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Influence of the presence of carbon dioxide on chemical composition of water in contact with mining waste

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ABSTRACT

Nowadays post mining areas are often reclaimed and used housing areas, sports areas and recreational areas. Mining waste weathering is a significant factor influencing the condition of the surrounding water and soil environment. It is necessary then to evaluate susceptibility of the waste to weathering in given conditions and predict the rate of the processes. The paper presents initial results of an experimental study evaluating the influence of the presence of CO₂ on the composition of leachate obtained when mining waste is exposed to water. The results of the experiments confirm the importance of the oxidation of pyrite and dissolution of carbonate minerals in changing the pH of water interacting with the waste.

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1. Introduction

Until 1980s hard coal mining waste was stored mainly on the surface (heaps, dumping grounds, dumps, etc.). When legal regulations changed, a system of managing that type of waste was developed. Popular forms of waste management are: using it for land levelling, land rehabilitation, and building earthen structures. From the legal point of view these are not waste storage facilities yet their characteristics are not significantly different from the ones of mining waste dumping grounds and the waste is still stored on the surface (Dulewski, Madej, & Uzarowicz, 2010).

Nowadays, post mining areas are often reclaimed and redeveloped as housing areas, sports areas and recreational areas (Paulo, 2008). Disturbing the structure of the objects and increased migration of oxygen into the subsurface may initiate the process of oxidation of pyrite and coal contained in

the mining waste. Direct consequences of pyrite weathering are water acidification, increase in the content of sulphates and iron in water, and an increase in temperature. The consequence of coal oxidation is an increase in concentration of carbon dioxide in pore air compared with atmospheric air. The mechanism of increase in temperature in objects erected of mining waste and description of its consequences (self-ignition) are issues which have been widely discussed in the literature. Yet, the research into influence of increased content of CO₂ in pore air on the intensity of weathering of pyrite contained in mining waste is poorly understood.

2. Weathering of mining waste

Mining waste produced by hard coal mining contains mudrocks, shales, mudstones, coal shales, sandstones and,

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rarely, conglomerates and shards of hard coal. In the waste there are also smaller amounts of such minerals as: chlorite, pyrite, carbonate minerals (calcite, dolomite, siderite, ankerite), gypsum, jarosite (Skarżyńska, 1997). Chemical composition of mining waste plays an important role in creating by-products and risk of polluting the environment through leaching soluble salts like chlorides and sulphates (Twardowska, Szczepańska, & Witczak, 1988).

Rock weathering is defined as physical, chemical or biochemical decomposition of a material under influence of such factors as:

- water (with dissolved gaseous and solid substances),
- air,
- temperature (high and low temperatures),
- microorganisms (Skarżyńska, 1997; Twardowska, 1981).

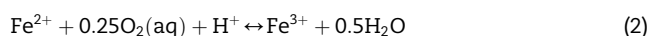
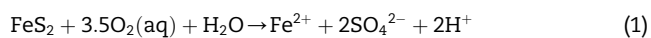
Taking into consideration composition of mining waste, the most common physico-chemical processes which occur during their weathering are:

- oxidation of sulphur compounds (pyrite, marcasite),
- dissolution of carbonate minerals (dolomite, calcite),
- dissolution of chlorides,
- ion exchange of clay minerals.

Weathering of the waste materials is a complex process with release of compounds into the aqueous environment as well as creating new secondary mineral phases (Dixon, Hossner, Senkayi, & Egashira, 1982; Jambor, Nordstrom, & Alpers, 2000; Van Breemen, 1973). It is common practice to evaluate the potential of weathering of mining waste by conducting controlled kinetic leaching tests. Both stationary tests (Ekinci, Colak, Cakici, & Sarac, 1998; Pisapia, Chaussidon, Mustin, & Humbert, 2007) and column tests are used (Kohfahl & Pekdeger, 2006; Pérez-López, Cama, Nieto, Ayora, & Saaltink, 2009). It is also useful to characterise the weathering products through the use of spectroscopic measuring techniques (Todd, Sherman, & Purton, 2003) and thermogravimetric analysis combined with analysis of the emitted gas (Thomas, Hirschausen, White, Guerbois, & Ray, 2003).

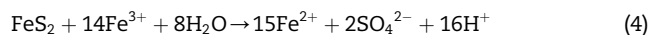
3. Pyrite weathering

Pyrite is the main form of sulphur in coal waste. Oxidation of pyrite is most often described with the following set of chemical equations (Appelo & Postma, 2005; Singer & Stumm, 1970):



As a result of oxidizing pyrite by oxygen molecules, sulphate ions, iron ions and protons are released into the solution. Ions of Fe(II) are oxidised into Fe(III) according to equation (2). At pH of over 3.5 ions of Fe(III) precipitate in form of iron hydroxide, which additionally intensifies water

environment acidification (reaction 3). At pH below 3.5 most of the ions of Fe(III) remain in the solution and are an additional oxidising factor:



Abiotic oxidation of pyrite in water environment is a relatively slow process. Extensive research is been dedicated to understanding the influence of various types of microorganisms on the catalysis of this process (Brunner et al., 2008; Hao, Murphy, Lim, Schoonen, & Strongin, 2009; Nordstrom & Southam, 1997; Pacholewska, 2007; Sasaki, Tsunekawa, Ohtsuka, & Konno, 1998; Vardanyan & Akopyan, 2003). It was shown that microorganisms can influence oxidation of pyrite directly (enzymes) or indirectly as a catalyst of oxidation reaction Fe(II) into Fe(III).

Temperature is also a significant factor. An increase in temperature, increases the rate of sulphide oxidation, especially pyrite contained in coal waste. Oxidation of pyrite is an exothermic process. If oxidation occurs in a closed system such as dumping grounds, dissipation of heat released in the process is not effective and as a consequence temperature in the system increases (Guo, Parizek, & Rose, 1994; Guo & Parizek, 1994). The role of temperature in the weathering process has been investigated by researchers in various configurations and in various locations (pure mineral, waste) for a long time.

One of the first research was conducted by Smith and Shumate (1970). The authors determined that the kinetics of oxygenation of pyrite depends on temperature, pH, partial pressure of oxygen, exposed surface, and the concentration of selected ions in the solution.

Schoonen, Elsetinow, Borda, and Strongin (2000) conducted research on the influence of temperature, illumination with sunlight and pH on oxidation of pyrite, monitoring concentrations of sulphate ions, iron ions and pH. It was noted, that coal waste is often exposed to sunlight thus the significance of such a type of tests. The rate of pyrite oxidation is strongly dependant on temperature. According to Schoonen et al. (2000) it is not possible to determine a temperature dependence of the process with Arrhenius equation because the value of activation energy depends on the type of an ion which the rate of reaction is referred to. Activation energy determined by them is between 56 and 88 kJ/mol which suggests, that the mechanisms of oxidation of sulphur and iron contained in pyrite is to a large extent independent on each other.

Wang, Bigham, and Tuovinen (2007) investigated chemical and microbiological oxidation of selected minerals in pyrite and marcasite with increasing temperature, monitoring concentration of iron ions and pH of the leachate. The authors observed that marcasite is more susceptible to extraction of iron ions. With an increase in temperature, intensity of chemical oxidation of minerals increases and the difference between the intensity rates of chemical and biological oxidation decreases. It was observed that, in spite of the fact that the process of oxidizing pyrite at increased temperature has been investigated for many years, still there are aspects which have not been fully explained. Understanding the mechanisms of sulphide minerals weathering should be useful in predicting the course of the processes in dumping grounds

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