Installation of natural vegetation on old tailing disposal area at Olympias Halkidiki mine after chemical stabilization and phytoremediation

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Before

1 year after

Metals were of great importance throughout the human history

From the antiquities.....

Metals were of great importance throughout the human history

.....to the modern society

Manipulation of mineral resources is closely connected with the environmental protection and land reclamation after mining processes.

Land reclamation task in mining sites is more difficult than mining it self

True sustainability in mining activities, exists only when reclamation processes are involved.

Extraction and processing of metals cause a number of problems and interfere with the environment, while they produce waste deposits which require special handling

These materials differ in their composition and properties. Varying from useful with good physical properties to toxic or difficult to handle.

Therefore there is no general rule for handling of these by-products.

Natural plant colonisation of these sites may take hundreds of years. This could not be regarded as process or strategy of reclamation or environmental restoration and moreover as rehabilitation.

Plant species grown under rich in metal environment absorb, assimilate or withstand in unusually high amounts of metals known as metallophytes

The exclusives.

The occasional pseudometallophytes

Several plant species have the ability to accumulate large amounts of heavy metals in their tissues

Asteraceae, Brassicaceae, Caryophyllaceae, Cyperaceae, Cunoniaceae, Fabaceae, Flacourtiaceae, Lamiaceae, Poaceae, Violaceae, Euphorbiaceae and many others

The main problems encountered in the mining areas are associated with

- Extreme values of pH in tailings ranges from 7 to 10, while in cases of sulphide minerals, the pH decreases dramatically
increased toxicity for grown organisms created by metals and metalloids.

lack of fine-grained material or inappropriate texture.
lack of nitrogen in most cases, available phosphorus and organic matter

reduced biological activity.

low water holding capacity and high or low infiltration rate.

low ion exchange capacity.

hardpan or cemented horizons appearance, which are due to the creation of secondary oxides and minerals.

strong wind erosion and instability

Tailings Management Facility (TMF)

The chemical composition of the tails material is affected by the composition of the ore and the method of flotation enrichment.

High concentrations of heavy metals and metalloids such as Cu, Mn, Fe, Zn, Pb, As, and others

Therefore chemical stabilisation is required

Stabilisation technique reduces the rate of movement of pollutants in the environment at acceptable level

Revegetation on mine tailings areas is a very difficult practice, due to heavy toxicity and plant nutrient deficiencies.

Olimpias site, over the years, water from tails was evaporated and the remaining materials, with high toxicity resulted in an acute risk of wind erosion and transport of pollutants over long distances.

Selection of plant species is one of the most critical factors in phytoremediation applied on contaminated areas to be successful.

Factors affecting the succesibility of the phytoremediation:

- the waste materials differ from tailings to tailing disposal are climatic conditions such as temperature and humidity differ from site to site only a limited number of plant species are tolerant in high salt and metal concentrations.

Plant selection criteria

Brassica jungea

- Pioneer native species which belong to the composition of native plant communities in the surrounding area.

Pioneer foreign species to the native plant community, but with ability to adaptable to tailings' conditions.

Species which belong to the composition of plant communities on the condition that they would address.

Non pioneer species, adaptable to tail conditions, alien to the place.

Species that are not grazed

(Alifrangis 2008)

Armeria maritime spp. halleri

Euphorbia cyparisias

Viola calaminaria

THE CHALENGE

The chalenge of our research team was to investigate why biological activities were absent from the old tailing site at the Olympias Halkidiki.

- First step was to stabilise the tailing material.
- Second step was the bioremediation.
- Third step was the instalation of natural vegetation

The aim of this research is the study of installation of natural vegetation on old tailing disposal area at Olympias Halkidiki mine, after chemical stabilization and phytoremediation.

MATERIALS AND ANALYTICAL METHODS

THE SITE

Since the 90´s the mine activity at Olympias Halkidiki were abandoned, leaving behind several old disposal areas and one big tailings management facility (TMF).

The variation of materials with depth is an important characteristic of the TMF

Mean chemical composition of tail material

As (%)	Mg (%)	Pb (%)	Zn (%)	Mn (%)	Cr (ppm)	Mo (ppm)	Ni (ppm)	Cu (%)	Fe (%)
0.47	1.38	0.18	0.16	3.24	65	84	<5		

Nutrients bioavailability of tail materials.

pH	Water-soluble (ppm)				Exchangeable with DTA (ppm)				Exchangeable with CH_3COONH_4			
	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe	Mg	K	Na	Ca
7.15	0.335	-	1.12	23.5	8.2	2.98	2.52	140.9	0.337	0.07	0.81	7.50

CHEMICAL STABILISATION

The chemical stabilisation achived with the use of different materials such as iron (Fe^0), $Al(OH)_3$, red mud, iron oxides, soil rich in iron oxides (oxisols), manganese oxides, byproducts rich in iron and manganese oxides.

Test trials

Laboratory test (160 treatments)

Glasshouse and field experiments were conducted

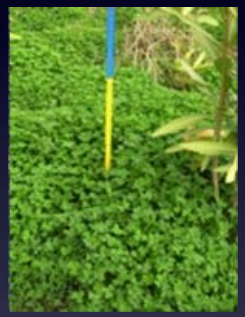
Treatments of the field experinment

Treatment	1	2*	3	4**	5	6	7
Tailing material (%)	50	50	60	60	100	-	50
Rich in Fe and Mn oxides materials (%)	20	20	10	10	-	-	45
Soil (%)	10	10	10	10	-	100	-
Rice husk (%)	10	10	10	10	-	-	5
Skeleton material (%)	10	10	10	10	-	-	-

*Mixture was inserted as layer at the bottom, while the tailing material with a thickness of 40cm at the top
**Inoculation with *Glomus intraradices* fungus.

The past

The future



Results

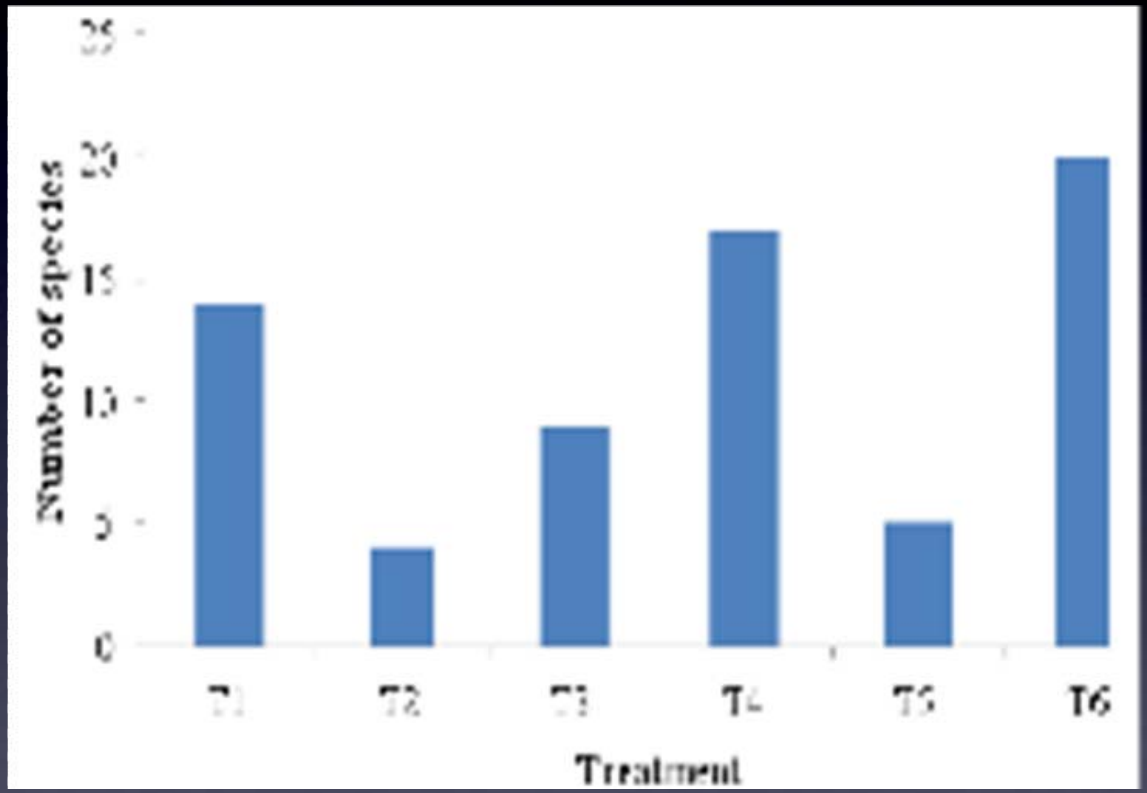









Number of plant species per treatment



Plant species one year after

Plant species	Treatment	Plant species	Treatment
Polygonum aviculare	1, 3, 4, 5, 6	Chenopodium botrys	4, 6
Tragus ralemosus	1, 2	Digitaria sanguinalis	4
Oxalis corniculata	1	Verbascum sf. undulatum	4
Persicaria sp.	1, 4	Ailanthus altissima	4
Chenopodium album	1, 4, 6	Aster tripolium	4
Centaurea diffusa	1, 3, 4,	Rumex pulcher	4
Cynodon dactylon	1, 2, 3, 4, 5, 6	Persicaria sp.	6
Sorbum halepense	1, 3	Cleome omithopodoides	6
Cichorium intybus	1, 2, 3, 4, 5, 6	Phytolacca americana	6
Euphorbia cyparisias	1, 3, 4, 6	Rumex acetosa	6
Echinocloa colum	1, 3, 4	Portulaca oleracea	6
Calystegia sylvatica	1	sanguisorba minor	6
Solonum nigrum	1, 2, 3, 4, 6	Ballota nigra	6
Cyperus longus	1, 6	Dactylis glomerata	6
Chenopodium botrys coromatics	3	Piptatherum miliaceum	6
Solanum elaeagnifolium	4	Rubus ulmifolius	6
Meliotus sp.	4	Carduus acicularis	6
Conyza bonariensis	4	Xanthium spinosum	6

Bioaccumulator factor (BCF)

Plant species	Treatment	Cu	Zn	Fe	Mn
Polygonum aviculare	1	1,82	4,59	233,37	105,07
Tragus ralemosus	1	3,37	4,03	609,94	499,10
Oxalis corniculata	1	3,54	7,17	578,58	676,02
Persicaria sp.	1	1,81	5,50	334,07	277,64
Chenopodium album	1	1,29	4,39	127,39	112,67
Centaurea diffusa	1	2,46	5,30	392,33	300,09
Cynodon dactylon	1	3,63	6,52	609,69	513,91
Sorbum halepense	1	1,29	4,19	5,30	39,26
Cichorium intybus	1	4,67	9,94	982,58	1161,20
Euphorbia cyparisias	1	2,07	5,34	323,60	210,19
Echinocloa colum	1	2,07	5,14	238,81	142,68
Calystegia sylvatica	1	1,42	5,22	148,63	150,22
Solonum nigrum	1	1,94	4,78	153,75	213,81
Cyperus longus	1	3,24	5,50	169,93	146,53
Cynodon dactylon	2	4,75	3,40	61,20	471,56
Tragus ralemosus	2	18,34	9,79	1227,67	8193,17
Chicorium intybus	2	18,69	9,52	786,54	4863,93
Solanum nigrum	2	41,83	18,01	2265,88	414,40
Echinocloa colum	3	3,92	5,08	45,87	281,12
Polygonum aviculare	3	1,63	3,10	22,93	214,13
Solanum nigrum	3	13,04	7,76	714,36	3531,86
Cynodon dactylon	3	7,84	5,98	467,92	2062,01
Euphorbia cyparisias	3	2,28	3,90	119,27	902,12
Cichorium intybus	3	14,70	12,63	1743,23	7755,97

The ratio among the nutrient bioavaliability and the tissue concentration.

When BCF >1 then the plant is hyperaccumulator

Bioaccumulator factor.

Plant species	Treatment	Cu	Zn	Fe	Mn
Centaurea diffusa	3	5,22	3,76	206,11	1403,67
Sorghum halepense	3	4,89	5,36	309,10	1964,74
Chenopodium botrys corom.	3	7,51	7,32	545,47	3254,43
Solanum elaeagnifolium	4	2,77	4,54	168,39	664,35
Centaurea diffusa	4	3,69	4,65	287,44	1145,43
Melilotus sp.	4	1,15	2,44	509,18	216,88
Chenopodium album	4	0,10	3,24	255,08	247,52
Cynodon dactylon	4	2,98	8,92	171,68	799,50
Euphorbia cyparisias	4	1,06	3,87	85,19	635,20
Echinocloa colum	4	1,06	5,63	129,32	629,58
Conyza bonariensis	4	6,71	5,73	226,25	1493,78
Sorghum halepense	4	0,00	2,61	16,61	230,81
Solanum nigrum	4	0,46	2,89	17,29	203,57
Polygonum aviculare	4	0,00	3,56	64,53	292,71
Cichorium intybus	4	3,61	4,57	479,13	1527,78
Chenopodium botrys	4	5,43	7,65	330,58	1691,59
Digitaria sanguinalis	4	0,39	4,49	120,36	436,59
Verbascum sf. undulatum	4	8,69	16,77	1148,29	664,35
Ailanthus altissima	4	0,39	4,04	69,17	3092,41
Persicaria sp.	4	0,19	4,15	155,68	314,76
Cichorium intybus	5	5,66	4,99	237,22	362,77
Polygonum aviculare	5	0,00	1,93	58,74	2029,05
Aster tripolium	5	0,94	2,95	17,54	634,85
Rumex pulcher	5	6,59	6,16	349,97	510,37
Cynodon dactylon	5	0,70	2,54	43,27	4050,82
Cyperus longus	6	7,35	16,56	156,01	374,46

Bioaccumulator factor.

Plant species	Treatment	Cu	Zn	Fe	Mn
Persicaria	6	0,00	21,14	62,49	682,74
Cleome omithopodoides	6	0,00	12,71	71,27	511,85
Cichorium intybus	6	28,85	29,99	350,26	964,42
Euphorbia cypparisias	6	0,00	17,52	68,21	629,84
Chenopodium album	6	3,50	24,49	55,84	255,53
Phytolacca americana	6	2,85	21,12	45,78	682,05
Polygonum aviculare	6	4,50	12,58	60,31	184,91
Chenopodium botrys	6	16,84	7,97	237,19	445,96
Cynodon dactylon	6	11,21	6,80	216,18	111,54
Rumex acetosa	6	25,14	20,38	325,70	352,06
Sanguisorba minor	6	11,41	7,14	173,42	163,44
Solanum nigrum	6	18,53	8,15	49,01	69,30
Ballota nigra	6	13,55	6,15	81,29	69,31
Dactylis glomerata	6	12,54	9,98	142,24	118,79
Piptatherummiliaceum	6	16,40	8,99	117,16	59,41
Rubus ulmifolius	6	11,71	3,62	46,70	35,48
Carduus acicularis	6	15,71	7,50	58,66	41,69
Xanthium spinosum	6	27,82	21,57	39,47	23,21

Thank you