

Temporal Variability of Arsenic in Municipal Well Water

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The maximum contaminant level (MCL) for arsenic (As) in drinking water was 50 micrograms per liter ($\mu\text{g/L}$) for many years and almost all water utilities in Illinois satisfied that MCL. In 2002, the MCL was lowered to 10 $\mu\text{g/L}$ and as a result several utilities were suddenly out of compliance and had four years to get their As concentrations below the new MCL. Most options for lowering As concentrations in potable water, such as drilling a new well or installing new equipment, are expensive. Most communities with high As concentrations in their source water have small populations with limited resources and meeting the new MCL could impose a severe economic burden. Temporal variations in source-water As concentrations may determine whether a utility is in compliance. That is, a short-term As increase or “spike” at the time of compliance sampling may result in a water utility being classified as out of compliance (Type I error). On the other hand, a short-term As decrease or “dip” may make a utility seem to be in compliance when, in fact, it is not (Type II error). Temporal As variations may also influence the choice of treatment method or operational parameters.

The goal of this project was to characterize short-term temporal variability. The communities sampled were Ridgway, Kenney, Grand Ridge, and Waterman, Illinois, and Kingman, Indiana. For each facility, the well was turned off overnight. Filtered and unfiltered samples were collected within 5 minutes of turning the pump on and every 45 minutes for a period of 5 hours. Arsenic concentrations were determined by inductively coupled plasma mass spectrometry. Historical data were taken from the Groundwater Quality Database which is maintained by the Center for Groundwater Science at the Illinois State Water Survey.

Summary of Arsenic Concentrations in Some Illinois Municipal Wells							
		Arsenic Concentration ($\mu\text{g/L}$)					
Community	Well	Minimum	Maximum	Range	Median	Number of Samples	Time Span (years)
Grand Ridge	2	34	46	12	39	6	12
Kenney	1	23	70	47	38	6	13
Ridgway	1	20	120	100	65	8	9
Ridgway	2	25	140	115	80	6	7
Ridgway	3	35	90	55	83	3	5
Waterman	2	6	20	14	15	5	18
Waterman	3	0	16	16	8	7	11

Long-term As variations (years) may be due to changes in recharge which result in changing geochemical conditions. However, they may also be due to pumping history as described below for short-term changes. As the table shows, there has been considerable variation in As concentrations in some wells. At times, the Waterman wells satisfied the MCL

without the need for special treatment. On the other hand, there were times when the Ridgway treatment system would have had to remove over 90% of the As to satisfy the MCL.

Various hypotheses have been proposed to explain short-term variations in As (minutes to hours). Groundwater with high As is typically anoxic (no dissolved oxygen) with a high iron concentration. One scenario for As variation is drawdown of the water level with a change from anoxic to oxic conditions. When the pump is shut off the dissolved oxygen oxidizes the soluble iron to insoluble iron oxide and some of the As adsorbs to the iron oxide, reducing the dissolved As concentration. The water level recovers while the pump is off and anoxic groundwater returns to the area around the well screen. When the pump is turned back on for the next pumping cycle the As concentration starts out low but the low-As water is quickly flushed out of the system and the As concentration returns to its ambient level. Another scenario is that for wells with long screens, groundwater is withdrawn from zones with different geochemical conditions (and different As concentrations) during a pumping cycle.

In the Kingman test, the As concentration jumped from 40 $\mu\text{g/L}$ in the first sample to ~ 70 $\mu\text{g/L}$ in subsequent samples. This is the same behavior as in scenario 1 above. Low-As water is rapidly flushed from the system. In the Ridgway test, there was a gradual increase in As over the first 2.5 hours from 58 $\mu\text{g/L}$ to 82 $\mu\text{g/L}$. Subsequent samples had ~ 72 $\mu\text{g/L}$. The Ridgway data may have been the result of spatially variable As concentrations. Previous research at the ISWS has shown that groundwater As concentrations can vary considerably over distances of less than 1 km. In the Kenney, Grand Ridge, and Waterman tests, the As concentrations were nearly constant at 38-40, 45-48, and 13-15 $\mu\text{g/L}$, respectively.

