Monitoring Well Integrity and Performance – What is Happening Underground?

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Abstract

High-quality, reliable groundwater analytical data are dependent upon many factors throughout the sample collection and laboratory analytical processes. Two aspects that are often overlooked include the condition and performance of the groundwater monitoring wells.

Many fossil plants have been operating for decades with groundwater monitoring networks that have been in place just as long. With new state and federal regulations for coal combustion residuals (CCR) groundwater monitoring, it may seem logical and cost effective to use existing monitoring wells “as is.” Collecting groundwater samples from monitoring wells without first performing well evaluation and maintenance may result in groundwater samples that are not representative of the aquifer being monitored. The United Stated Environmental Protection Agency (EPA) CCR Rule and many state regulations mandate reporting total (unfiltered) groundwater samples. This emphasizes the need for thorough surface and subsurface evaluations and well maintenance programs. The age of monitoring wells should also be considered as there have been advances in monitoring well installation and well construction materials resulting in more representative groundwater samples.

This paper highlights the importance of verifying well integrity and implementing a monitoring well maintenance program. Collecting groundwater samples from older monitoring wells without first performing surface and subsurface evaluations and well redevelopment may result in groundwater samples with elevated turbidity and total suspended solids (TSS) therefore, influencing the representativeness of the groundwater samples (Puls and Barcelona, 1996) may contribute to false positives of exceedances of groundwater protection standards.
Introduction

One of the most critical components of a successful monitoring program is the collection of representative groundwater samples. This not only includes the selection/installation of monitoring wells in the correct locations and depths, but also ongoing evaluation of the performance as well as surface and subsurface condition of these monitoring wells. With the implementation of The United States Environmental Protection Agency (EPA) Coal Combustion Residuals (CCR) Rule, many public utilities were required to establish groundwater monitoring networks around existing CCR units. Many fossil plants have been operating for decades and have aged groundwater monitoring networks. If these monitoring networks are currently being sampled for other programs, legacy “as is” monitoring wells should not be included in certified CCR networks without proper evaluation. The EPA CCR Rule and many state regulations mandate reporting total (unfiltered) groundwater samples. This paper evaluates the need for thorough well-maintenance programs comprised of surface and subsurface evaluations, routine well redevelopment and other performance evaluations to produce more representative and higher quality groundwater samples.

Constituents of concern for CCR units are inorganic aqueous species that, under certain geochemical conditions, can be adsorbed to nanoparticles and colloidal particles within the aquifer. Samples collected with elevated turbidity because of sediment settling within the well screen or damaged well screens have a potential for elevated concentrations of inorganic constituents. Without proper maintenance and rehabilitation programs, the condition of monitoring wells can begin to affect the quality and representativeness of samples collected.

Preliminary Evaluation of Candidate Wells for CCR Monitoring Network

Often monitoring wells in certified CCR monitoring networks were installed many years ago, prior to current installation technology, regulatory guidelines or best management practices. A first step in evaluating the representativeness of candidate wells for a CCR monitoring network is to review well completion and boring logs, determine if the monitoring wells are constructed to current standards and are completed in the water-bearing zone of interest (uppermost aquifer). Items to consider in this preliminary evaluation include the hydraulic conductivity of the zone being monitored; well screen length; well screen and backfill construction technique and materials; monitoring well diameter; and proper placement of surface casing, well seals and caps.

The determination of the appropriate water-bearing zone to be monitored is the most important decision when establishing a monitoring well network. This decision requires collaboration and careful planning with project personnel and in some cases regulatory agencies. Although this process is outside of the scope of this paper, it is important to consider the long-term implications of this decision.

Once the uppermost aquifer has been identified, existing wells screened in this zone should be evaluated. In general, hydraulic conductivities of the monitored zone should
be greater than 1.0 E-5 cm/sec vertical conductivity. The transmissivity of the material should also be considered when determining the uppermost aquifer. Well construction details should be reviewed and monitoring wells with 3.05 m (10-foot) well screens and 10.16 cm (4-inch) diameter casings should be given preference, as these tend to produce more representative groundwater samples. Water levels should be above the well screen to allow for complete well development of the sediments adjacent to the well screen. They should also provide sufficient available drawdown for hydraulic testing and low flow sampling. The last construction detail to consider is the filter pack size and placement around the well screen. Prior to the mid-1990s, filter pack material was commonly placed through drill tooling or by tremmie method (Ohio EPA, 2008). More recently, pre-packed well screens are the installation of choice. These are pre-manufactured, much easier and more efficient to install and minimize the potential for uneven placement, bridging of filter pack material or the creation of preferential flow pathways.

Make a Decision to Include or Abandon Wells in Certified CCR Networks and Establish a Maintenance and Redevelopment Program

After performing the suggested surface and subsurface evaluations, extended maintenance should be compared to the cost of installing new wells. Down-hole video logging of the monitoring wells is extremely useful in identifying subsurface damage and can give an indication of the resources necessary to rehabilitate and properly maintain the well. Review of historical field data (turbidity, oxidation-reduction potential [ORP], etc.) and analytical data, including total suspended solids (TSS), should also be included in order to gain a comprehensive understanding of the condition and performance of monitoring wells. If samples collected have consistent elevated turbidities, redevelopment should be considered or a new well should be installed (Puls and Barcelona, 1996). Older wells (defined as 25 years) should be evaluated whether their performance is adequate and they are still meeting the established design criteria (EPA, 1992). The EPA guidance also recommends abandoning monitoring wells that produce turbid samples (EPA 1992). Typically, wells with increasing turbidity are damaged or improperly completed. When this is determined to be the case, the wells should be repaired or removed from a network.

Once the well network is certified by a licensed engineer, the facility owner should set up a well maintenance and redevelopment program and periodic checks should be performed to evaluate well performance (EPA 1992). At a minimum, the following should be included in a monitoring well maintenance program:

- Surface Inspections and Maintenance
  - Condition of Well Pad to ensure that surface water cannot infiltrate the well pad
  - Condition of Protective Outer Casing and PVC Riser or Stick-up
  - Security – presence of lock
  - Condition of Sealable Well Cap
• Subsurface Inspections and Maintenance
  o Total well depth should frequently be measured to determine if sediment is accumulating in the well
  o Pump intake depth should be measured to determine if the intake could be effected by sediment accumulation
  o Downhole camera inspections should be performed to determine scaling or damaged or cracked well screen
  o Removal and inspection of dedicated pumps and tubing for buildup of iron floc and/or bacterial fouling

• Performance Testing
  o Periodic hydraulic conductivity tests (slug or pumping tests) should be performed to determine if values are decreasing.
  o Well Re-development
  o Simulated Well Purge

Program specific criteria regarding maintenance actions (primarily well re-development) must also be established in the monitoring well maintenance program. Surface and subsurface inspection activities should be established at a set frequency and thresholds should be set to trigger well rehabilitation or performance testing.

Review Field and Analytical Data to Determine Well Performance

In addition to these tests and inspections, field parameter data should be considered when evaluating monitoring well performance. Figure 1 shows the impact of different sampling methods on total mercury concentrations. The wells included in this study had not been redeveloped for a long period of time. Multiple purging and sampling techniques were performed to assess the influence on sample results. It is clear that low-flow sampling, which is widely recognized to reduce groundwater turbidity during sampling, reduced analytical results for total mercury compared to other methods. The results for mercury are generally representative of other cationic species of Appendix IV constituents. The large difference between total and dissolved concentrations in samples collected under EPA low flow purging methods is a warning that well maintenance or performance testing is needed. Sediment in the bottom of the well causes the very high total concentrations observed in the bailer method results and could cause increased total concentrations even under low flow sampling. After thorough evaluation, it was concluded that accumulation of sediment in the well sump contributed to high dissolved and total concentrations in the both sets of well samples.
Groundwater monitoring under the CCR Rule requires sampling for, and laboratory analysis of, Appendix III and IV constituents. Some of the Appendix IV constituents, such as arsenic, cobalt, cadmium and molybdenum, can be adsorbed to iron oxyhydroxide nanoparticles (Brinza, 2010). Biologically mediated oxidation-reduction reactions near stilling ponds (active or closed) have the potential to produce these nanoparticles, requiring wells with these fluctuating ORP conditions to undergo more frequent maintenance. Nanoparticles with adsorbed constituents can pass through the 0.45-micron filter normally used for “operationally defined” dissolved samples.

Anoxic groundwater in wells located very close to the waste boundary can be influenced by vertical seepage from the unit and exhibit iron floc or slime at commencement of the well purge. Unless a new, active CCR unit with a liner is being monitored, the concentrations of these constituents are extremely variable, despite the “contamination source” being at a relatively steady state. For example, as shown in Figures 2, 3 and 4, high arsenic concentrations in the sampling record of well MW-105 can be associated with turbidity and high TSS samples. Both parameters increased after a hiatus in sampling between baseline and assessment monitoring. A multivariate pairwise analysis method was performed using JMP™ software to determine correlations between constituents under ORP conditions less than zero millivolts. For the well shown in these figures and on Table 1, arsenic exhibits positive correlations of 0.56 and 0.23 to turbidity and TSS, respectively. A correlation has also been observed between TSS and
total iron of 0.64 under low ORP conditions. Types and magnitudes of correlations may vary by well location depending on whether the well has oxic or reducing conditions and the proximity to discharge areas where fines and organics have settled in stilling ponds. Finer particles and the presence of organics tend to concentrate the constituents in these areas. In some cases, frequent well redevelopment can lower these constituent concentrations in groundwater samples. At CCR sites situated along rivers, inflow of oxygenated surface water during high river stages is observed to increase ORP periodically. The phenomena of fluctuating ORP is localized to areas where low ORP conditions are subsumed by settling of fine grained materials in stilling ponds and/or native organic matter is present. In summary, the concentrations of arsenic and other constituents are influenced by the dynamic electrochemistry of changing redox conditions and adsorption as a function of pH in a dynamic system.

Figure 2. Association of arsenic with highly turbid (>5 NTU) samples

Figure 3. Arsenic concentrations correlated to high TSS in groundwater
Figure 4. Turbidity and TSS increasing after hiatus in well maintenance, performance testing, and sampling

Table 1. Pairwise correlations for MW-105

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<tr>
<th></th>
<th>TSS Arsenic Result</th>
<th>Cadmium Result</th>
<th>Cobalt Result</th>
<th>Iron Result</th>
<th>Lithium Result</th>
<th>Molybdenum Result</th>
<th>ORP Result</th>
<th>pH (Field) Result</th>
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Conclusion

The EPA CCR Rule and many state regulations mandate reporting total groundwater samples. Well maintenance programs comprised of surface and subsurface evaluations, well maintenance and performance testing can lower the possibility of collecting turbid and high TSS samples and increase the likelihood of collecting representative groundwater samples. In general, significant fluctuations in concentrations of constituents of concern could be indicators of poor well performance. While the term “false positive” is commonly associated with analytical data, it can also apply to a sample result that is unrepresentative of site conditions. Performance of surface and subsurface inspections, maintenance and well performance evaluations (including well redevelopment) prior to the occurrence of “false positives” is preferred. This eliminates the need for explanation of results that are perpetrated into a data set.
References

Brinza, L., June 2010, Interactions of molybdenum and vanadium with iron nanoparticles, Submitted in accordance with the requirements for the degree of Doctor of Philosophy. The University of Leeds, School of Earth and Environment.

