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The Science and Non-Science of Minesite-Drainage Chemistry

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Abstract

For minesite-drainage chemistry, pre-mining predictions typically underestimate the occurrence and severity of water-quality problems upon mining. After a century of detailed studies at minesites around the world, why are we not improving from the successes and failures, from all the conferences, publications, books, and websites? After all this effort, the success of scientific predictions should at least be better than 50% from a random coin toss, but it is not. Why is this?

Mining is a major economic activity. Thus, non-scientific factors can be important, including economic, social, and political aspects. Through time, success rates above 50% (random) point to the dominant, preferred factors. Because predictions of minesite-drainage chemistry are reasonably accurate only about 25% of the time, this represents 75% success rate for non-science. Therefore, non-scientific factors are often preferred over the scientific factors.

A major problem for non-experts is that the non-scientific predictions are hidden in the guise of science, and thus non-experts believe they are given science-based predictions. Analytical procedures for minesite-drainage chemistry are typically correct. However, human interpretations often distort and "adjust" the analytical results until they are no longer reasonable and no longer reflect the results. This is a basic explanation of why pre-mining predictions often underestimate aqueous concentrations and environmental effects. This distortion-by-interpretation can only be detected by a detailed reinterpretation of analytical results, which is beyond the capability and time of non-experts. While reinterpretation can be made by an expert, the problem remains that most experts are the ones causing the dismal scientific success rate of predictions in the first place.

Until the science of minesite-drainage chemistry improves and overtakes random error and non-science, remembering the following is helpful. If a proposed minesite predicts no significant increases in aqueous concentrations after any mitigation measures, statistics show it is likely wrong about that (75% probability of being wrong). If a proposed minesite predicts no acid rock drainage (ARD) after any mitigation measures, then it has about a 50% (random) probability of being correct about that. If a minesite already has ARD, there is about a 90% probability it was predicted to have low ARD potential before it started.

1. SOME IMPORTANT DEFINITIONS AND DETAILS

Some definitions and details are a good place to start.

1.1 Minesite-Drainage Chemistry

"Minesite drainage chemistry" is a general term representing the chemistry of waters passing over or through one or more minesite components, like tailings and mining-disturbed rock. This chemistry includes parameters and elements like pH (acidic, near neutral, and alkaline), metals, nonmetals, and nitrogen species. The term also includes acid rock drainage (ARD) and acid mine drainage (AMD).

1.2 Mitigation of Minesite-Drainage Chemistry

"Mitigation" generally means the reduction of frequency, magnitude, or severity of environmental risks; abatement of potential impacts or threats; and to alleviate or to become milder. Before a minesite is built, mitigation measures can be identified, costed, and applied on and around a minesite if drainage chemistry is predicted to have unacceptably high concentrations.

The old adage, "A stitch in time saves nine", is relevant here. In this case, pre-mining prediction of drainage chemistry, with reasonable design and construction of mitigation measures, is better and can be cheaper than reactive mitigation after a water-quality problem arises and environmental damage occurs. In monetary terms, the adage can mean one dollar of good predictive work may avoid nine dollars of reactive after-the-fact mitigation and restoration (total cost of one dollar). Nowadays it would be more realistic to say: one hundred thousand dollars of reasonably accurate predictions may avoid tens of millions to billions of dollars in long-term costs and liabilities. Economically, this would be considered excellent "return on investment", but only if predictions are reasonably accurate.

The corollary of the adage, for wrong predictions, is: one dollar of poor predictive work adds one dollar onto the later cost of nine dollars of reactive after-the-fact mitigation for drainage chemistry (total cost of ten dollars). Again, realistically, the failure of pre-mining predictive work means a minesite faces the unexpected long-term costs of tens of millions to billions of dollars. You may be surprised to find this corollary frequently applies to minesites, as explained below.

1.3 The Accuracy of Prediction and Mitigation of Minesite-Drainage Chemistry

Maest et al. (2006a and 2006b) and Kuipers et al. (2006) compiled comparisons of (a) predicted drainage chemistries before mining to (b) measured drainage chemistries after mining started. They found:

- Three-quarters (75%) of mining case studies with close proximities to waters underestimated (underpredicted) drainage chemistry and thus the downstream environmental effects. This was often due to overestimation of the effectiveness of mitigation measures.

- Of minesites already with ARD, 89% were initially predicted to have low potential for ARD.

- Of the sites with low ARD potential, 44% were already acidic at time of their report. More could become acidic later due to "lag times" that delay the onset of ARD.

Converting these percentages into successes and failures of predictions (see Figure 1), we find:

1) For minesites close to water, only 25% accurately predicted, when including mitigation, drainage chemistry and environmental effects. The majority, 75%, were wrong and failed by underestimating concentrations. And 0% overpredicted concentrations. Thus, there was a strong bias towards underestimating concentrations and environmental effects.

2) For minesites already with ARD, only 11% were accurately predicted to have ARD and 89% were wrong and failed by originally predicting a low potential for ARD. Again, there was a strong bias towards underestimating concentrations and environmental effects.

3) For minesites that started with predicted low potentials for ARD, 56% (or perhaps less through time) were correct, and 44% (or perhaps more through time) were wrong. Thus, there was no strong bias towards accurate predictions or towards wrong predictions. It was almost a random 50% reliability, for the issue (ARD) often said to be the most onerous and costly that the mining industry faces.

These statistics are generally consistent with my experiences around the world over the last 32 years (e.g., Morin and Hutt, 1997).

2. SCIENCE AS A MEANS TO IMPROVE THE ACCURACY OF PRE-MINING PREDICTIONS OF DRAINAGE CHEMISTRY

When a minesite is proposed, a basic question would be, "Will this minesite adversely affect drainage chemistry and downstream water quality after it is built: yes or no?". Similar questions can be answered when an existing minesite is about to close, or when a closed minesite is being improved or re-opened.

A yes-or-no answer will have some probability of being wrong. Random, coin-toss probability would yield "yes" 50% of the time and "no" 50% of the time. So, for any minesite, the accuracy of random yes-no predictions would be 50%, and the accuracy of random predictions for a group of minesites would be 50%. With the application of science and experience, one would expect accuracy to be better than random. So why is it worse than 50% for minesite-drainage chemistry? What is going on?

Science can be generally defined as knowledge from observation, experience, or study. Science is also facts or truths arranged to show the operation of general laws.

In research fields like particle physics and quantum mechanics, science is active and critical to advancement and improvement. But what would be the opposite of science? Non-science! How can non-science be of any value or advantage?

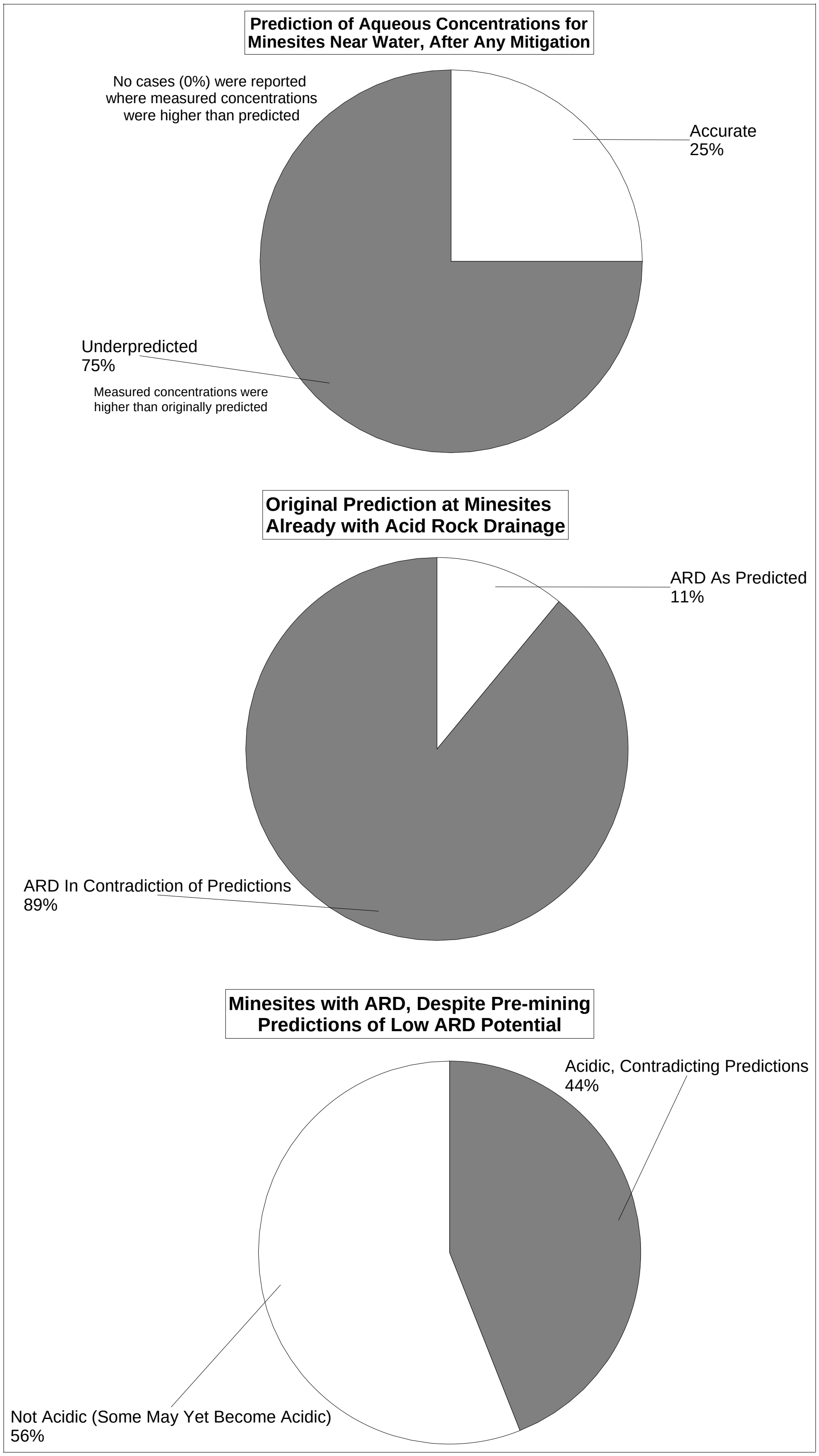

Figure 1. Three comparisons of drainage-chemistry predictions before mining, including mitigation, to measured chemistry during mining; the darker portion of each pie chart represents errors in pre-mining predictions.

For mining in general and drainage chemistry in particular, non-science can include economic and social factors, like jobs and trade, and politics. As a result, any valid scientific concern that could slow or stop a mining development may be an invalid non-science concern (see Figure 2). Also, any valid non-science prediction or mitigation can be an invalid scientific concern (a wrong prediction or wrong mitigation).

From this perspective, a scientific success rate down to 10% begins to make sense, because it represents up to a 90% non-science success rate. The direction of the increasing percentage above random 50% signifies the success of that effort. Thus, for minesite-drainage chemistry, the percentages above 50% signify the dominant success of non-science.

3. THE NON-SCIENCE OF MINESITE-DRAINAGE CHEMISTRY

At this time, a single minesite can reflect monetary investments and profits of millions to billions of dollars. As with any economic endeavour, a timely, successful, and profitable return is expected by stakeholders.

Minesite-drainage chemistry represents water quality on a minesite and, when poor, can lead to adverse environmental effects downstream and downgradient of the site. Pre-mining predictions of future poor-quality drainage chemistry, and subsequent requirements of expensive mitigation measures, can represent major monetary losses and time delays for a mining project. This can create a conflict between mining and prediction-mitigation, and between science and non-science.

Over the last century of drainage-chemistry studies and mitigation measures, we have learned much about what works and what does not at minesites around the world. This includes learning from others' mistakes, so that we do not repeat those mistakes. That is good science - that would mean prediction and mitigation should be much more than 50% accurate and reliable.

However, accuracy and reliability are less than random 50%, even after a century of learning and repeated mistakes. After a century of detailed studies, the explanation cannot be an immature science that requires more knowledge and facts to improve accuracy. Therefore, there must be strong intention behind the common scientific errors. In fact, with an accuracy as low as 25% for general drainage chemistry and 10% (for ARD minesites), there is obviously a strong driving force resulting in accuracy notably below the random error of 50%.

The explanation cannot be the lack of case studies and of experience, as hundreds of conference proceedings, books, and reports demonstrate. Are practitioners in minesite-drainage chemistry particularly prone to not learning or not improving? I think not. Would you hire someone to fix your motor vehicle if they had a success rate of 25% or less? Would you trust a medical doctor if he admitted his diagnoses were correct only 25% of the time or less?

Therefore, I conclude there has been, and continues to be, a strong preference for non-science over science in the field of minesite-drainage chemistry. This is a reasonable explanation for the ongoing, poorer-than-random, repeating errors of underestimating drainage chemistry and overestimating the effectiveness of mitigation. In this case, the failure of science represents the great success of non-science. This means that non-science has a success rate up to 90%! That is what we would expect from a dedicated, concerted effort to accomplish something.

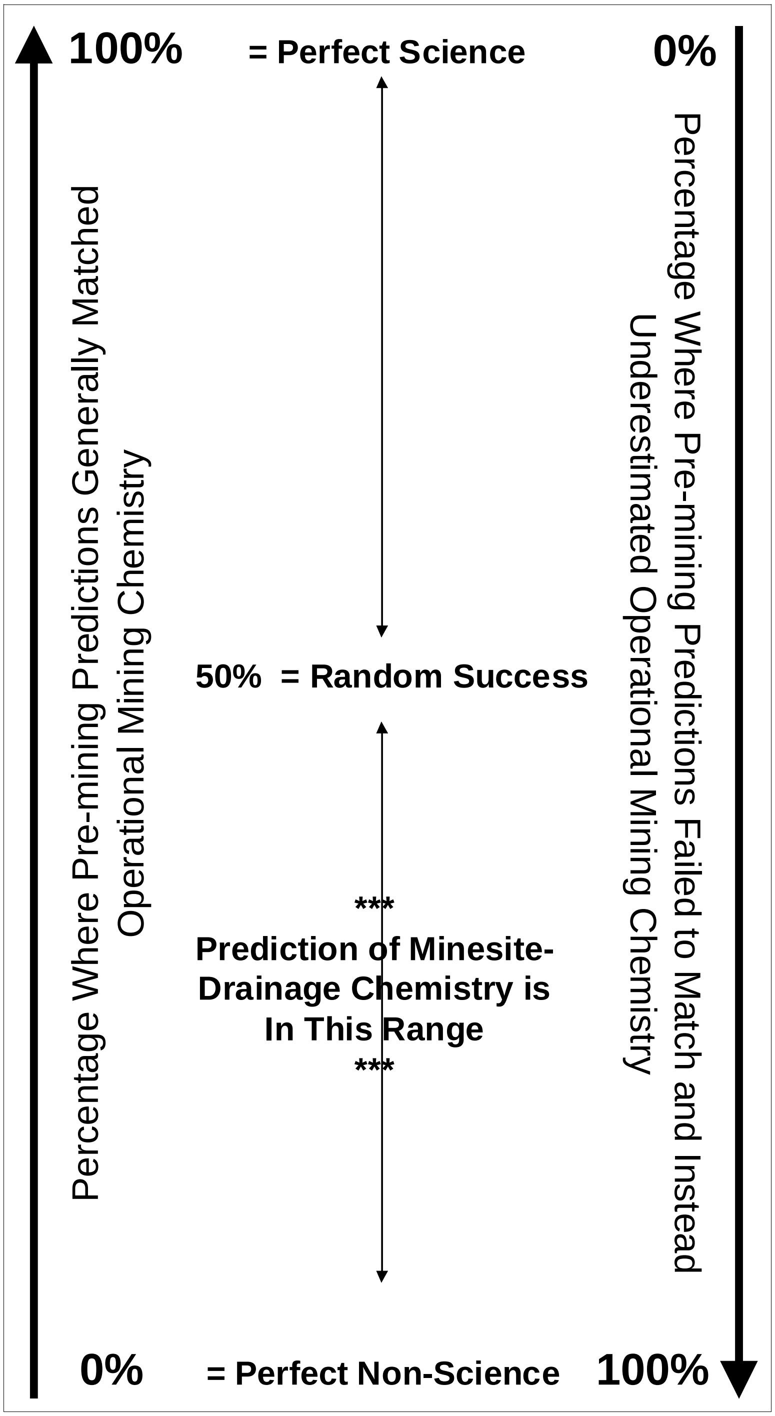

Figure 2. The diametrically opposed trends in science and non-science comparing drainage-chemistry predictions before mining to measured chemistry during mining; the failure of science is the success of non-science.

4. MITIGATION AS A JUSTIFICATION FOR NON-SCIENCE

Mitigation has been used as a "crutch", to allow for errors in predictions that underestimate aqueous concentrations and environmental effects. The rationale can be stated this way, "we will underestimate aqueous concentrations so that the minesite will be approved by stakeholders, but ensure mitigation measures are discussed to handle the problems that will likely arise." Sometimes this is carried out unconsciously, or rationalized and justified as humans do so remarkably well (explained and demonstrated by Tavris and Aronson, 2007).

The problem with this crutch is that mitigation often does not consider:

- site-specific complications that render some proposed mitigation measures not fully effective;
- high, long-term costs for effective mitigation; and,
- long times until effective mitigation is achieved.

BP's leaking oil well in the Gulf of Mexico in 2010 is a good example. Despite concerns on how well construction was increasing risks, mitigation measures were in place[1]. However, the failure of well caps and power generators meant some stated mitigation measures failed. Eventually, the mitigation measure of drilling a parallel well and plugging the leaking well succeeded. This success came only after months of time and billions of dollars in environmental and economic damage.

These problems were also recognized in mitigation for potential oil spills in Arctic waters. The Pew Charitable Trust's U.S. Arctic program found that oil-spill response plans[2]:

- fail to account for the harsh climate and remote location realistically.
- make overly optimistic assumptions about a cleanup.

Returning to mining, this explains why I have heard mining companies make statements like, "If we knew then what we know now, we would have mined this deposit differently or not at all". In many of these cases, that statement is, in effect, "If we had scientific rather than non-scientific predictions at the beginning, we would have mined this deposit differently or not at all". That is the price and fate of applying non-science at the beginning and later facing the opposing and expensive scientific reality. Failures in scientific predictions up to 90%, and thus up to 90% success of non-scientific predictions, show this approach remains the overwhelming preference.

5. HOW CAN ONE IDENTIFY SCIENCE AND NON-SCIENCE IN MINESITE-DRAINAGE CHEMISTRY?

The basic truth to spotting whether science or non-science applies to predicted drainage chemistry for a proposed minesite is: most people cannot tell. This is not due to a lack of reports, conferences, and book on the types of analytical procedures for predicting drainage chemistry. Most proposed minesites have conducted many of these procedures, such as acid-base accounting (ABA),

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[1] http://en.wikipedia.org/wiki/Deepwater_Horizon_oil_spill#Short-term_efforts ; http://thetyee.ca/CanadianPress/2010/11/08/US-Gulf-Oil-Spill-Investigation-5070439/

[2] http://sync.sympatico.ca/news/arctic_waters_vulnerable_to_oil_spill_report/d77c14d6

humidity cells, and larger-scale on-site kinetic tests (Price, 2009). Many of these have been in use for many decades. That is rarely where the problem lies.

When I have checked for predictive errors in drainage chemistry, they often lay in the human interpretations of the analytical results. Remarkably, experts have obtained analytical data showing drainage-chemistry problems, and then explained there were no significant problems by ignoring or adjusting the data. I have been truly astounded by this, and can entertain for hours by repeating these.

Within thousands of pages of an environmental assessment, I have seen major unjustified underestimations of predictions mentioned in only one sentence, and only once. If a reader missed or did not understand that one sentence in a thousand pages, as non-experts are prone to do, then the prediction error underestimating drainage chemistry would have been missed.

Therefore, one has to return to analytical data, re-interpret the data, and then compare it with the stated predictions (Figure 3). At times, new samples have to be collected and analyzed. Obviously, this requires much experience and costs much money, and is rarely done. Sometimes a company will explain it had hired national or international experts and their interpretations should be accepted. But it is these national or international experts that are creating the dismal scientific prediction record and the excellent non-scientific successes.

Until the science of minesite-drainage chemistry improves and overtakes random error and non-science, remembering the following is helpful. If a proposed minesite predicts no significant increases in aqueous concentrations after any mitigation measures, statistics show it is likely wrong about that (75% probability of being wrong). If a proposed minesite predicts no acid rock drainage (ARD) after any mitigation measures, then it has about a 50% (random) probability of being correct about that. If a minesite already has ARD, then there is about a 90% probability it was predicted to have low ARD potential before mining.

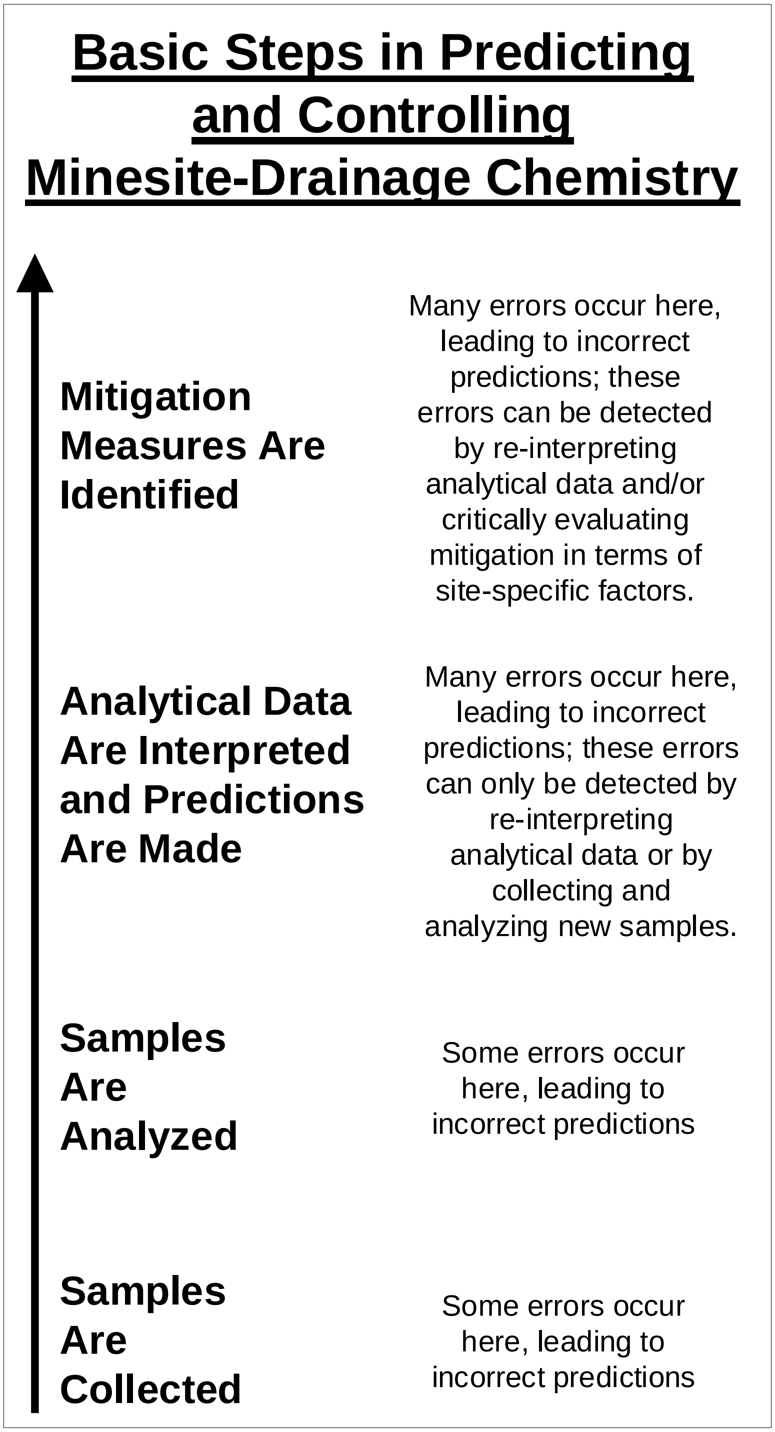

Figure 3. Basic steps in predicting and controlling minesite-drainage chemistry, with potentials for scientific errors and subsequent success for non-science.

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