“MULTIBARRIER AND MINE SITE REDEVELOPMENT”

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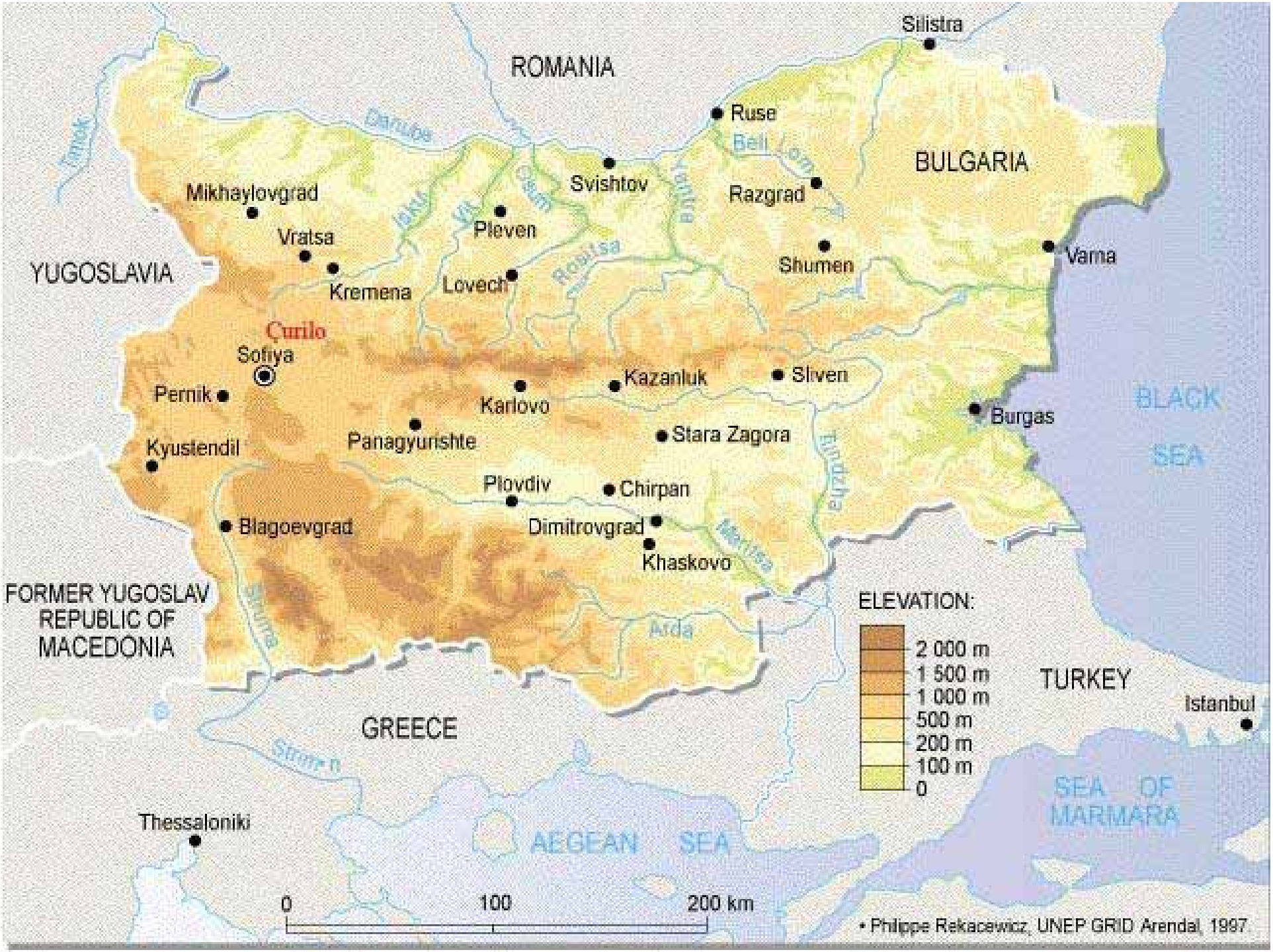
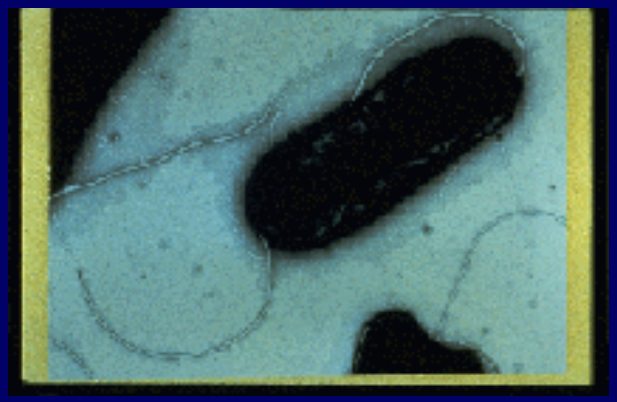
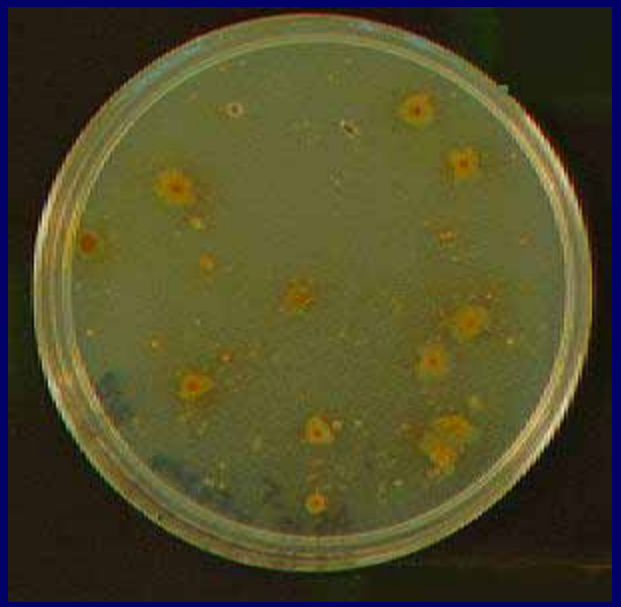

Silistra
ROMANIA
Ruse
Beli Lom
BULGARIA
Svishtov
Razgrad
Mikhaylovgrad
Vratsa
Pleven
Iskur
Vit
Osam
Yantra
Rositsa
Shumen
Varna
YUGOSLAVIA
Kremena
Lovech
Çurilo
Sofiya
Pernik
Kazanluk
Sliven
Karlovo
Burgas
BLACK SEA
Kyustendil
Panagyurishte
Stara Zagora
Tundzha
Plovdiv
Chirpan
Blagoevgrad
Dimitrovgrad
Maritsa
Khaskovo
FORMER YUGOSLAV REPUBLIC OF MACEDONIA
Struma
Arda
ELEVATION:
2 000 m
1 500 m
1 000 m
500 m
200 m
100 m
0
TURKEY
Istanbul
GREECE
Strymon
SEA OF MARMARA
Thessaloniki
AEGEAN SEA
0
100
200 km
• Philippe Rekacewicz, UNEP GRID Arendal, 1997

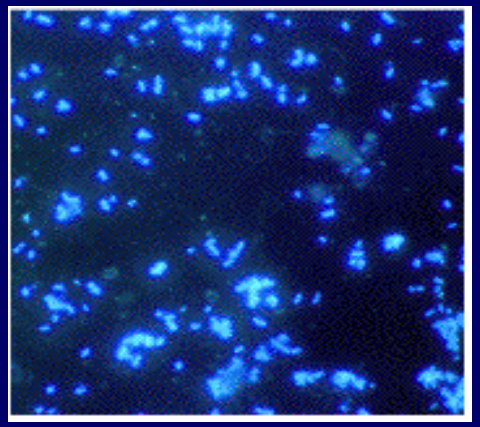
Acidithiobacillus ferrooxidans bacteria on a liquid nutrient medium



Colonies of *Acidithiobacillus ferrooxidans* on a solid nutrient medium with a ferrous iron as an energy source



Acidithiobacillus thiooxidans
on a solid nutrient medium
with S^0 as an energy source



Acidithiobacillus thioooxidans
in a liquid nutrient medium

Microorganisms in the acid mine drainage and in the effluents from the permeable reactive multibarrier

Microorganisms	In AMD	In barrier effluents
	Cells/ml	
Fe^{2+}-oxidizing chemolithotrophs (at pH 2)	10^4 - 10^7	0 – 10^2
Aerobic heterotrophs (at pH 2)	10^1 – 10^4	10^1- 10^3
$S_2O_3^{2-}$-oxidizing chemolithotrophs (at pH 7)	0 – 10^3	10^1 – 10^4
Aerobic heterotrophs (at pH 7)	0 – 10^2	10^1 - 10^4
Anaerobic heterotrophs (at pH 7)	0 - 10^1	10^4 - 10^7
Sulphate-reducing bacteria	0 - 10^1	10^4 – 10^7
Cellulose-degrading microorganisms	ND	10^3 – 10^6
Bacteria fermenting sugars with gas production	ND	10^3 – 10^7
Ammonifying bacteria	ND	10^2 – 10^5
Denitrifying bacteria	ND	10^2 – 10^5
Fe^{3+}-reducing bacteria	ND	10^3 – 10^6
Methane-producing bacteria	ND	10^1 – 10^4

Data about the dump effluents before and after the treatment of the dump

Parameters	Acid Mine drainage	Multibarrier effluents	Permissible levels for waters intended for use in agriculture and industry
Temperature, ^{o}C	(+1.2)-(+25.1)	(+1.4)-(+27.5)	-
pH	2.42 – 4.25	6.22 – 7.83	6 – 9
Eh, mV	(+290)-(+597)	(-140)-(-280)	-
Dissolved O_2, mg/l	1.7 – 6.0	0.2 – 0.4	2
TDS, mg/l	930 – 2972	545 – 1827	1500
Solids, mg/l	41 – 159	32 – 104	100
DOC, mg/l	0.5 – 2.1	51 – 159	20
SO_4^{2-}, mg/l	532 – 2057	275 – 1225	400

Data about the acid mine drainage and of the effluents from the permeable reactive multibarrier (continuation)

Parameters	Acid Mine drainage	Multibarrier effluents	Permissible levels for waters intended for use in agriculture and industry
U, mg/l	0.10 – 2.75	< 0.05	0.6
Ra, Bq/l	0.05 – 0.50	< 0.03	0.15
Cu, mg/l	0.79 – 8.24	< 0.20	0.5
Zn, mg/l	0.59 – 15.84	< 0.20	10
Cd, mg/l	<0.01 – 0.10	< 0.004	0.02
Pb, mg/l	0.08 – 0.55	< 0.02	0.2
Ni, mg/l	0.23 – 1.45	< 0.03 – 0.10	0.5
Co, mg/l	0.15 – 1.04	< 0.03 – 0.10	0.5
Fe, mg/l	41 – 671	0.7 – 9.5	5
Mn, mg/l	3.2 – 29.3	0.5 – 4.8	0.8
As, mg/l	0.05 – 0.32	< 0.01	0.2

Content of pollutants in the dead solid plant biomass in the permeable reactive multibarrier

Pollutants	Content, mg/kg dry biomass				
	November 2004	March 2005	August 2005	March 2006	September 2006
Uranium	10 – 32	17 – 71	23 - 88	32 – 114	32 – 122
Radium	5 – 14	10 – 32	15 - 41	21 – 53	23 – 57
Copper	28 – 73	37 – 134	44 - 181	60 – 225	62 – 221
Zinc	14 – 51	28 – 82	37 - 190	51 – 230	59 – 242
Cadmium	2 – 12	6 – 19	6 - 27	8 – 41	8 – 44
Lead	8 – 30	7 – 59	10 - 64	15 – 73	15 – 77
Nickel	8 – 35	9 – 62	9 - 77	15 – 90	19 – 95
Cobalt	5 – 30	11 - 51	14 - 70	17 – 82	16 – 90
Manganese	32 – 109	37 - 135	44 - 190	51 – 210	55 – 233
Arsenic	2 - 14	6 - 23	10 - 31	12 – 44	12 – 51

Sulphate-reducing bacteria in the effluents from the permeable reactive multibarrier

Sulphate-reducing bacteria	Cells/ml
Desulfovibrio (mainly *D. desulfuricans*)	10^4 - 10^7
Desulfobulbus (mainly *D. elongatus*)	10^2 - 10^7
Desulfococcus (*D. postgatei*)	10^2 - 10^6
Desulfobacter (*D. multivorans*)	10^2 - 10^5
Desulfotomaculum (mainly *D. nigrificans*)	10^1 - 10^4
Desulfosarcina (*D. variabilis*)	10^2 - 10^5
Desulfomonas (non-identified species)	10^1 - 10^4

Removal of pollutants from the drainage waters during the different climatic seasons

Pollutant	Pollutant removal, g/24h	
	During the warmer months	During the cold winter months (at 0 - 5 °C)
Uranium	62 - 242	23 - 82
Copper	91 - 451	32 - 154
Zinc	190 - 974	41 - 387
Cadmium	1.4 - 5.9	0.5 - 1.7
Lead	21 - 77	8.2 - 24
Nickel	48 - 145	21 - 53
Cobalt	41 - 122	15 - 44
Manganese	109 - 1090	51 - 334
Arsenic	14 - 41	0.5 - 18

CONCLUSIONS

- The constructed pilot-scale multibarrier performed an efficient cleanup of acid drainage polluted with radionuclides, heavy metals and arsenic during different climatic seasons;

- Considerable portions of iron and uranium were removed in the alkalizing drain of the multibarrier. However, the microbial dissimilatory sulphate reduction and the sorption of the pollutants by the solid organic biomass in the second unit of the multibarrier were the main processes involved in the water cleanup;

- The efficiency of treatment markedly depended on the temperature. In the cold winter months when the microbial growth and activity were considerably decreased, the role of the biosorption mechanism by the solid organic substrates was essential;

- The multibarrier effluents were enriched in dissolved organic compounds and usually still contained iron and manganese in concentrations higher than the relevant permissible levels. These pollutants were removed in the natural wetland located near the multibarrier.

THANK YOU!!!