin grasses. The text "Thank you for your patience!" is overlaid in the center in a bright yellow font.

**Thank you for your patience !**



# Anymore Questions?



*Anymore Questions?*

**If yes !**

**Contact Person**

**Prof. Dr. Siegmund R. Fröhlich**

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**+49 175 3813546**