Internet Case Study #9:
Contribution of Bacteria to Sulphide-Mineral Reaction Rates in Natural Environments

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Introduction

It is fascinating to hear different viewpoints about bacterial contributions to sulphide-mineral reactions in natural environments. There are many who believe bacteria greatly accelerate the rates. This view is often based on old papers like Singer and Stumm (1970) that discussed the acceleration. Unfortunately, publications that discredited much of that work, like Morth et al. (1972), are rarely mentioned or remembered. It would be enlightening to return to the older literature, like Colmer et al. (1950), to see if there were actually data showing bacterial effects or whether a cause-and-effect relationship was assumed simply because of the presence of bacteria.

This bacteria-centric view is also expressed by biohydrometallurgists, who have demonstrated the effects of *Thiobacillus ferrooxidans* in very warm, enclosed, engineered chambers. Of course, these chambers do not necessarily simulate actual in-field conditions at a minesite.

Therefore, it is worthwhile to review recent studies related to bacterial effects, to see what the latest information is saying about bacterial contributions of sulphide minerals under natural environment conditions.

There is little doubt that bacteria are present everywhere in the environment - this is well known to the medical sciences. In fact, there is actually no way to preclude or completely eradicate bacteria in minesite components, like a mined-rock pile or tailings. So the key question is whether they accelerate sulphide-mineral reaction rates under certain conditions, like within a specific pH range.

Morin and Hutt (1997) reported on a series of humidity cells, with some cells inoculated once with *T. ferrooxidans* and accompanying uninoculated replicate cells (Figure 1). While the inoculated cells showed increased reaction rates for a few weeks after inoculation, the rates inevitably returned to the uninoculated rates. This probably meant that the inoculated cells carried too many bacteria, which eventually died off and re-equilibrated to the more stable levels and rates in the uninoculated cells, which no doubt already contained *T. ferrooxidans*. This is one reason why constant inoculation of cells is not necessary and may in fact yield rates that cannot be sustained naturally.

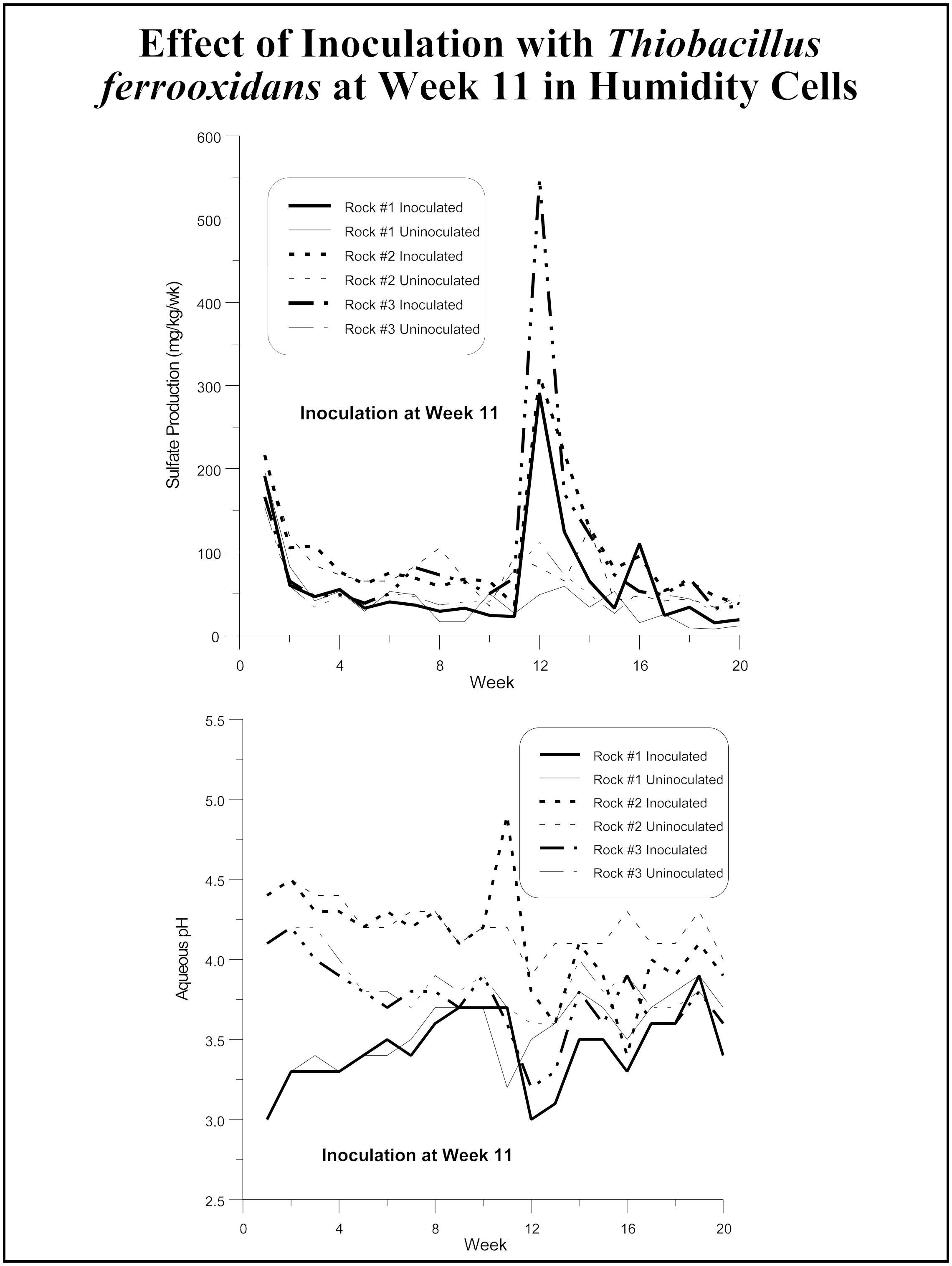

FIGURE 1. Example of Short-Term Effects from Inoculating Humidity Cells with *Thiobacillus ferrooxidans*.

Recent studies of bacterial contributions to sulphide-mineral reactions have been carried out under field conditions and in laboratories under field-like conditions (Kwong et al., 1995; Nicholson, 1994; Van Stempvoort and Krouse, 1994). These studies were conducted under sterile (abiotic) and biotic conditions, and over a large range of pH from 1 to 8. The resulting reaction rates remained relatively constant, often within a factor of two, across these ranges of conditions.

Also, Kirby and Brady (1998) measured ferrous-iron oxidation rates, which are reportedly affected by *T. ferrooxidans*, under field conditions by diverting acidic drainage into a plexiglass containing a stirrer, probes, and an aerator. Rates measured at four sites ranged from less than $1x10^{-9}$ to $3.27x10^{-6}$ mol/(L•s). However, there was no general correlation with pH, dissolved oxygen, or iron concentrations, precluding the development of a rate equation. A compilation of these rates and others from the literature (Figure 2) shows no clear trend, no close adherence to biotic or abiotic trends, and shows variations up to three orders of magnitude between two pH units.

Therefore, recent evidence is repeatedly showing that bacteria under near-natural conditions do not significantly accelerate reaction rates over abiotic conditions, nor within certain pH ranges. Why? There seem to be a number of possible explanations. For example, either (1) bacteria do not significantly affect sulphide-mineral reaction rates, (2) current technology cannot detect the actual bacterial contribution to rates, and/or (3) the bacterial effect is relatively constant across the ranges of environmental conditions.

It is important to note that there are countless bacteria of countless species, and humans have not defined most of them and their effects on the environment around them. There could be bacteria which thrive on controlling the metabolism of *T. ferrooxidans* and in effect "farm" and control it for survival. This would prevent uncontrolled acceleration of reaction rates. Interestingly, *T. ferrooxidans* often comprises less than 10% of bacterial populations in minesite components (D.W. Barr, personal communication) and thus one has to ponder what the other, more numerous bacteria are doing. Obviously they are not dormant. Perhaps some of these accompanying species can accelerate rates under conditions that are unfavourable to *T. ferrooxidans* so that no significant

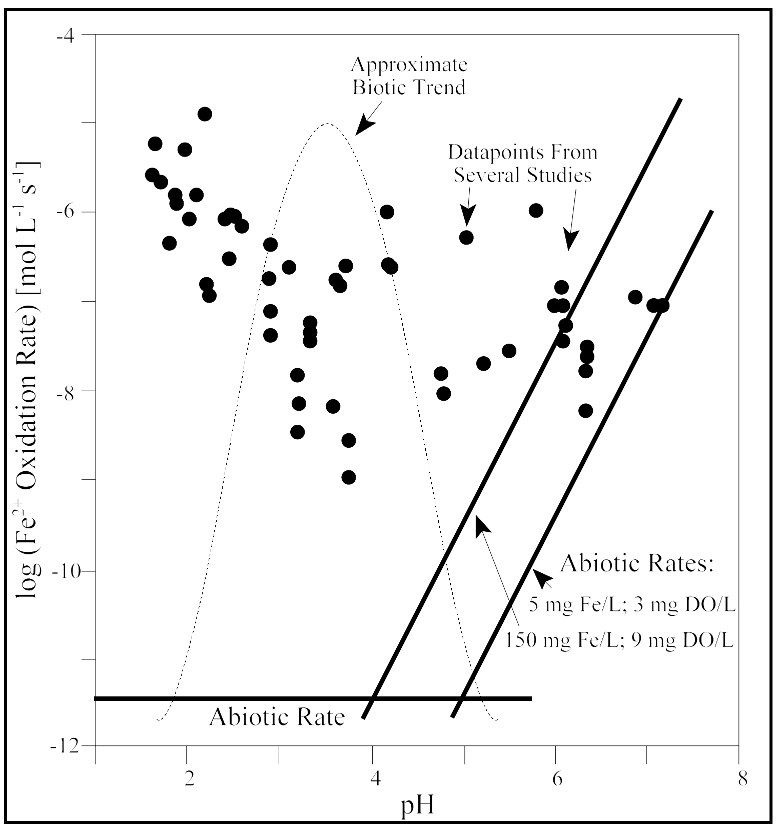

FIGURE 2. Compilation of Ferrous-Iron-Oxidation Rates (adapted from Kirby and Brady (1998).

change in rate is observed when it is inactivated.

Also, bacteria have shown a remarkable ability to adapt to changing environmental conditions. For example, one population of *T. ferooxidans* at an Arctic minesite reportedly could not even reproduce above 12ºC, although its "textbook" optimum temperature is around 30ºC (Dawson and Morin, 1996). So the contributions expected from bacteria in their textbook range could actually be occurring under very different conditions.

The actual contribution of bacteria to reaction rates of sulphide minerals and, in fact, for all minerals can be important to the assessment, prediction, and control of minesite-drainage chemistry. Fortunately, the current ambiguous situation can be simplified by noting that, whatever the bacterial contribution, it seems to be relatively constant across most natural conditions. In effect, it mimics a mathematical constant that is always present and therefore does not have to be adjusted or quantified in many cases.

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