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Acidity dynamics in mining lakes and their sediments: A hydrologic and biogeochemical process model

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The acidification of lakes stemming from strip mining of sulfidic minerals and sulphur bearing coal constitutes a pervasive environmental problem worldwide. Previous empirical work suggested that the sulphur, iron, and acidity dynamics in such systems is mainly driven by the input of ferrous iron and sulphate rich groundwaters. Subsequent oxidation leads to proton generation by deposition of ironhydroxides, such as schwertmannite and jarosite, and pH values that are typically near three in lake water and more neutral in the sediments. In the sediments acidity can be consumed by reducing processes, i.e. iron and sulphate reduction, and the sequestration of acidity in form of reduced inorganic sulphur. These processes are further subject to groundwater-surface water interactions, which modify the biogeochemical dynamics at the sediment water interface and control the material flow in such waters. We developed a system dynamics model that incorporates the interaction of the mentioned hydrological, geochemical, and biogeochemical processes and parameterized and tested it in the Lake 77, Lusatia, Germany, which has been intensively analyzed in the past. The analysis shows that the few processes considered explained the pH in lake water, the sedimentation of iron and the formation of sediments quite closely. The distribution of iron and sulphate reduction as well as pore water profiles in the sediments was influenced by groundwater seepage, which matches empirical observations. The lake water pH was quite insensitive to minor changes in the water and material balances as well as changes in neutralization processes. The model thus substantiates earlier empirical results under consideration of quantitative interactions between processes.