The results of culture-dependent and culture-independent analyses demonstrated that although there are diverse communities of microorganisms in the well during all tested phases, bacteria of the iron cycle dominate the populations during extended periods of non-pumping.

CONCLUSIONS AND RECOMMENDATIONS

This initial set of laboratory experiments leads to several preliminary conclusions about short term effects of strongly oxidizing conditions on mineral transformations and arsenic release. Exposure of St Peter sample to high chlorine solution significantly enhances sulfide oxidation (by a factor of 2) compared with oxidation by 8 mg/L O_2 in water. The patterns of As and sulfate release in the 8 mg/L O_2 water experiment suggest that As is released as a dissolved phase and is not removed by adsorption to Fe oxides over the course of the 24-hour experiment. As concentrations remained elevated under these moderately oxidizing conditions compared to those under high-chlorine treatment. This may be due to a difference in the type of Fe oxide that forms under each condition or in the rate of oxide formation.

The patterns of As, Fe and sulfate in the high chlorine experiment indicate cycling of iron and arsenic in the system. Rapid precipitation of Fe oxides followed the initial release of dissolved As and Fe, and the As released during sulfide oxidation subsequently adsorbed to the Fe oxide precipitate, effectively removing As from solution. Increases in Fe and As in solution later in the 24-hour experiment is attributed to deflocculation of the Fe oxides. In previous studies, Fe oxides have been shown to release nanoparticles to solution (Tadanier et al. 2005). These nanoparticles can easily pass through 0.2 micron filters, and their formation is significant because they can be suspended in well water. If the nanoparticles remain in association with aquifer solids, they are effectively sequestered under oxidizing conditions.

The field experiments reported on here support the conclusion that microbially facilitated reduction of arsenic-bearing iron (hydr)oxides contributes low, but regulatory significant, concentrations of arsenic to well water. Water with a longer residence time in the well tends to have higher concentrations of arsenic, iron and other trace metals such as nickel and zinc. Strongly reducing geochemical conditions develop in the well during periods of non-use. The development of lower quality well water in stagnant well water correlates with growth of DIRB and DARB microorganisms in the well.

Water quality at the test well improved under pumping conditions without chlorine treatment, and under pumping following i*n situ* disinfection with low-dose chlorine, as currently recommended by the DNR for arsenic-impacted regions of the State. Chlorine treatment caused oxidizing conditions in the well bore for less than one day, but there were no apparent detrimental affects to water quality. This finding is consistent with earlier work at this site by Sonzogni et al. (2004), which demonstrated that high-dose chlorination had no detrimental effect in this setting. In fact, effective well disinfection may reduce arsenic in well water in settings where the arsenic is a result of biogeochemical reactions that occur within the well.

Here, where the St. Peter aquifer is under confined conditions and the source of arsenic is likely reduction of Fe(hydr)oxides, short-term imposition of oxidizing conditions is unlikely to lead to arsenic release because sulfides are not the source of aqueous arsenic. In fact, effective chlorination may limit arsenic release by reducing the numbers of iron-reducing and other anaerobic bacteria. The low-dose chlorination treatment at the test well reduced the numbers of all microorganisms tested, but the populations recovered within three weeks. This suggests that either fresh formation water re-inoculated the well or that biofilm and scale in the well harbored some microbes from the disinfectant.

Taken together, this set of laboratory and field experiments do not provide scientific evidence for recommendation of low-dose well chlorination in all arsenic-impacted areas of Wisconsin. Presumably, in areas such as southeast Wisconsin, where the source of aqueous arsenic is reductive dissolution of Fe (hydr)oxides (Root et al. 2005), imposing strongly oxidizing conditions over short time periods is unlikely to exacerbate arsenic release because the source is not sulfide minerals. In this setting, high-dose chlorination may be preferable because it may be more effective in ridding the well of pathogenic and nuisance bacteria.

In northeast Wisconsin, the St. Peter sandstone aquifer contains arsenic-bearing sulfide minerals and arsenic-bearing iron oxides. The complexity and variability in arsenic geochemistry and aquifer mineralogy in this region preclude a single preferred method for well disinfection. Where the aquifer is under confined conditions, well water has very low DO, and aqueous arsenic is relatively low (about a few tens of μg/L), the source of arsenic is more likely attributable to reduction of iron hydr(oxides). Under these conditions at the test well, effectively ridding the well of Fe-reducing bacteria (though routine pumping or *in situ* chlorination) improved well water quality. In earlier work, Sonzogni et al. (2004) demonstrated that high-dose chlorination had no detrimental effect in this setting.

Where water levels in wells completed in the St. Peter aquifer suggest unconfined conditions (that is, where static water levels are close to the elevation of the top of the formation), well water is generally oxygenated, and where aqueous arsenic concentrations are relatively high, the source of aqueous arsenic is likely oxidation of arsenic-bearing sulfide minerals. The current guidelines for low-dose chlorination are appropriate in this setting. The laboratory experiments reported on here demonstrate that strongly oxidizing conditions imposed under high-dose chlorine treatment can increase the rate of sulfide oxidation. However, the experiments also indicated that strongly oxidizing conditions favor the formation of iron oxides and lead to complex cycling of iron and arsenic. These experiments were limited in nature and do not provide conclusive evidence of long-term geochemical impacts to water quality from high-dose chlorination.