Environmental effects of the acid rains and mine drainage around the Murgul VMS copper deposit, Eastern Pontides, Turkey

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The Murgul copper deposit is located 7 km to the south of Murgul (Artvin) in the north-eastern part of Turkey and has been in modern operation since the 1940's. The deposit is hosted in dacitic pyroclastics of Upper Cretaceous and covered by acidic tuffs, mudstone, micritic limestone and sandstone of Upper Cretaceous. The massive lens composed mainly of chalcopyrite and sphalerite is already mined out and the current production is from the stockwork zone within the dacitic pyroclastics. The ore is composed mainly of pyrite and chalcopyrite, and sphalerite, galena and sulphosalts to a lesser extent. There is a vertical variation in the chemistry and mineralogy of the deposit; sphalerite and galena increase towards upper levels of the deposit (Akçay and Tüysüz, 1998). Quartz is the main gangue mineral; baryte, sericite, gypsum, siderite and ankerite also occur in minor amounts. The stockwork zone is characterised by an intense silicic alteration grading outward into sericite and chlorite-rich zones (Schneider *et al.*, 1988).

The Murgul deposit has a reserve of 30,000,000 tons of ore grading at 0.97% Cu. Annual production is about 3 million tons of ore yielding 25000–30000 tons of Cu concentrate, 25000–30000 tons of sulphur and 10000–15000 tons of sulphuric acid (Akçay and Tüysüz, 1998).

Water and sediment pollution

The Murgul Cu deposit is one of the best examples of mining showing the extent of environmental pollution that might be caused in case of no protection. Both waste and tailings disposal are done into two creeks flowing near the mine site. The alluvial cover of these creeks, therefore, is composed mainly of pyrite. Discharged water from the flotation plant may contain up to 25 vol.% suspended material most of which is pyrite and is the prime reason for the high pyrite concentration in the alluvium. Dissolution of pyrite and other minerals originating from the waste and addition of H^+ into the solution is counteracted by the addition of alkalies into the water discharged from the flotation plant. This keeps the pH of he creek water in a reasonable level (8.05 ± 0.45). The sediments in the creeks, contain <500 to >2500 ppm Cu, <30 to >120 ppm Pb, <250 to >1500 ppm Zn, <2.5 to >11 ppm Cd, and <3% to >12% Fe (Table 1). The lowest concentrations are from the zones not affected by the mine disposal. Coupled with the high amounts of suspended material, such high Cu and Fe concentrations in the sediments have been causing a great danger to the living organisms in the vicinity. The effects of this sediment pollution continue for more than 15 km into the main Çoruh river flowing via Turkey into Georgia. These high heavy element concentrations are also detected in water samples that

TABLE 1. Comparison of element concentrations from different sampling sites

Parameter	Discharged flotation water	Damar Creek	Kabaca Creek	Murgul Stream	Çoruh River	Mean polluted water	Clean stream water	Enrichment factor	Spring water	Tap water
pH	9.70	8.15	7.59	7.99	8.31	8.11	8.30	0.98	7.60	7.64
Cu (mg/l)	2.21	2.21	2.07	3.15	0.17	2.62	0.03	87	0.00	0.01
Pb (mg/l)	1.99	1.52	0.38	2.37	0.19	1.79	0.02	90	0.18	0.11
Zn (mg/l)	2.45	1.74	0.51	1.36	0.04	1.45	0.01	145	0.05	0.16
Cd (ig/l)	31.00	28.11	14.00	15.38	6.80	20.53	6.00	6.8	12.00	11.00
Fe (mg/l)	4.88	2.32	0.69	4.37	1.62	3.31	0.30	11	0.04	0.01

TABLE 2. Lateral and vertical differences between the Cu concentrations along two soil profiles

	Profile I		Profile II	
	Cu-I.1	Cu-I.2	Cu-II.1	Cu-II.2
Depth (cm)	25-35	45-50	25-35	45-50
Min (ppm)	33	33	45	43
Max (ppm)	138	138	5299	4213
Mean (ppm)	71	66	692	550
		Enrichment factors		
	Cu-I.1	Cu-I.2	Cu-II.1	Cu-II.2
Cu-I.2	0.93	1.00	10.49	1.00
Cu-II.1	9.78	10.49	1.00	1.00
Cu-II.2	7.78	8.34	0.80	1.00

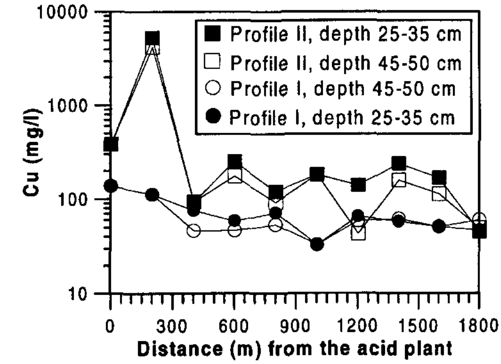

FIG. 1. Lateral and vertical distribution of Cu in the soil profile near the acid plant.

contain 0.01 to 6.15 mg/l Cu, 0.02 to 4.37mg/l Pb, 0.01 to 4.76 mg/l Zn, 2 to 89 µg/l Cd, and 0.01 to 6.9 mg/l Fe. compared with the clean waters, polluted waters show a significant enrichment in heavy elements.

Soil and vegetation pollution by the acid plant

After the closure of the acid plant which was originally planned to produce sulphuric acid from pyrite in Murgul deposit, the nature has started to heal itself but the contamination incorporated into the soil cover still persists. Soil samples were collected at two different depths, one near the surface and the other at a deeper section (in the B horizon) along two profiles constructed 750 m apart and at right angles to the direction of the escape of gases from the plant chimney.

All the elements analysed are significantly enriched near the acid plant, but Cu shows the highest anomaly contrast. Comparison of each sampled depth along the soil profile near the plant (Profile II) indicates that higher concentrations come from the near surface zone. The anomaly contrast between the near surface and deeper samples increases away from the acid plant showing the strongest effect of acid rains near the plant (Table 2). However, significant enrihments of Cu as well as other analysed elements (Pb, Zn, Cd and As) are laterally detected along the entire length (1800 m) of the soil profile II (Fig. 1).

There is a strong decrease in the concentration of elements (Cu, Pb, Zn, Cd and Fe) in samples along the Profile I further away from the plant. Through the depth of this profile there is not a significant change in the element concentrations. In fact, higher concentrations along this profile are obtained in samples from deeper zones (45-50cm deep). Such a pattern may be attributed to the normal element distribution within the soil profile and hence indicates that the element enrichment in near surface samples along the Profile II is caused by the acid rains and continues to a depth of >50cm. An enrichment factor of 9.8 times for Cu (using the mean values) from Profile I to Profile II is a further support for the increasing effects of the acid rains near the plant.

The effect of the acid rains are physical and manifest itself in the devastation of the vegetation cover. In order to prevent such an environmental contamination, the acid plant was closed in 1990. However, after eight years since the closure, the effects of acid rains still persist in the soil profile as well as in the streams around the Murgul deposit as demonstrated above. These significantly high element concentrations (especially of Cu) pose a great danger mainly to animals and human beings whose lives depend on these animals (Thornton *et al.*, 1986).

References

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