

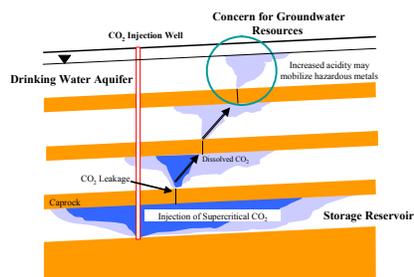


CONTAMINATION OF GROUNDWATER BY HAZARDOUS INORGANIC CHEMICAL CONSTITUENTS THROUGH INDUCED ACIDIFICATION DUE TO CO₂ LEAKAGE FROM A STORAGE FORMATION

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INTRODUCTION

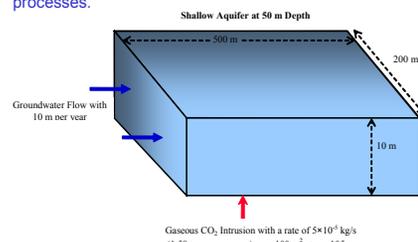
- Leakage of CO₂ from storage reservoirs into potable aquifers and its impact on the water quality is a potential concern (Wang and Jaffe, 2004).
- CO₂ dissolution in groundwater decreases pH, which can affect the solubility of minerals containing hazardous inorganic chemical constituents such as Pb, As, Hg, Sb, Se, Cu, Ni, Co, Zn, Cd, Mo, and U, and cause their concentration to increase, possibly exceeding EPA specified health based limits (HBLs) for drinking water.
- Dissolution of some chemical constituents could be further enhanced through carbonate complexation.



- Because many geochemical and hydrogeological factors can affect the dissolution and precipitation behavior of these constituents, their mobilization can be best studied through reactive geochemical transport modeling.
- We have investigated mobilization of Pb and As in an aquifer in response to CO₂ intrusion using the TOUGHREACT simulator (Xu et al., 2006).
- A large number of simulations have been performed to address sensitivities to system variables including rock mineral composition, adsorption, cation exchange, co-precipitation, reaction kinetics, hydrological properties and CO₂ flow rates.

PROBLEM SETUP

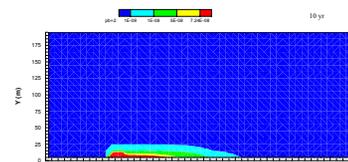
- The aquifer shown in the figure below is a simplified 2D horizontal depth-averaged bi-symmetrical model. The setup of the CO₂ intrusion problem is similar to the case studied in Wang and Jaffe (2004).
- In contrast to Wang and Jaffe (2004), we (1) considered a multi-phase flow problem, in which the intrusion of gaseous CO₂ with subsequent dissolution, (2) used measured mineralogical compositions, (3) considered sorption, cation exchange, and co-precipitation processes.



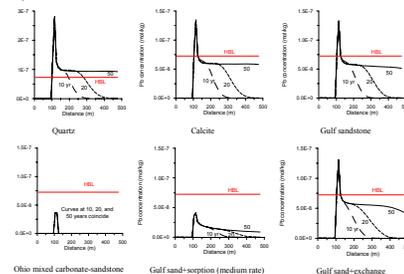
- We used the following mineralogical compositions:
 - Quartz and galena (1:1, poorly buffered; Wang and Jaffe)
 - Calcite and galena (1:1; Wang and Jaffe)
 - Gulf coast sandstone with calcite (add 1% galena)
 - Ohio mix carbonate-sandstone with dolomite and calcite (add 1% galena).
- Eighteen simulations using different combinations of mineralogy, sorption, exchange, co-precipitation, and dissolution kinetic rate were conducted to study lead (Pb) dissolution. Two simulations have been conducted to date for study of arsenic (As) leaching.

MODEL RESULTS

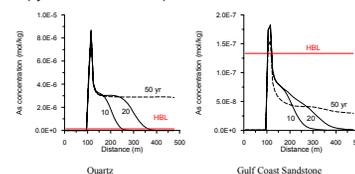
- A case with only quartz and galena results in lead concentration above the EPA HBL of 15 ppb (7.24×10^{-8} mol/L), which is consistent with Wang and Jaffe (2004). This case is the most conservative with a poorly pH-buffered mineralogy, and neglects Pb mitigating processes.



- Lead concentration profiles along x-axis at y = 0 m from some of our simulations. The spike at x = 105 m is caused by the two-phase zone.



- The predicted arsenic (As) concentrations leached from arsenopyrite have similar pattern as lead cases.



SUMMARY

- Lead concentrations due to CO₂-related dissolution can exceed HBL, provided that the aquifer is poorly buffered and conservative assumption are made.
- A relatively small calcite inventory of about 2% (Gulf Coast sandstone) provides a good buffer helping to keep pH high. The buffer capability of Ohio mixed carbonate-sandstone with both calcite and dolomite is even stronger, as increased lead concentrations are confined to the small two-phase region.
- Lead concentrations are not sensitive to plus/minus one-order-of-magnitude changes in the galena dissolution kinetics (rate). Even a 1% galena inventory provides a long-lasting source in solution.
- Current sorption model results in decreasing lead concentration below HBL. Cation exchange is less important. Our investigations on co-precipitation are ongoing.
- A limited number of arsenic simulations indicate that the pattern of its concentrations is similar to that of Pb.
- Further work includes (1) more adsorption and co-precipitation models, (2) additional mineralogies, and (3) evaluating other relevant heavy metals.
- A related poster, "Database Analysis of the Distribution of Hazardous Metals in Potable Groundwaters", is presented by Apps et al. (the same session).

REFERENCES

- Wang, S., and P.R. Jaffe, Dissolution of a mineral phase in potable aquifers due to CO₂ releases from deep formations: effect of dissolution kinetics, Energy Conversion and Management, 45(18-19), 2833-2848, 2004.
- Xu, T., E.L. Sonnenthal, N. Spycher, and K. Pruess, TOUGHREACT - A simulation program for non-isothermal multiphase reactive geochemical transport in variably saturated geologic media: Applications to geothermal injectivity and CO₂ geological sequestration, Computer & Geoscience, v. 32 p. 145-165, 2006.

ACKNOWLEDGEMENTS

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