Does Acid Mine Drainage From Coal Mining Contaminate Fertile Soils And Crops?

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In several countries like China or Vietnam, open-pit coal mining is one of the major causes of pollution (freshwater, soil or air). Indeed, overburden and acid mine drainage from coal mining contaminate soils and induce pollution and thus unproductive wastelands. Open-pit coal mining involves ore excavation which releases large quantities of spoil. Subsequent pollution with the characteristic leaching of trace metal elements (e.g., Cd, Cu, Pb or Zn), potentially toxic, occurs and is of major concern for population cultivating near mining sites. Coal mining raises particularly strong concerns, for several reasons. It is a very large-scale activity (7269 Mt were extracted worldwide in 2016) and extraction levels are increasing to meet increasing demands for electricity in many countries.

Numerous sulfides are found in these waste rock materials. These minerals may include pyrite (FeS_2), chalcopyrite ($CuFeS_2$), covellite (CuS), chalcocite (Cu_2S), galena (PbS), greenockite (CdS), or sphalerites and wurtzites [(Zn,Fe)S]. Acid mine drainage due to the oxidation of these sulfide bearing waste rock is a common environmental problem associated with coal extraction.

Pyrite oxidation is by far the more common sulfides responsible of acid mine drainage. It generates ferrous ions [Fe(II)] and then ferric ions [Fe(III)], and it is a very complex process. A general equation for this process is as follows:

$$FeS_2 + 7/2\ O_2 + H_2O \Leftrightarrow 2\ SO_4^{2-} + Fe^{2+} + 2\ H^+$$

The sulfide oxidation to sulfate solubilizes Fe(II), which is subsequently oxidized to Fe(III) as follows:

$$Fe^{2+} + \frac{1}{4}\ O_2 + H^+ \Leftrightarrow Fe^{3+} + \frac{1}{2}\ H_2O$$

Both reactions can occur spontaneously and are catalyzed by microorganisms that derive energy from oxidation reaction. Produced Fe(III) can then also oxidize additional pyrite and be reduced into Fe(II) as follows:

$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \Leftrightarrow 2\ SO_4^{2-} + 15\ Fe^{2+} + 16\ H^+$$

The main effect of these reactions is to release proton (H^+), which lowers pH and maintains Fe(III) solubility.

Acid mine drainage from coal mining thus enhances the solubility, mobilization and bioavailability of trace metal elements, potentially toxic. In such contaminated areas, colloidal and suspended particulates (present in water used to irrigate agricultural land) may further transport these trace metal elements.

Trace metal elements may have dangerous effects on staple crops' growth (e.g., rice…). They can accumulate in edible parts of these cultivated plants, posing a serious health risk to populations leaving near coal mining. Indeed, Cd, Cu and Pb could have adverse effects on wheat (*Triticum aestivum* L.) or rice (*Oryza sativa* L.) growth. Toxic metal tolerance is known in rice, sunflower, wheat and leguminous species. Such tolerance lead to an increment in metal uptake and to metal concentration in edible plant parts, posing a severe health risk for population.

In a recent study, Marquez et al. (2018) try to quantify the mobility and partitioning of trace metal elements (i.e., Cd, Cu and Pb) around coal mining activities in Vietnam. Their results highlighted that native rice plants were adjusted to growing in trace metal element contaminated soils. Although, local population is exposed to severe health risk.

Cadmiun, Pb and Cu enrichment in rice paddy soils was suggested by complimentary methods (i.e., sequential extractions and bulk chemical analyses). Lead is shown to be equally distributed between mineral and organic phases. Copper is linked with carbonates and organic matter. Smaller fractions of Pb and Cu are also associated to iron and manganese oxides. Only 25% of Cd, 9% of Pb and 48% of Cu are associated with the exchangeable fraction. This fraction is considered mobile and thus bioavailable for plant uptake. Moreover, effects of increasing trace metal element concentrations on local and control rice varieties, show marked differences in growth (e.g. Figure 1 for Pb). The local variety grew close to control values, even upon exposure to higher trace metal element concentrations. The development of the control rice variety is significantly modified by increasing trace metal element concentrations. This result suggests toxic trace metal element accumulation in the edible parts of crops occur.

Figure 1. Effect of increasing Pb concentrations (from 0 to 500 µmol/L in growth medium) on the growth of the control rice variety (Marquez et al., 2018).

These findings are described in the article:

Marquez, J., Pourret, O., Faucon, M.-P., Weber, S., Hoàng, T. and Martinez, R. (2018) Effect of Cadmium, Copper and Lead on the Growth of Rice in the Coal Mining Region of Quang Ninh, Cam-Pha (Vietnam). Sustainability 10, 1758.

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