A FUZZY QUALITATIVE MODEL FOR THE DEFINITION OF REDOX POTENTIAL AND pH INFLUENCE IN THE AMD OF THE PODEROSA MINE SYSTEM (Iberian Pyrite Belt SW Spain)

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1. Purpose

Poderosa Mine is an abandoned pyrite mine, located in the Iberian Pyrite Belt, which discharges its acid mine drainage or AMD-polluted waters into the river Odiel. The main aim of this work focuses on establishing possible reasons for interdependence between the redox potential (EH) and pH measured in the Poderosa mining channel with a set of variables that define the physical-chemical properties of the AMD. In addition to pH and EH, the variables under study include conductivity, temperature (T), Total Dissolved Solids (TDS) and Dissolved Oxygen. Modelling is accomplished through the use of Artificial intelligence techniques, in particular Fuzzy logic and Data mining.

2. Methodology

With the aim of achieving the objective mentioned above, Sampling of water was carried out at the end of the rainy season (May 2012), and following a brief period of precipitation, when the tunnel carried a volume of water close to 10 L/s. Measuring and sampling was performed along the channel from its source to its mouth. There were a total of 16 sites, with a distance of approximately 10 meters between each pair of measuring stations. The first site was located inside the mining tunnel and the last at the mouth, in the Odiel river. Two sites were also sampled corresponding to the points where two tributaries entered the channel being studied. The point 8 corresponds to the first tributary, carrying waters from mining installations, while point 15 was located in tributary carrying water from other lower-level installations, which do not form part of the Poderosa mine. Such tributary shows characteristics that are clearly different from those of the Poderosa channel and less affected by AMD. Point 16 corresponds to the main channel under study, but located a few meters before the confluence with the less-affected tributary.

Both pH and conductivity were measured *in situ*, three consecutive times to avoid reading errors. A CRISON 507 pH-meter and a CRISON 524 conductimeter were used. The rest of the physical parameters, including Redox Potential, were measured using a Hydrolab Quanta portable probe. The equipment used to carry out the analysis of the metals was a Perkin-Elmer AAnalyst 800-model atomic absorption spectrophotometer equipped with a hydride generator and an air/acetylene flame atomizer. The sulfates were determined using ionic chromatography with chemical suppression (Standard Methods, 4110).

3. Results and Discussions

The data from the analytics were processed using the Predictive Fuzzy Rules Generator (PreFuRGe) software tool, which allows an immediate qualitative analysis of the information contained in the resulting volume of data.

Two figures were obtained, using fuzzy rule graphs: the behavior of the redox potential and pH, respectively, against the other variables corresponding to the concentrations of sulfates, Cu, Zn, Mn, Ni, Pb, As, Sb, Fe(II), Fe(III), Conductivity, TDS, T and DO. In these cases the variables pH and Redox Potential are treated as “consequents”. The universe of discourse of each variable, i.e. the values that the variables can take, has as extreme values the maximum and minimum that were obtained analytically.

In the case of Cd, Ni, Sb, TDS presents similar behavior against the variations in pH and redox potential, though inverse, i.e. when the values of pH or EH increase, the concentration of these metals decreases.

In the other hand, Fe(II), and Fe(III) and sulfates have completely inverse behavior with regard to Redox Potential and pH, increasing in concentration when Redox potential decreases and when pH increases, and remaining at medium values when redox is at an extreme low and when pH is at an extreme high. This might be explained by the fact that the extreme high pH values happen to be 3.04 and 4.0, which is the pH range at which Fe(II) oxidizes to Fe(III) and subsequently precipitates as ferric oxy-hydroxy-sulfates. The values taken by As can be explained by the sorption of As into the solid iron-rich phases. The global process includes the oxidation of Fe(II) followed by the hydrolysis and precipitation of Fe(III) and the form of schwertmannite. Further, trace elements may be sorbed and/or coprecipitated at different rates depending basically on pH, as well as on the activity of the SO_4^{2-} anion (which determines the speciation of metals).

4. Conclusions

The application of fuzzy logic techniques to characterize hydrochemical processes can not only set if a parameter is related to another, but also how they are related in terms of their development throughout the range of the variable.

The tools based on classical statistics, which are widely used in this context, prove useful for defining proximity ratios between variables based on Pearson’s correlations. Nevertheless, in addition to making it easier to handle large volumes of data and producing easier-to-understand graphs, the use of fuzzy logic tools and data mining results in better definition of the variations produced by external stimuli on the set of variables.

This fuzzy tool is adaptable and can be extrapolated to any system polluted by acid mine drainage using simple, intuitive reasoning.