

Mechanism of acidic water generation and leaching of heavy metals by galvanic interactions and cation substitution in iron sulfide ores

*Shusaku Kon¹, Shunsuke Shinagawa¹

1. Public Works Research Institute

Exposure of sulfide minerals contained in construction generated soil/rock to air and rain can cause leaching of naturally occurring heavy metals such as cadmium, lead, arsenic, and fluorine, as well as acidic water, which may result in environmental pollution and health hazards in the surrounding area. It is necessary to understand the source and elution mechanism of heavy metals and acidic water in order to establish appropriate evaluation methods and countermeasure construction. On the other hand, the sources and elution mechanisms of heavy metals and acidic water are often unclear because of complex interactions among different reaction rates of mineral species, chemical reactions between minerals, and elution enhancement by bacteria.

Among sulfide minerals, pyrite is the most ubiquitous mineral and is frequently mentioned as a source of arsenic leaching and acidic water. In fact, when samples are taken from areas where pyrite is distributed from naked eye observation and rainwater exposure tests are conducted, leaching of heavy metals and acidic water tend to be detected in a short period of time. It is known that the reaction rate between pyrite and water is low, so that heavy metals of pyrite origin are difficult to elute in a short period of time. However, they are easily eluted in an electrochemical environment, and their elution is accelerated in an acidic environment by the decomposition of sulfide minerals by bacteria. Therefore, it is assumed that the tendency to detect heavy metals in a short period of time is caused by either or both of these environments, but there are limited previous studies that have clearly shown or visually captured these phenomena.

To visually confirm the leaching of heavy metals and acidic water in sulfide minerals distributed in rocks, samples were taken from iron sulfide ore bodies distributed in sedimentary rocks of the Mino Belt and observed using a scanning electron microscope. The collected iron sulfide ore bodies were mainly distributed with pyrite, chalcopyrite, and arsenopyrite, and contained some sphalerite and pyrrhotite. Among the sulfide ores, the chalcopyrite in contact with the pyrite and arsenopyrite showed voids, indicating that selective dissolution of the chalcopyrite was occurring. This phenomenon is considered to be galvanic interaction, in which electrons are exchanged between minerals due to the difference in electrode potentials when different sulfide minerals are in contact, and desorption of iron ions, sulfide ions, etc. is accelerated. In this sample, the source of acidic water in this initial stage is considered to be chalcopyrite. In addition, covellite (CuS) was precipitated on the surface and along the fractures of the arsenopyrite in contact with the pore zone after the dissolution of the chalcopyrite, and copper oxide was distributed on the surface of the covellite. The precipitation of covellite indicates that copper ions leaving the chalcopyrite are replaced by iron and arsenic ions, which are cations of arsenopyrite sulfide, and contribute to the leaching of arsenic. The chalcopyrite acts as a "temporary" retarder of the leaching of arsenic in the arsenopyrite because of the selective ionic release. On the other hand, copper ions of chalcopyrite ore origin replace arsenic ions, which are cations in arsenopyrite, resulting in the leaching of arsenic. Furthermore, it is thought that the surface portion of the covellite replaced by arsenopyrite reacts with water to generate sulfate ions, eventually generating acidic water and the distribution of copper oxide, which is the "grounds" of the covellite.

In this presentation, I will discuss the sources and mechanisms of heavy metals and acidic water by showing electron microscope images that capture the leaching of chalcopyrite by galvanic interactions between sulfide minerals and the substitution of cations in arsenopyrite.

Keywords: acidic water, galvanic interaction, arsenic, pyrite, chalcopyrite, arsenopyrite