IMPACT OF DISMANTLED MINES ON WATER RESOURCES IN SARDINIA (ITALY)

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ABSTRACT

In south-western Sardinia the areas around Monteponi and Montevecchio, that once represented the heart of the former mining industry, have been investigated for the chemical deterioration of the environment. The sources of contamination have been identified mainly in the watering of the galleries and the abandonment of maintenance in the tailings dams. The mitigation of the polluting effect due to the presence of Hg, Cd, and Pb in the water and the soils may be obtained by hard and soft technologies, but it will require expensive reclamation.

INTRODUCTION

Sardinia was the most important mining region of Italy for a long time. Most of the mining activity was devoted to the exploitation of Pb, Zn, Cu, Sb, and F ores. The decline of their economic importance, which was largely a consequence of the displacement of mining activities in less developed countries, led to the abandonment of the works nearly everywhere on the island. Due to the economic difficulties faced by the last companies that owned the mines, and the lack of an environmental policy to manage the connected risk, an effective restoration of the mine areas which are at present exposed to a serious environmental hazard has not been possible.

The impact of the contamination from abandoned mine works in Sardinia is enhanced by the environmental peculiarity of the region: a semi-arid climate with few but sometimes heavy rain events, long periods of drought and heat; scarcity of shallow groundwater and of vegetable cover; and large and numerous water reservoirs to collect the runoff, which were built to meet the water demand of the island but with not enough attention to quality. This environmental scenery on the one hand, implies an easy development of the weathering processes responsible for the mobilization of the contaminants, and on the other hand degradation of the few, poor soil and water resources.

OBJECTIVES AND METHODOLOGY

This presentation must be considered as a critical review of published and unpublished data to describe the chemical contamination of the water bodies produced by the abandonment of mining activity, and to highlight the priority emergencies that the local communities and the regional government will have to face in the near future. Though all the areas involved by mining activity have been considered, our attention has been focused on the mining districts of Iglesias and Guspini-Arbus in the south-west of the island (Fig. 1), where the works were developed intensively and for longer than a century, the population density higher, and the water supply not enough.

The water bodies considered as receptors of contamination are groundwater and surface waters; the sources of pollution have been restricted to the exposed ores and waste materials filling up abandoned pits and galleries (subjected to weathering as a consequence of the rise of the water table after the cessation of dewatering systems) and to the mine tailings abandoned in the settling ponds. When only major risk sources are taken into account, situations connected with small heap leaching plants and waste rocks deposits may be neglected as well as materials transported by the wind.

IGLESIAS DISTRICT

Cessation of pumping in the Monteponi mine

Monteponi is at the centre of an area around Iglesias, where lead and zinc ores in the Lower Cambrian limestone-dolomite formations have been exploited by 40 mines spread out over 150 square kilometres. The entire underground gallery system had to be drained at a depth which increased regularly as the mine works got deeper. Between 1928 and 1990 at Monteponi, where the main drainage was installed, the water table was lowered from 15 to 160 meters below sea level. At the end of the period the mean flow rate to keep the mine dry was 1800 l/s, transported to the sea by an 8 kilometre drain which was partially underground. In the last period the isotope and element composition of the drained water indicates a marine contribution slightly higher than 60%. The mixed water was highly enriched in toxic metals. During the last years, when the flow of the drain was at the maximum, the dissolved content transferred

into the sea in tons/year was approximately 100 for zinc, 5 for lead, 2.7 for mercury, 2.5 for silver, and 0.4 for cadmium. In 1996 the main mining activity was stopped due to high exploitation costs.

If the dewatering posed as main environmental problem the flow into the sea of contaminated salt water, the watering posed to the attention the hazard that a rise of the water table could contaminate water resources at the periphery of the mining system that were used to supply the town of Iglesias (Cidu and Fanfani, 1998).

While the mobility of zinc and cadmium is always high in any oxidized environment, that of lead, mercury, and silver is significantly increased by the chloride content in the water, due to the stability of the Cl-complexes. This aspect was not fully understood nor carefully considered; consequently at the stoppage of pumping the main concern was the hazard of contamination of fresh shallow groundwater by salinization. Indeed, in the water of Campo Pisano a moderate salinization effect was actually observed (doubling of Cl, Na, SO_4, and Br dissolved amounts), but it was accompanied by a dramatic increase in zinc (from 0.4 to 4 ppm), cadmium (from 0.3 to 17 ppb), and mercury (from 2 to 10 ppb). The ongoing stratification process is expected to be completed in the next few years. This will allow to prevent the loss of fresh water resources due to salinization, though cleaning of the flooded galleries where ores and mine wastes are still contaminating the shallow groundwater will take much longer. However, controlled pumping of water from the upper flooded galleries of the Campo Pisano peripheral mine may be planned to supply water to the industrial area of Portovesme in a relatively near future.

"*Red Muds" case*

Other sources of heavy pollution in the area are the fine sediments from several abandoned flotation ponds in the valley of Rio San Giorgio, which flows into a marsh not far from the end of the Monteponi drain. A

different source is represented by the " Red Muds" dump, which marks out the landscape so deeply that it is subjected to preservation regulations as an industrial monument. It consists of metallurgical wastes from an electrolytic plant which used sulphuric acid, $FeSO_4$ and MnO_2 in the processing of Zn oxidized ores (calamines) from 1925 to the early 70's. The wastes are stored in an enormous heap, rising 40 meters, supported by cane fences on the slopes. They contain iron oxy-hydroxides mixed with Zn amounts in the range 8-10%, and calcium sulphate and minor toxic elements, such as Cd and Pb. This dump is supposed to be the main causative agent of contamination in the valley, since the runoff transfers dissolved contents of Zn and Cd in hundreds and units of ppm respectively in a nearly neutral solution to the Rio San Giorgio. Pore water in the dump exhibits contents higher than 1 ppm for Pb, Cu, Co, Ni, and Tl, besides Zn and Cd. To avoid the contamination of the Sa Masa marsh below by the Rio San Giorgio, it would be necessary to reclaim the "Red Muds" deposit by removing the less scenic part of the deposit and treating the outflowing leachate.

GUSPINI-ARBUS DISTRICT

The role of the abandoned flotation ponds

In the Montevecchio-Ingurtosu mining area, lead and zinc ores were long exploited in a system of overlapping galleries that developed for a length of 100 kilometres at a depth ranging from the surface to 600 meters underground. Approximately 3 million tons of metals were exploited from 1848 to 1991 when all mining works were stopped.

The closure of the mines was not followed by any serious attempts to minimize the impact of the former mining activity and the territory appears clearly degraded all around. Among the main sources of contamination are flotation tailings stored in sedimentation ponds now abandoned. This material, which has been subjected to instability, partially eroded in time, and transported several kilometres downstream, suffers a weathering process resulting in the leaching of toxic heavy metals (Caboi et al., 1999).

The geochemical schemes describing acid mine drainage depend on the different buffer capabilities of the rocks surrounding the ore body at the different sites. The abundance of siderite and other carbonate minerals associated with sulphides in the soutwestern area (Ingurtosu) produces a nearly neutral pH in the streamlets flowing into the sea, and dissolved lead and cadmium contents up to 0.1 and 0.5 ppm. The geochemical control in the precipitation of the metals is represented by the equilibrium with hydrozincite ($Zn_5(CO_3)_2(OH)_6$) and cerussite ($PbCO_3$) minerals, and an amorphous Zn-Si-O-H phase. All are capable of subtracting large amounts of toxic metals, such as cadmium and lead, to the water solution. In the north-eastern part of the district (Montevecchio), carbonate minerals are less abundant and buffering less efficient. The leachate emerging from the largest tailing pond is seasonally affected by dilution with pH in the range 3.6-2.7, zinc at levels of 200-400 ppm, and cobalt, nickel, cadmium, and lead with contents from 1 to 2 ppm.

In 1936 the tailings dam partially collapsed after a heavy rainstorm, and soils were heavily contaminated. A desert area is recognizable at present a few kilometres downstream from the abandoned pond. Reclamation of the area is strongly recommended to prevent toxic metals from reducing the agricultural productivity in the area downstream and further contaminating the lagoon. A soft remediation technology could be represented by adsorption, phytodepuration, and settlement of contaminants in engineered ponds.

Flooding of the mines

In the district there is another larger source of heavy metal pollution than the sediments in the abandoned ponds, since heavily polluted water flows out of a few adits and drainage tunnels.

This phenomenon already existed when the mine was active, but it became worrying shortly after closure, when most mine galleries were no longer drained by pumps and were flooded by the water infiltrated from the surface. The material used to fill in parts of the mines after they were definitely exploited is made up of fine wastes or gangue which were once economically unsuitable but now highly hazardous for their contaminating power because of the oxidation of iron and sulphur in the sulphides. This originates a low pH, high metal and sulphate contents in solution, and precipitation of a red oxy-hydroxides mud. Also in this case the pollution may be limited by the buffering effects of carbonate minerals and the temporary adsorption on iron solid phases.

The risks connected with the outflow of contaminated water from the abandoned mines were not carefully considered at closure and no strategy was prepared to reduce the impact on the environment. A significant outflow (1.5 l/s) from a mine adit east of Montevecchio with a pH of around 4 and a metal dissolved content up to 2400 ppm for zinc, 24 for cadmium, and 3 for lead (Caboi et al., 1996), which was known ever since the mine had been operating, could be good evidence of what could have occurred in other

parts of the abandoned mine system. In 1998 a large amount of water (20 l/s) with a pH of about 6 started to flow out of the shaft of Casargiu in the south-western part of the area, as soon as the natural recharge filled a large extent of the mine works. The deposition of a red mud into the beds of small streamlets, mostly dry during the year, degraded a unique desert landscape of dunes and Mediterranean vegetation reaching as far as to the sea. The quantity in tons per year of dissolved metals flowing into the sea is estimated on the basis of 1999 data (two years after the water appeared at the mine surface) 30 for zinc, 0.24 for Ni, 0.15 for Co, 0.025 for Cd and 0.001 for Pb.

Though the area is practically uninhabited, the landscape value of the area urgently requires a chemical treatment of the water in order to reduce contaminating effects.

CONCLUSIONS

The most important contamination effects as a result of the end of mining activity in south-western Sardinia are the following:

- the quality deterioration of the shallow groundwater in the peripheral areas of the Monteponi mine, which makes it impossible to exploit this resource, at least in the near future;
- the chemical contamination of the coastal marsh downstream from Rio San Giorgio, due to seepage from the tailings ponds and from the wastes of the electrolytic plant;
- the role of abandoned tailings ponds in spreading the contamination to the area of Montevecchio-Ingurtosu with different local environmental risks depending on the low or high buffering capacity of the wastes;
- the natural flooding of the abandoned galleries, which causes a red stream flowing from Casargiu directly to one of the most attractive desert beaches in Sardinia.

In all these cases, specific remediation techniques must be applied depending on the specific sources and targets. A limitation of the use of some of the environmental resources in the area may also be suggested.

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