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POLLUTIONS OF CYPRUS MINE COMPANY (CMC) WASTES ON SOIL, WATER AND THE MEDITERRANEAN IN CYPRUS

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ABSTRACT

All forms of life surrounding us are dependent on natural sources like soil, water and air, within strong bounds of harmony. Unbroken and constant existence of natural life is the result of these healthy and delicately balanced interrelations. Any kind of material introduced in natural life or any ecosystem resulting in natural life fragmentation is defined as "a pollutant". Pollutants may be the reasons of chemical and/or physical change in ecosystems in a stretch of time or may exist in a stable form for relatively longer time periods, in the environment.

Copper mine plantations located around Gemikonagi Harbour of Lefke Region in Cyprus have a history of 5000 years. The name of the island "Cyprus" is generated over the terms of Cyprium, Cuprum, and finally Cyprus -all meaning "copper". Cyprus is known as being the place where copper has been produced in the form of metal for the first time in the world.

Crude gems of the reserve plantations (an uncovered one at Lefke, a covered one at Karadag and chemical wastes, accumulated wastes, wastes of copper process with cyanide, mayor wastes of copper flotation establishment, waste pools with pyrite consisting 25-30 % sulphur at Gemikonagi harbour in the region of Karadag, south west of Lefke, north part of Trodos magmatic solid) are the sources of soil, vegetation, underwater and sea water pollution and beside all, air pollution by particles of mine and sulphur gasses relevant to high temperatures at summer times.

By Gemikonagi puddle, where a soil-filled dam has been constructed over Maden (Mine) Stream, we see mine areas. In these locations, iron, coppered sulphur and tailing carried to surface waters are the source of an acidic environment for drinking and irrigation waters connected to the condensation of heavy metals.

1. INTRODUCTION

The region is in Trodos magmatic complex, where Trodos lava pads of iron (pyrite), and copper (calcopyrite) are located. Copper mines are located around Gemikonagi Harbour in Lefke, North Cyprus Turkish Republic. As a natural result of the long term history of copper production, the name of the island "Cyprus" is generated over the terms of "Cyprium" and "Cuprum" that finally combined together in the word "Cyprus" meaning "copper".

Trodos solid is an area where ocean sheet has reached earth surface. There are mines rich of sulphur involving pyrite, calcopyrite, marcasit, sfalarid, galen, bornit, with copper, zinc, iron and sulphur lairs. These lairs mostly occur at the base or upper part of the lava pads in upper levels of the Trodos solid.

Sources of pollutants that have threatened the livelihood of soil, underground waters and sea ecosystems, as well as air pollution (caused by sulphur gases and mine particles due to the high temperatures in summer), have been crude gem reservoirs -an uncovered one at Lefke, and a covered one at Karadag and chemical wastes, accumulated wastes, wastes of gold process with cyanide (Figure 1), major wastes of copper flotation plants, waste pools with pyrite consisting 25-30 % sulphur at Gemikonagi harbour in the region of Karadag, south west of Lefke, and north part of Trodos magmatic solid (Figure 2). There are mines also at Gemikonagı puddle which have been constructed over Maden (Mine) Stream as a soil filled dam.

Fig 1. The little waste hill was developed by CMC

Fig.2. One of waste pools in CMC area

Lefke- Gemikonagi gem plantation has been intensively operated by Cyprus Mine Company (CMC) from 1913 till 1974, when its activities ended (Figure 3), leaving back all the wastes produced in the form of a 'valley of death' (Figure 4).

Fig. 3. The CMC plant process

Fig. 4. The wastes of CMC in Mediterranean coastline

Local pollution caused and left after the mine plantation indicates four distinctive levels of image from sea level to mountain areas.

These are:
(i) Wastes of gold consisting in cyanide at the entrance area of Gemikonagi plantations,
(ii) Wastes of copper flotation at the entrance areas of Gemikonagi plantations,
(iii) Waste pools consisting in condensed pyrite mineral having 30% sulphur inside, separated to uprising 6 branches of waste pools,
(iv) Low copper accumulations and also wastes of trailing in apparent streams at Karadag region due to mine production extractions. In the regions of copper plantations and near areas of uncovered inactive gem production plantations, areas of stock for gem and gem wastes have the tendency to penetrate into sea ecosystem due to rain waters and land inclinations by surface flow. Beside, wastes founded on the surface like calcopyrite ($CuFe_2$), pyrite (FeS_2), and mineral rich of sulphur, get in reaction with rain waters and free oxygen and rise the condensation of the wastes and the acid level of waters, thus raising pollution parameters in surface waters, surrounding soils, coastline and sea water (Figure 5).

Fig. 5. Abnormal colour condensation in Mediterranean waters by the coastline

The source of the blue colour observed on the upper parts of Gemikonagi puddle and in direct connection points with Maden stream within the same puddle is the copper element. Gem wastes, chemical material wastes, solid wastes left after the gem plantation are observed from sea level to upper areas at Gemikonagi, increasing the environmental problem.

2. MATERIAL AND METHOD

Sample materials that are used in pollution analyses were taken from mine wastes, soil, waters and plants under influence of CMC in Lefke Region, Cyprus, on 25.03.1999 and 9.10.1999. Physical, chemical and heavy metal analyses on these samples within were completed according to the principles defined in a consolidated literature (Slavin,1968; Merck,1973; Chen,1991).

3. RESULT AND DISCUSSION

The following diagram presents data coming from laboratory analyses carried out in the 4 different samples taken from the waste pools 1,3,5,6. These pools, taken from the mentioned mine plantation waste area, were located in gradually different heights down to sea level, and give an image of the set (Table 1).

Table 1. Waste Analysis Results (Waste pools are given numbers considering their locations from upper to lower in altitude, that is a numeric order from Karadağ to Gemikonagi)

Sample No	**1. Pool**	**3. Pool**	**5. Pool**	**6. Pool**
pH	1.69	2.42	2.79	2.51
Total Soluble Salt in Water (%)	1.90	1.45	0.83	0.98
Sand (%)	17.44	25.44	21.44	29.44
Silt (%)	45.64	67.64	47.64	63.64
Clay (%)	36.92	6.92	30.92	6.92
Texture	Siltly clay loam	Silt loam	Clay loam	Silt loam
Organic matter (%)	3.93	2.06	1.15	3.45
S (%)	16.82	7.95	4.85	7.09
Zn (ppm)	63	94	110	43
Cu (ppm)	280.50	1102.87	936.75	369.75
Fe (%)	9.0669	4.8900	3.8713	14.7719
Mn (ppm)	74.75	209	594	50.5
Cd (ppm)	1.15	1.10	1.00	1.50
Co (ppm)	99.12	50.75	22.87	68.62
Pb (ppm)	82.75	13.50	11.25	31.50
Cr (ppm)	9.50	59.62	39.75	19.87
Mo (ppm)	177.87	20.00	18.00	295.50

Reaction of saturation percentage (pH) is ultra acid, total soluble salt in water, strongly saline. Data on potential microelements and heavy metals are maintained from the $HClO_4$ + HF solution which wastes are fragmented in. According to these data; sulphur (S) 4.85-16.82% ; iron (Fe), 3.8713-14.7719 %, manganese (Mn) 0.0051-0.0209 %; zinc (Zn) 0.0043-0.0110 %, copper (Cu) 0.0281-0.1103 %; cadmium (Cd), 0.0001-0.00015 %; cobalt (Co) 0.0023-0.0099 %; lead (Pb) 0.0012-0.0083 %; chrome (Cr) 0.0010-0.0060 %; molybdaen (Mo) 0.0018-0.0296 % in dispersion levels (Figure 6).

According to maintained research data, the gem plantation kept active economically by CMC consisted in 1.3 % Cu and more than 45 % S up to 1974 till they were exhausted. Following this phase the same firm started a research for new potential areas of reservoirs and determined that in Lefke A1 (0.35% Cu), Lefke A2 (0.56% Cu), and Lefke A3 (0.36% Cu) reserves are potential mines reservoirs. In waste pools, Cu gem is in concentration of 0.0281-0.1103 % levels. Thus we understand that the gem plantation has drained 1/20 percentage of the potential Cu into the waste pools and this caused concentration of Cu in these pools 10 times higher than the percentages of lithosphere. We observe that in 3th and 5th pools zinc (Zn), copper (Cu), manganese (Mn) and chrome (Cr), in 1st and 6th pools iron (Fe), cadmium (Cd), cobalt (Co), lead (Pb) and molybdean (Mo) are concentrated according to analysed data.

Dispersion of sulphur is at maximum level of concentration at 1st waste pool and this datum reaches up to 16.82 % . Considering the level of sulphur dispersal as 0.08 % in lithosphere, percentage of wastes are calculated to be 200 times more. Current intense data of high accumulation percentages indicate the dimensions of sulphur pollution at the area.

Reactions (pH) in the waste pools are very acidic. These reactions concentrate the chemical defragmentations and at the end heavy metals are free. This last phase leads penetration of heavy metals into underground waters, surface waters, sea water and nearby lands causing an increase in environmental pollution every passing day**.** At the sampling phase from the upper sections it is realised that the surrounding is in intense odour of sulphur. Due to condensation of very high acid in solution of sulphureos and sulphuric acid, while taking samples in touch with the surrounding material it is observed that our skin is effected from this acidic condition very negatively. Beside all clay+silt particles spreading around up to 70-80 % extend by the help of surrounding winds in form of dust clouds create environmental pollution rich of heavy metals and sulphur.

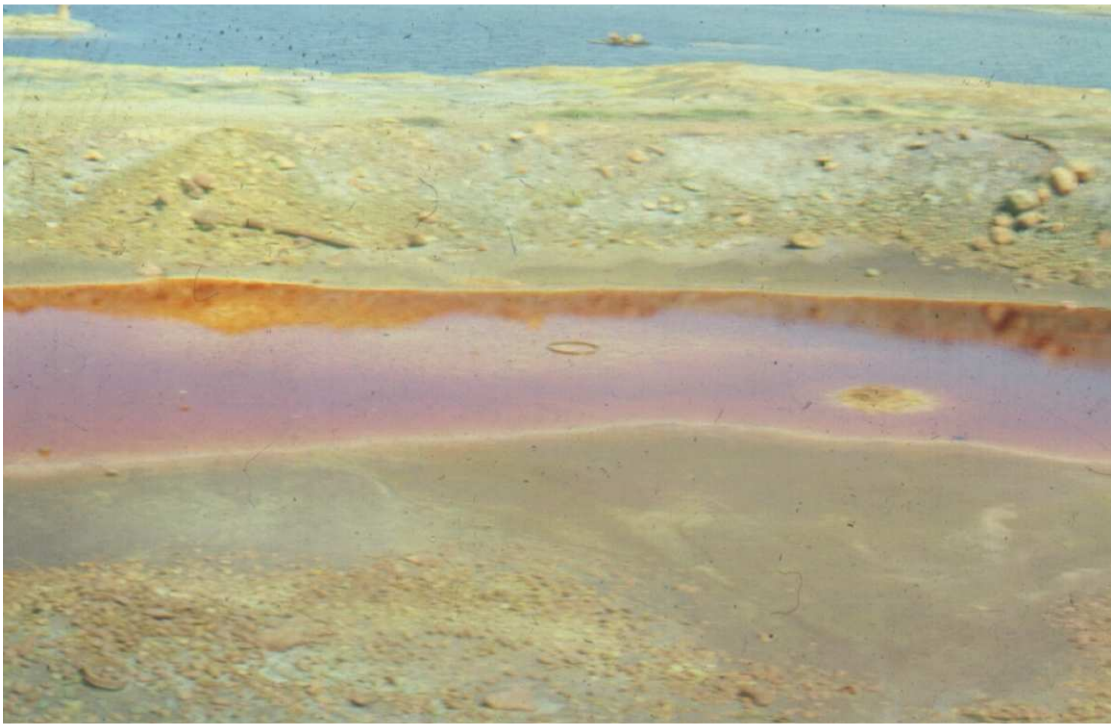

Fig. 6: Reddish colour from iron, yellowish from sulphur

Samples are taken from the soil, plant and water under the influence of copper plantation Gemikonagi, Lefke, North Cyprus Turkish Republic on 09.10.1999 and analysed (Table 2,3,4).

Table 2. Some physical and chemical analyse results of soils

	Particle size distribution							
Sampling site And depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	CaCO3 (%)	Total soluble Salt in water (%)	Org. mat. (%)
Azer Baycan's garden								
Ap (0-10)	59.44	36.00	4.56	Sandy loam	6.77	2.64	0.115	10.29
C1 (10-28)	67.44	30.00	1.56	Sandy loam	6.85	1.07	< 0.03	3.56
Altan Öksüz's garden								
Ap (0-14)	57.44	28.00	14.56	Sandy loam	7.02	1.94	0.130	4.65
C1 (14-40)	47.44	32.00	20.56	Loam	7.02	0.82	0.090	1.96
Mehmet Özakdenizli's garden								
Ap (0-14)	47.44	44.00	8.56	Sandy loam	4.58	1.19	0.215	2.43
C1 (14-33)	53.44	36.00	10.56	Sandy loam	4.54	0.82	0.215	1.03
Özdemir Şamlıdağ’s garden								
Ap (0-14)	57.44	30.00	12.56	Sandy loam	7.13	35.72	0.160	1.96
C1 (14-32)	59.44	22.00	18.56	Sandy loam	7.43	36.83	0.085	1.55

Heavy metal distribution as Iron (Fe) 2.08-6.10 %, copper (Cu) 24-504 ppm, manganese (Mn) 687.3-1099.8 ppm., zinc (Zn) 55.0-217.5 ppm, cadmium (Cd) 0.78-1.85 ppm, cobalt (Co) 14.0-38.0 ppm., lead (Pb) 11.3-45.0 ppm, chrome (Cr) 2.3-25.9 ppm, aluminium (Al) 0.18-5.18 % are the dispersion levels that generally increase along the depths of surface soil.

Table 3. Soil samples observed to consist in above heavy metal measurements

Sampling site and depth(cm)	Fe (%)	Cu (ppm)	Mn (ppm)	Zn (ppm)	Cd (ppm)	Co (ppm)	Pb (ppm)	Cr (ppm)	Al (%)
Azer Baycan' s garden									
Ap (0-10)	3.85	369.0	871.5	217.5	1.17	30.0	16.3	11.3	1.69
C1 (10-28)	4.85	210.0	1099.8	132.5	1.02	26.0	12.5	9.2	2.17
Altan Öksüz' s garden									
Ap (0-14)	2.08	231.0	767.8	92.5	0.93	22.0	45.0	11.5	1.69
C1 (14-40)	4.33	204.0	767.8	92.5	1.12	26.0	23.8	20.3	5.18
Mehmet Özakdenizli' garden									
Ap (0-14)	6.10	504.0	684.8	87.5	1.07	35.0	22.5	25.9	3.43
C1 (14-33)	4.29	453.0	809.3	80.0	0.78	38.0	11.3	4.5	1.47
Özdemir Samlidag' s garden									
Ap (0-14)	3.15	90.0	996.0	67.5	1.76	22.0	27.5	22.3	1.61
C1 (14-32)	2.68	24.0	687.3	55.0	1.85	14.0	26.3	2.3	0.18

Referring to analysed results given above, the element of iron is relatively in high levels in garden of Mehmet Özakdenizli and this data indicated 6.10 % maximum level of condensation. Iron element is found to be increasing in condensation through under surface horizons, indicating (i) surface wash of soil, and (ii) mine plantation as the sources of this character of condensation. In general iron concentration at this type of soil is found to be at 2.00-3.50 % dispersal levels.

The level of copper on the researched soil is definitely in higher concentration than the accepted average values 5-110 ppm of this kind of soil. Except that for the garden of Özdemir Samlidag, there is a definite copper pollution of soil.

Likewise, cobalt level is in higher concentration according to analyse results considering the expected 15 ppm level at surface soil.

Average dispersal concentration of lead in the lithosphere is 16.0 ppm but analysis results indicate a general higher level. An accumulation of lead at the surface soil is definitely existing: a sample analysis from the garden of Altan Öksüz gives the result of 45.0 ppm lead element.

Like the lead element, chrome has a tendency to accumulate at biologically rich humus soil and it indicates a concentration at the surface soil that is 25.90 ppm at some surface layers.

Referring to the analysis results, water sample reactions (pH) is slightly acidic at Gemikonagi and slightly alkaline on upper parts of the same area. In all these three samples there is a pollution of evaporation remnant. The seawater indicates a very profound pollution with all specifications.

Table 4. (Continuing). Some chemical analyse results in water samples

				Water soluble cations (me/l)			**Total**	**Water soluble anions (me/l)**				**Total**				
Sampling number	Sampling site and artesian well owners	PH	EC (mmhos/cm)	Ca^{++}+ Mg^{++}	K^{+}	Na^{+}	**Cation (me/l)**	Cl^{-}	SO_4^{--}	CO_3^{--}	HCO_3^{-}	**Anion (me/l)**	SAR	Irrigation water-class	Evaporation waste (g/l)	Boran (ppm)
1	Gemi Konagi small dame - deep sluice	6.61	780	7.10	0.02	1.88	9.00	1.38	4.88	-	1.90	8.16	1.00	C3S1	0.79	0.20
2	Gemi Konagi small dame -Upper side	7.40	700	6.50	0.02	1.61	8.13	1.38	3.89	-	1.90	7.17	0.89	C2S1	0.71	0.05
3	Altan Öksüz's garden	6.55	1350	9.90	0.05	3.52	13.47	2.92	5.80	-	5.80	14.52	1.58	C3S1	1.32	0.15
4	Rayif Altiner's garden	6.13	1200	9.60	0.02	3.47	13.09	2.57	7.39	-	4.70	14.66	1.58	C3S1	1.98	0.15
5	Sea water	7.66	58000	15.90	6.41	52.17	74.48	66.91	3.37	-	4.10	74.38	18.50	C6S4	46.71	6.00
6	Mehmet Özakdenizli's garden	6.96	1200	9.40	0.05	3.43	12.88	2.87	4.92	-	5.40	13.19	1.56	C3S1	1.07	0.20

In water samples from the bottom sluice at the very low section of Gemikonagi puddle, iron (Fe) 0.17ppm, copper (Cu) 0.282 ppm, manganese (Mn) 0.168 ppm., zinc (Zn) 0.200 ppm., cadmium (Cd) 0.0029 ppm., cobalt (Co) 0.033 ppm., aluminium (Al) 0.407 ppm. data are maintained as analysis results while very low concentration of lead and chrome is defined (Table 5). According to these analysis results there is a pollution of copper from CMC wastes in water (Figure 7).

Table 5. (Continuing). Heavy metal concentrations in Water Samples

Sampling number	Sampling site and artesian well owners	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	Cd (ppm)	Co (ppm)	Pb (ppm)	Cr (ppm)	Al (ppm)
1	Gemi Konagi small dame – Underside	0.17	0.282	0.168	0.200	0.0029	0.033	-	-	0.407
2	Gemi Konagi small dame – Upperside	0.12	0.021	0.019	0.020	0.0029	-	-	-	-
3	Altan Öksüz's garden	0.05	0.011	0.000	0.070	0.0039	-	-	-	-
4	Rayif Altiner's garden	0.08	0.014	0.008	0.125	0.0044	-	-	-	-
5	Sea water	0.25	0.024	0.025	0.026	0.0320	0.180	0.34	0.023	-
6	Mehmet Özakdenizli's garden	0.06	0.008	0.000	0.275	0.0039	0.020	-	-	-

Figure 7. Reddish colour from iron, yellowish from sulphur due to mine wastes in CMC area

According to heavy elements concentration dispersal results maintained from the leaves of particular plants, boran is found as being most condense in the orange leaves and 31.1 ppm; magnesium in bean leaves and 0.66 ppm; iron in bean leaves and 175.0 ppm, manganese in cabbage leaves 141.0 ppm, zinc is bean leaves and 27.0 ppm, copper in bean leaves 24.2 ppm, molybdean at level of microamount in all samples, cobalt in cabbage leaves 4.95 ppm, chrome in orange leave 26.0 ppm, nickel in mandarin and bean leaves and 5.3 ppm are the identified data (Table 6).

According to above data there is a condensed accumulation of iron in bean leaves. Concentration of copper in cabbage and mandarin leaves are nearly reaching the level of toxic while exceeding in orange and bean. Chrome is found as being 26 ppm in leaves of orange and as this level is higher than the 5-20 ppm criteria, chrome exceeds the acceptable level. When we consider lead dispersal in plants, lead in cabbage is lower but in bean is higher than 5-20 ppm criteria while the lead in other plants are in this spectrum. So there is lead pollution in plants also.

Table 6. Analyse results of leaves

Location of sampling and plant spiecies	Humidity (%)	B (ppm)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	Co (ppm)	Cr (ppm)	Cd (ppm)	Pb (ppm)	Ni (ppm)
Azer Baycan's garden													
Mandarin leave	60.7	30.7	0.40	127.5	30.8	15.0	17.7	trace	3.58	6.0	0.90	14.5	5.3
Altan Öksüz's garden													
Orange leave	63.3	31.1	0.26	134.3	29.0	10.0	21.6	trace	3.58	26.0	0.95	16.0	4.9
Mehmet Özakdenizli's garden													
Bean leave	82.9	17.6	0.66	175.0	98.8	27.0	24.2	trace	3.03	2.0	0.48	22.5	5.3
Özdemir Samlidag's garden													
Cabbage leave	88.1	12.9	0.34	96.8	141.0	17.0	13.6	trace	4.95	4.0	0.55	7.3	3.5

4. CONCLUSION

Lefke as a harbour city and its nearby inland areas, as well as the Mediterranean coastlines, loose visual and functional qualities due to CMC mine wastes pollution .This problem extends the boarders of Lefke, North Cyprus Turkish Republic or another part of Cyprus but reaches up to region wide level consisting in the Mediterranean coastline boarders.

It is vital to have precautions urgently set up for the natural resources under pollution of sulphur and some heavy metals at the region, as listed below:

1 Preventing the penetration of tailing and mine accumulations in the drainage basin to Gemikonagi Puddle at Lefke Mine stream. Periodic controlling of the puddle waters and of the wells that are located at the puddle foundation and preventing the use of these waters for drinking and irrigation.

2 Accumulated wastes of mine, wastes of chemicals, wastes of scraps left behind after the completion of establishments at Gemikonagi are also the sources of visual pollution beside natural resource pollution at soil, vegetation, and waters. Thus it is needed to observe the sources of pollution continuously in order to define the chemical functions. This can be done by taking samples from the depths 0-1 m, 1-2.5 m, 2.5-4 m, 4-5.5 m, 5.5-7 m, 7-8.5 m.

3 Preventing the access of human and any animal to the area by green fence convenient to the ecology of the region or by wire fence. Putting emphasis on creating the green fence and making use of its resistance and acceptable impermeability to storms, so helping decreasing the level of pollutants spreading around.

4 Preventing the penetration of rain waters to the area of waste at the south part of the region by constructing circulation channels at the above parts of the basin is vital and urgent to prevent the decharge of the soluble heavy metals, beside very acidic reactions, in these waters.

Likewise, a global approach rather than a local seeking for financial and logistic support at the international arena would be the most intelligent and professional attitude to handle this problem. This problem should also be transferred to international civil initiative and court in order to reach long term results and not to face such kind of experiences further more.

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