Perchlorate on Mars and the Future of Subsurface Characterization and Remediation

by Scott D. Warner

Never has the role of the ground water professional, whether hydrogeologist or engineer, been as crucial as it is today. Locally, nationally, and globally, we face unprecedented challenges in, for example, the areas of (1) securing and fairly distributing clean water to human and ecosystem receptors, (2) remediating chemically impacted groundwater when less and less capital is available for the work, and (3) proving to the political and social forces in our world that we should not wait until the "well runs dry" to use scientific methods to optimize the distribution of our stressed water resources. Often it takes a historic turning point, a *watershed* event, sometimes positive, sometimes negative, to get the flywheel spinning and create the momentum for developing truly useful techniques and approaches to ground water remediation, resource protection, and water supply.

For example, the modern age of ground water remediation arguably began on August 7, 1978, when President Jimmy Carter declared a federal emergency at the infamous Love Canal in New York, marking the first time federal emergency funds were allocated for a situation not related to a natural disaster. The Comprehensive Environmental Response, Compensation, and Liability Act, commonly known as the Superfund Act, was enacted shortly thereafter by the U.S. Congress (December 11, 1980), and our industry was "born."

Almost 30 years to the day after President Carter made his Love Canal declaration, a startling but rather unheralded (at least to the public—scientists around the world were captivated) event took place that may one day be regarded as signaling a new era for the ground water remediation professional. The National Atmospheric and Space Administration (NASA) announced on August 4, 2008, that analytical results for a soil sample collected by its Phoenix Mars Lander suggested the presence of perchlorate! (The NASA release can be found online at http://www.nasa.gov/home/hqnews/2008/aug/HQ_08199_Phoenix_Results.html.)

Perchlorate is a chemical component (regardless of its cationic form) that has undergone a great deal of scrutiny in the 13 years since U.S. Senator Barbara Boxer's May 6, 1996, hearing on perchlorate in water, even though forms of the compound itself have been part of industrial processes for more than 60 years. We know that regulatory considerations for perchlorate in the second half of the 1990s and in the 2000s caused increasing scientific review, and many of us found ourselves characterizing sites for the potential presence of perchlorate in subsurface systems—on Earth, not Mars! Furthermore, ground water remediation systems began to be developed to remove perchlorate, either actively or passively, from ground water. Although a federal standard for perchlorate has not been developed, the health advisory level of 15 µg/L in drinking water issued by the U.S. Environmental Protection Agency in January 2009 confirms that our industry will be concerned with perchlorate for the foreseeable future.

Let's face it, even though a chemical we are most familiar with in terrestrial systems (its presence is mostly from humans, but some is also from natural sources) has now been discovered elsewhere in our solar system, we are not about to embark on a cleanup program for Martian soil (the Super-*Planet*-fund?). Nevertheless, I submit that this impressive laboratory feat of remotely collecting and analyzing soil samples in space, 35 million miles from us, will have a profound impact on our industry, on characterization methods as well as remediation principles. Even if it does not occur right away, it will over time.

Remote Characterization Opportunities

How many ground water remediation professionals have been faced with this question: *Is there any way to reduce the costs to characterize this site?* Or how about this question from a regulator or environmental attorney: *How do you know what subsurface conditions exist BETWEEN sampling points?*

Probably most, if not all, of us (or at least one or more of our colleagues) have been asked these questions. How do we continue to find ways to perform cost-effective, efficient characterization, and find and implement techniques that integrate information from a variety of innovative methods, *without necessarily having to drill more points or collect more samples?* The answer may lie in the application of remote sensing and related non-invasive and/or low-labor real-time characterization techniques—methods that allow for the robotic collection of physical specimens for analysis (the Mars Phoenix Lander example) and methods that allow for the collection and analysis of in situ and integrated data in real time using probes and sensors in place of collecting physical specimens for off-site laboratory analysis.

I am not suggesting that these types of data collection techniques represent new concepts for site characterization or ground water monitoring; in fact, such methods involving innovative characterization and assessment techniques have been developing for several decades and many have been successfully applied. An example of a widely accepted, easily applied method that provides useful characterization information with less intensive labor input is the membrane interface probe (MIP) technology. As many of us have discovered over the past decade, the MIP has proven effective (in cost and technical prowess) for providing real-time, multifaceted subsurface physical and chemical data when applied during ground water contamination field investigations.

Earlier discussions of applying remote sensing techniques for ground water resource evaluations by Meijerink (1996) and more recent summaries of techniques for contaminant studies by Boulding and Ginn (2003), for example, have brought forth written dialogues on several other remote sensing and characterization methods. The results of research performed by the U.S. Department of Energy, U.S. EPA, and many academic institutions on innovative characterization methods, including many new geophysical methods (cross-borehole tomography and resistivity, ground water penetrating radar, electromagnetics, even video logging that can be transmitted via telemetry) abound in the literature (e.g., National Research Council 2004). The EPA's Superfund Monitoring and Measurement Technology Verification Program and related programs (http://www.epa.gov/nerlesd1/cmb/projects.htm), for example, have also focused on developing and testing such methods. These concepts have regularly been the subject of articles in *Ground Water Monitoring and Remediation*, offering further evidence that information on the application of these methodologies is widely available to the ground water professional.

Few of these methods, however, with the exception perhaps of the MIP, have approached commonplace status (and even the greatly successful MIP system may not be used as frequently as it could be). Why have they not? Well, the development of these methods takes both time and money, and no one is asking our industry to implement a system that likely costs billions of dollars to develop and implement (the Mars Phoenix Lander example again). Perhaps there still remains some reluctance among both a large number of site owners and the regulatory community to allow these techniques to be more widely applied. Such reluctance, ironically, works against the psyche of the ground water professional who may then feel that there is little tolerance for using a method that, even if incredibly successful, is considered to not yet be demonstrated in the field to the point that site owners will spend the money to implement the tools and regulatory case workers will regularly give the use of the methods the thumbs up.

(Many of you reading this perhaps do not fall into the generalized population of owners and regulators that were the subject of the preceding paragraph. Perhaps you represent one of the groups that have allowed—and have perhaps encouraged—these techniques to be applied; if you do, I commend you—and I would like to work with you!)

Two approaches that will remedy the apparent logjam in getting more of these techniques to be used will be (1) further, and perhaps mandatory, education for regulators (from groups such as the Interstate Technology Regulatory Council [ITRC], online at www.itrcweb.org); and (2) more federal and state research funding for site owners and practitioners to apply these techniques with less risk to carry than if it were on their own dime. Expansion of the Strategic Environmental Research and Development Program (SERDP) and other government-sponsored application programs would be greatly beneficial, as would greater promotion of these programs.

Prioritizing Subsurface Remediation

So, what does the apparent detection of perchlorate on Mars really mean? For one thing, it appears to confirm that this chemical occurs in nature (a fact already proven in earth systems). For another thing, it demonstrates that remote sensing methods, even in this rather extreme example, are feasible. Really, though, it is not perchlorate and remote characterization that are the issue. Rather, it is prioritizing remediation. Obviously, we do not need to remedy all sites that are impacted by a chemical or constituent (whether the chemical source is natural or anthropogenic), particularly if the chemical promotes negligible risk to human or other receptors in its current setting. So perhaps the detection of perchlorate on Mars is someday going to be considered that watershed event that prompted us to use prioritization more appropriately in determining what sites need remediation, what sites are better left for monitoring, and even what sites need no action at all.

Many years ago, progress on prioritizing sites based on risk seemed to be gaining ground. We had various methods available for implementing risk-based corrective action strategies, and each regulatory jurisdiction was making decisions that really appeared to promote prioritization principles (e.g., the use of quantified decision analysis was beginning to take hold). Today, considering the dwindling amount of spending available for remediation projects, prioritization is crucial and we must develop consistent, effective, and nonburdensome methods by which to prioritize sites and focus on the ones that will create more risk of harm to important environmental receptors. While prioritization tools have been developed, it is not apparent to me that we have been successful in making them as readily accessible to our industry, including the regulatory and legal community, as we could. Decision optimization must be a high priority for our industry, and again, we must recognize the benefit of using venues such as the ITRC and other teaching and advocacy groups available to most states and local agencies.

As for remedial methods, the detection of perchlorate on the Red Planet does not yet lead us to the development of new cleanup technologies. True, we often find that we develop new remediation techniques through serendipitous discoveries (such as the observation during a test of well construction materials in the late 1980s at the University of Waterloo that iron metal can promote the destruction of chlorinated hydrocarbon compounds such as trichloroethylene). Perhaps the discovery of perchlorate on Mars will give us a better understanding of the environment for which this particular chemical exists, an understanding that likely will allow us to develop new methods capable of destabilizing perchlorate (as an example) so that we may continue to implement more effective (i.e., shorter-time-frame and lower-cost) remediation methods.

What Lies Ahead

While it truly is mind boggling that we were able to sample Martian soil, analyze that sample in situ, and subsequently transmit the results 35 million miles back to Earth, this article is not about either perchlorate or Mars. It is *somewhat* about the tremendous talent we have for designing and implementing "out-of-this-world" approaches. More importantly, this article is intended to encourage groups and individuals to take action.

Ground water remediation professionals are encouraged to implement new, well-thought-out ideas without fear of retribution from the public if certain methods do not achieve all intended goals the first time.

Lawmakers and industry are encouraged to contribute additional research money to private and public entities engaged in the development and testing of new characterization and remedial methods.

Regulatory agents are encouraged to continue their education pertinent to understanding new characterization and remediation tools and to actively prioritize sites based primarily on the level of risk a site poses to important receptors.

We know that our efforts to advance the development of characterization and remediation methods will continue the trend that has led to more focused, time-expedient, and resource-conservative techniques. We have come a long way since the use of large-scale ground water pumping to remove chemically impacted groundwater was commonplace, and a long way since we could rely on only a few widely spaced soil borings and groundwater wells to characterize a large, complex site. We should expect to see more and more requests to apply specialized characterization methods (as discussed previously), and more and more requests to use targeted and innovative remediation methods intended to substantially reduce risk to a site (even if *all* contaminant mass cannot effectively be removed). Finally, we could all stand to continue our education with respect to new methods, techniques, and skill building. The practitioners in our field will continue to be sought-after professionals, and we need to be ready to support stakeholders with technically effective, cost-efficient, and environmentally considerate tools and strategies intended to solve the many water resource and contaminant problems we will continue to face.

After all, we need to be ready when we are called upon to put together a cost estimate to remediate a few hundred yards of extraterrestrial soil.

References

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