

**CO-OCCURRENCE OF DRINKING WATER  
CONTAMINANTS LITERATURE SEARCH**

**FINAL DRAFT REPORT**

**JANUARY 27, 1999**

### Description of Literature Search

REF  
Z  
5862.7  
-W3  
C66

An automated literature search was performed using the DIALOG database search engine.  
The databases searched are listed below:

Databases	Period of Analysis	Copyright and Publisher
Ei Compendex(R)	1970-1998/Jul W2	© 1998 Engineering Info. Inc.
CAB Abstracts	1972-1998/May	© 1998 CAB International
BIOSIS PREVIEWS(R)	1969-1998/JUN W2	© 1998 BIOSIS
Water Resour. Abs.	1967-1998/Apr	© 1998 Cambridge Scientific Abs.
WATERNET(TM)	1971-1998/Q2	© 1998 American Water Works Association
Wilson Appl. Sci. & Tech. Abs.	1983-1998/May	© 1998 The HW Wilson Corporation
AGRICOLA	1970-1998/May	© format only 1998 The Dialog Corporation
Toxline(R)	1965-1998/Apr	© format only 1998 The Dialog Corporation
EMBASE	1974-1998/Jun W1	© 1998 Elsevier Science B.V.
Enviroline(R)	1975-1998/May	© 1998 Congressional Info. Service
Pollution Abs	1970-1998/May	© 1998 Cambridge Scientific Abstracts
Energy SciTec	1974-1998/May B2	© 1998 Contains copyrighted material
NTIS	64-1998/Jul W1	© Comp&distr. 1998 NTIS, Intl. Copyright All Right
GEOBASE(TM)	1980-1998/Apr	© 1998 Elsevier Science Ltd.
Pascal	1973-1998/May	© 1998 INIST/CNRS

The key words used in the literature search are shown in the list below. The numbers shown to the left of the keyword are the number of hits associated with the keyword combination. A list of titles was generated and scanned for potentially relevant articles. Abstracts were obtained for these articles. These abstracts were filtered for relevance and full articles were obtained for each pertinent document. Each of these articles was reviewed. Information was extracted into a MS Access database. A hardcopy of this database is contained in the following section of this appendix. The earlier mentioned list of key words used in the literature search are as listed below:

Search #	Number of Hits	Key Words
S1	13291	CO(1W)OCCUR? OR CO-OCCURRENCE
S2	286	S1 AND (CONTAMINANT OR POLLUTANT)
S3	25	S1 AND (DRINKING OR POTABLE)(2N)WATER
S4	11	S1 AND ANTIMONY
S5	6	S1 AND ASBESTOS
S6	12	S1 AND BARIUM
S8	39	S1 AND CADMIUM
S9	43	S1 AND CHROMIUM
S10	21	S1 AND MERCURY
S11	82	S1 AND NICKEL
S12	17	S1 AND NITRITE
S13	123	S1 AND NITRATE
S14	2	S1 AND RADIUM
S15	8	S1 AND SELENIUM
S16	1	S1 AND THALLIUM
S17	29	S1 AND CYANIDE
S18	2	S1 AND RADON
S19	37	S1 AND ARSENIC
S20	13	S1 AND RADIONUCLIDE
S21	123	S1 AND SULFATE
S22	18	S1 AND URANIUM
S23	43	S1 AND MICROBES
S24	3	S1 AND CRYPTOSPORIDIUM
S25	1	S1 AND BERYLLIUM

A hard copy of the information included in the MS Access database is contained in the following sections. The first section contains bibliographic information for the 64 articles identified. The second section contains the notes that were extracted from each article. A description of the fields for this section is listed below:

**Article ID:** Corresponds to the Article ID number in the Bibliography table.

**Notecard #:** The first two digits refer to the Article ID number for the article from which the note is extracted. The last two digits represent the order of the notes for an article.

**Topic:** Categorizes the notes according to the following general subject areas.

Constituent Species: Notes that describe the various species or oxidation states of a contaminant.

Distribution/Transport in Soil Profile: Notes that describe a contaminant's movement through the soil profile and its sorption characteristics.

Factors Affecting Geochemistry: A general category for notes that describe the hydrogeologic conditions under which a constituent is found.

Geographic Location/Distribution: Notes that describe how a constituent is distributed geographically or among media (e.g. ground water, surface water, soils, etc.)

Seasonal Variation: Notes that describe seasonal fluctuations in the concentration of a constituent.

Source(s) - Anthropogenic: Notes that describe industrial, agricultural, municipal, or other anthropogenic sources of a constituent.

Source(s) - Natural: Notes that describe mineralogic or atmospheric sources of a constituent.

Study Methodology: Notes that describe relevant data-gathering techniques.

**Constituent:** Categorizes the notes according to constituents. If a note discusses more than one constituent, this keyword will reflect the constituent that is the primary subject of the note.

**Co-Occurrence?:** This field is used to flag those notes that make specific reference to the co-occurrence of two or more species.

**Co-Occurrence Notes:** For those notes that are flagged as "co-occurrence" notes, this field contains a list of the co-occurring constituents.

## *Co-Occurrence of Drinking Water Contaminants Literature Search - Bibliography*

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### **Article ID 1**

**Author** Hanshaw, Bruce B. and William Back

**Title** Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems

**Source** William Back & D.A. Stephenson, eds. Developments in Water Science (12): Contemporary Hydrology. Elsevier Scientific Publishing Company. New York.

**Volume** 12                      **Number**                      **Date** 1979                      **Pages** 287-312

**Summary** Good diagrams showing the chemical changes associated with groundwater/marine water interactions and flows (fig. 1) and processes (biological/physical and chemical) associated with the evolution of carbonate aquifers (fig. 2).

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### **Article ID 2**

**Author** Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson

**Title** Arsenic Species as an Indicator of Redox Conditions in Groundwater

**Source** William Back & D.A. Stephenson, eds. Developments in Water Science (12): Contemporary Hydrology. Elsevier Scientific Publishing Company. New York.

**Volume** 12                      **Number**                      **Date** 1979                      **Pages** 373-392

**Summary** Editor's Notes

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### **Article ID 3**

**Author** Back, William

**Title** Geology and Groundwater Features of the Smith River Plain, Del Norte County, California

**Source** United States Government Printing Office, Washington

**Volume**                      **Number**                      **Date** 1957                      **Pages** 76 pp.

**Summary**

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### **Article ID 4**

**Author** Cowart, J.B.

**Title** Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.

**Source** William Back and Rene Letolle, eds. Symposium on Geochemistry of Groundwater. Elsevier Scientific Publishing Company: New York.

**Volume** 16                      **Number**                      **Date** 1982                      **Pages** 185-194

**Summary**

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### **Article ID 5**

**Author** Tyson, A.W., P. Bush, R. Perkins and W. Segars

**Title** Nitrate occurrence in Georgia's domestic wells

**Source** Proceedings from Clean Water-Clean Environment conference in Kansas City, Missouri, U.S.A., published by the American Society of Agricultural Engineers

**Volume** 2                      **Number**                      **Date** March 5-8, 1995                      **Pages** 231-238

**Summary**

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**Article ID 6****Author** Chen, Hsiao-wen, and Marc Edwards**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities**Source** Water Quality Technology Conference (Proceedings), Boston, MA, November 17-21, 1996**Volume**                      **Number**                      **Date** 1996                      **Pages** 17 pp.**Summary**

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**Article ID 7****Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley**Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River**Source** Water Quality Technology Conference (Proceedings), New Orleans, LA, November 12-16 1995.**Volume**                      **Number**                      **Date** 1995                      **Pages** 1587-1601**Summary**

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**Article ID 8****Author** Moore, Rhett C. and Joseph M. Fenelon**Title** Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95**Source** U.S. Geological Survey Fact Sheet 110-96, U.S. Department of the Interior, U.S. Geological Survey.**Volume**                      **Number** 110-96                      **Date** May 1996                      **Pages** 4**Summary**

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**Article ID 9****Author** Wright, Winfield G. and Catthy J. Janik**Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado**Source** U.S. Geological Survey, Fact Sheet FS-243-95**Volume**                      **Number**                      **Date** 1995                      **Pages** 4**Summary**

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**Article ID 10****Author** Pollen, Michael R. and Cindy L. Christian, Craig D. Nordgren, Jonathan D. Pollen**Title** Occurrence and Significance of Cryptosporidium parvum and Giardia lamblia in Surface Waters on Alaska's North Slope**Source** Proceedings of the 1996 8th International Conference on Cold Regions Engineering, Fairbanks, AL**Volume**                      **Number**                      **Date** August 12-16, 1996                      **Pages** 494-505**Summary**

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**Article ID 11**

**Author** Segars, William I.

**Title** Nitrates in Groundwater: Some Facts on Occurrence

**Source** Poultry Digest

**Volume** 54

**Number** 8

**Date** August 1995

**Pages** 24-25

**Summary**

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**Article ID 12**

**Author** Kolpin, Dana W. and Donald A. Goolsby

**Title** A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA

**Source** Groundwater Quality: Remediation and Protection (Proceedings of the Prague Conference, 1995). IAHS Publication No. 225.

**Volume**

**Number** 225

**Date** 1995

**Pages** 13-20

**Summary**

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**Article ID 13**

**Author** Milvy, Paul and C. Richard Cothorn

**Title** Scientific Background for the Development of Regulations for Radionuclides in Drinking Water

**Source** Chapter One of: C. Richard Cothorn and Paul Rebers, eds., Radon, Radium and Uranium in Drinking Water (USA: Lewis Publishers, Inc.)

**Volume**

**Number**

**Date** 1990

**Pages** 1-16

**Summary**

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**Article ID 30**

**Author** SAIC

**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources

**Source** SAIC, McLean, VA

**Volume**

**Number**

**Date** November 10,  
1997

**Pages** 60

**Summary**

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**Article ID 31**

**Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg

**Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data

**Source** Environmental Monitoring and Assessment

**Volume** 47

**Number** 2

**Date** September 1997

**Pages** 197-221

**Summary**

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**Article ID 32****Author** Waypa, John J., Menachem Elimelech, and Janet G. Hering**Title** Arsenic Removal by RO and NF Membranes**Source** Journal AWWA**Volume** 89**Number** 10**Date** October 1997**Pages** 102-114**Summary**

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**Article ID 33****Author** Armon, R. and Y. Kott**Title** Distribution Comparison Between Coliphages and Phages of Anaerobic Bacteria (*Bacteroides fragilis*) in Water Sources, and Their Reliability as Fecal Pollution Indicators in Drinking Water**Source** Wat Sci Tech**Volume** 31**Number** 5-6**Date** 1995**Pages** 215-222**Summary**

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**Article ID 34****Author** Wyszomirski, P. and J. Zarebski**Title** Uranium in Kaolins and Co-occurring Mining Waters of Some Lower Silesian Kaolin Pits (Poland)**Source****Volume****Number****Date****Pages** 121**Summary**

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**Article ID 35****Author** Hering, Janet G., Pen-Yuan Chen, Jennifer Wilkie, Menachem Elimelech, and Sun Liang**Title** Arsenic Removal by Ferric Chloride**Source** Journal AWWA**Volume** 88**Number** 4**Date** April 1996**Pages** 155-167**Summary**

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**Article ID 36****Author** Waypa, John J., Jennifer A. Wilkie, and Menachem Elimelech**Title** Removal of Arsenic from Water by Membrane Processes**Source** 1995 Annual Conference Proceedings; American Water Works Association; Water Research Anaheim, CA**Volume****Number****Date** June 18-22, 1995**Pages** 627-634**Summary**

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**Article ID 37**

**Author** Back, William

**Title** Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain

**Source** U.S. Department of the Interior Geological Survey Professional Paper 498-A, United States Government Printing Office

**Volume**                      **Number**                      **Date** 1966                      **Pages** 42 pp.

**Summary**

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**Article ID 38**

**Author** Back, William

**Title** Origin of Hydrochemical Facies of Ground Water in the Atlantic Coastal Plain

**Source** Chapter 9 in Benchmark Papers in Geology: Chemical Hydrogeology (William Back and R. Allan Freeze, eds.), Hutchinson Ross Publishing Company, Stroudsburg, Pennsylvania

**Volume** 73                      **Number**                      **Date**                      **Pages** 79-87

**Summary**

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**Article ID 39**

**Author** Chen, Hsiao-wen and Marc Edwards

**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities

**Source**

**Volume**                      **Number**                      **Date**                      **Pages**

**Summary**

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**Article ID 41**

**Author** SAIC

**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule

**Source** SAIC, McLean, VA

**Volume**                      **Number**                      **Date** June 1, 1998                      **Pages** 166 pp.

**Summary**

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**Article ID 42**

**Author** Boyle, R.W., and I.R. Jonasson

**Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting

**Source** Journal of Geochemical Exploration

**Volume** 2                      **Number**                      **Date** 1973                      **Pages** 251-296

**Summary**

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**Article ID 43****Author** Steinheimer, Thomas R., Kenwood D. Scoggin, and Larry A. Kramer**Title** Agricultural Chemical Movement through a Field-Size Watershed in Iowa: Subsurface Hydrology and Distribution of Nitrate in Groundwater**Source** Environmental Science & Technology**Volume** 32**Number** 8**Date** April 15, 1998**Pages** 1039-1047**Summary**

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**Article ID 44****Author** Wilkie, Jennifer A., and Janet G. Hering**Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada**Source** Environmental Science & Technology**Volume** 32**Number** 5**Date** 1998**Pages** 657-662**Summary**

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**Article ID 45****Author** Frey, Michelle M. and Marc A. Edwards**Title** Surveying Arsenic Occurrence in US Drinking Water**Source** Journal AWWA**Volume** 89**Number** 3**Date** March 1997**Pages** 105-117**Summary**

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**Article ID 46****Author** Wilkison, Donald H. and Randall D. Maley**Title** Occurrence of Herbicides, Nitrite Plus Nitrate, and Selected Trace Elements in Ground Water from Northwestern and Northeastern Missouri, July 1991 and 1992**Source** USGS Open-File Report**Volume** 94-332**Number****Date** 1994**Pages** 89 pp**Summary**

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**Article ID 47****Author** States, Stanley, Kathleen Stadterman, Louis Ammon, Paul Vogel, Julie Baldizar, Denise Wright, Louis Conley, and Jan Sykora**Title** Protozoa in River Water: Sources, Occurrence, and Treatment**Source** Journal AWWA**Volume** 89**Number** 9**Date** September 1997**Pages** 74-83**Summary**

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**Article ID 48**

**Author** Reid, Joe

**Title** Arsenic Occurrence: USEPA Seeks Clearer Picture

**Source** Journal AWWA

**Volume** 86

**Number** 9

**Date** September 1994

**Pages** 44-51

**Summary**

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**Article ID 49**

**Author** Wilkison, Donald H. and Randall D. Maley

**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94

**Source** USGS Water-Resources Investigations Report

**Volume** 96-418

**Number**

**Date** 1996

**Pages** 34pp

**Summary**

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**Article ID 50**

**Author** Black, E. Kathleen and Gordon R. Finch

**Title** Detection and Occurrence of Waterborne Bacterial and Viral Pathogens

**Source** Water Environment Research

**Volume** 66

**Number** 4

**Date** June 1994

**Pages** 292-298

**Summary**

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**Article ID 51**

**Author** Battaglin, William A. and Donald A. Goolsby

**Title** Statistical Modeling of Agricultural Chemical Occurrence in Midwestern Rivers

**Source** Journal of Hydrology

**Volume** 196

**Number**

**Date** 1997

**Pages** 1-25

**Summary**

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**Article ID 52**

**Author** Galvin, Rafael Marin

**Title** Occurrence of Metals in Waters: an Overview

**Source** Water SA

**Volume** 22

**Number** 1

**Date** January 1996

**Pages** 7-18

**Summary**

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**Article ID 53**

**Author** Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray

**Title** The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study

**Source** Ground Water Monitoring and Remediation

**Volume** 15

**Number** 1

**Date** Winter 1995

**Pages** 142-149

**Summary**

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**Article ID 54****Author** Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie**Title** Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?**Source** Environmental Geosciences**Volume** 3**Number** 3**Date** 1996**Pages** 143-153**Summary**

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**Article ID 55****Author** Flanigan, Kevin G.**Title** Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards**Source** The Water Future of Albuquerque and Middle Rio Grande Basin, Proceedings of the 39th annual New Mexico Water Conference, November 3-4, 1994, Albuquerque, New Mexico**Volume****Number****Date** 1994**Pages** 295-305**Summary**

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**Article ID 56****Author** Chapin, Charles E. and Nelia W. Dunbar**Title** A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico**Source** The Water Future of Albuquerque and Middle Rio Grande Basin, Proceedings of the 39th annual New Mexico Water Conference, November 3-4, 1994, Albuquerque, New Mexico**Volume****Number****Date** 1994**Pages** 257-276**Summary**

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**Article ID 60****Author** Bhatt, Kailash**Title** Occurrence and Distribution of Nitrate and Pesticides in Bowdle Aquifer, South Dakota**Source** Environmental Monitoring and Assessment**Volume** 47**Number** 3**Date** September 1997**Pages** 223-237**Summary**

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**Article ID 61****Author** Aceil, S.M.**Title** The Study of Naturally Occurring Radioactive Materials (NORM) in Waters of the State of Mississippi**Source** 1996 Proceedings of the 26th Mississippi Water Resources Conference**Volume****Number****Date** 1996**Pages** 295-306**Summary**

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**Article ID 62****Author** Chrstensen, Victoria G. and Larry M. Pope**Title** Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria during Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996.**Source** USGS Report No. USGS/WRI-97-4153**Volume**                      **Number**                      **Date** 1997                      **Pages****Summary**

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**Article ID 63****Author** Stackelberg, Paul E., Jessica A. Hopple, and Leon J. Kauffman**Title** Occurrence of Nitrate, Pesticides, and Volatile Organic Compounds in the Kikkwood-Cohansey Aquifer System, Southern New Jersey**Source** USGS Water Resources Investigation Report 97-4241**Volume**                      **Number**                      **Date** 1997                      **Pages****Summary**

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**Article ID 64****Author** Zeigler, Andrew C., Donald H. Wilkison, and Randall D. Maley**Title** Occurrence of Selected Pesticides, Nutrients, Selected Trace Elements, and Radionuclides, in Ground and Surface Water from West-Central Missouri - July 1990-March 1991.**Source** Open File Report - US Geological Survey**Volume**                      **Number**                      **Date** 1994                      **Pages****Summary**

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**Article ID 65****Author** Tuthill, Anna, D.B. Meikle, and Michael C.R. Alavanja**Title** Coliorm Bacteria and Nitrate Contamination of Wells in Major Soils of Frederick, Maryland**Source** Journal of Environmental Health**Volume** 60                      **Number** 8                      **Date** 1998                      **Pages** 16-20**Summary**

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**Article ID 66****Author** Moorhead, Daryl L., W. Shane Davis, and Craig F. Wolf**Title** Coliform Densities in Urban Waters of West Texas**Source** Journal of Environmental Health**Volume** 60                      **Number** 7                      **Date** 1998                      **Pages** 14-18**Summary**

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**Article ID 67****Author** Valentine, J.L.**Title** Environmental Occurrence of Selenium in Waters and Related Health Significance**Source** Biomedical and Environmental Sciences**Volume** 10**Number** 2-3**Date** 1997**Pages** 292-299**Summary**

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**Article ID 68****Author** Fan, Anna M. and Valerie E. Steinberg**Title** Health Implications of Nitrate and Nitrite in Drinking Water: An Update on Methemoglobinemia Occurrence and Reproductive and Developmental Toxicity**Source** Regulatory Toxicology and Pharmacology**Volume** 23**Number** 1, Part 1**Date** February 1996**Pages** 35-43**Summary**

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**Article ID 69****Author** Daniel, P.A., N. Dumoutier, V. Mandra, N. Tambo, and T. Kamei**Title** Cryptosporidium: a Risk Assessment**Source** Water Supply**Volume** 14**Number** 3/4**Date** 1996**Pages** 387-401**Summary**

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**Article ID 70****Author** Goolsby, D.A., W.A. Battaglin, and E.M. Thurman**Title** Occurrence and Transport of Herbicides and Nitrate in the Mississippi River During the 1993 Flood.**Source** American Water Resources Association: Responses to Changing Multiple-Use Demands: New Directions for Water Resources Planning and Management**Volume****Number****Date** April 1994**Pages****Summary** This article does not have useful co-occurrence information

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**Article ID 71****Author** Bright, D.A., M. Dodd, and K.J. Reimer**Title** Arsenic in SubArctic Lakes Influenced by Gold Mine Effluent: The Occurrence of Organoarsenicals and 'Hidden' Arsenic**Source** The Science of the Total Environment**Volume** Vol.  
180**Number** No. 2**Date** February 9, 1996**Pages****Summary**

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**Article ID 72****Author** Back, William and Ivan Barnes**Title** Relation of Electrochemical Potentials and Iron Content to Groundwater Flow Patterns**Source** Hydrology of Aquifer Systems**Volume**                      **Number**                      **Date** undated (circa 1962)                      **Pages** C1-C16**Summary**

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**Article ID 73****Author** Korte, Nic**Title** Naturally Occurring Arsenic in Groundwaters of the Midwestern United States**Source** Environ Geol Water Sci**Volume** Vol. 18                      **Number** No. 2                      **Date** 1991                      **Pages** 137-141**Summary**

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**Article ID 74****Author** Schlottmann, J.L. and G.N. Breit**Title** Mobilization of As and U in the Central Oklahoma Aquifer, USA**Source** Water Rock Interaction**Volume**                      **Number**                      **Date** 1992                      **Pages** 835-837**Summary**

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**Article ID 75****Author** Longtin, Jon P.**Title** Occurrence of Radon, Radium, and Uranium in Groundwater**Source** Journal AWWA**Volume**                      **Number**                      **Date** undated (circa 1987)                      **Pages****Summary** This article has no useful co-occurrence information.

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**Article ID 76****Author** Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes**Title** Arsenic in Ground Water of the Western United States**Source** Ground Water**Volume** 26                      **Number** 3                      **Date** May-June 1988                      **Pages** 333**Summary**

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**Article ID 77****Author** Garcia, Kerry T.**Title** Ground-Water Quality in Douglas County, Western Nevada**Source** US Geological Survey Water Resources Investigations Report 87-4269**Volume**                      **Number**                      **Date** 1987                      **Pages****Summary**

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**Article ID 78****Author** Goolsby, Donald A., R.C. Severson, S.A. Wilson, Kurt Webber**Title** Geochemistry of Soils and Shallow Ground Water, With Emphasis on Arsenic and Selenium, in Part of the Garrison Diversion Unit, North Dakota, 1985-1987**Source**

<b>Volume</b>	<b>Number</b>	<b>Date</b>	<b>Pages</b>
		unknown (circa 1989)	

**Summary**

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**Article ID 79****Author** Middelburg, R.F.**Title** Occurrence of Arsenic in the Dry Creek Basin, Sonoma County, California**Source** USGS Water Resources Investigations 76-30

<b>Volume</b>	<b>Number</b>	<b>Date</b>	<b>Pages</b>
		May 1976	

**Summary** No useful co-occurrence information found in this article.

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**Article ID 80****Author** Eccles, Lawrence A.**Title** Sources of Arsenic in Streams Tributary to Lake Crowley, California**Source** USGS Water Resources Investigations 76-36

<b>Volume</b>	<b>Number</b>	<b>Date</b>	<b>Pages</b>
		June 1976	

**Summary**

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**Article ID 81****Author** Ficklin, Walter H., David G. Frank, Paul K. Briggs, and Robert E. Tucker**Title** Analytical Results for Water, Soil, and Rocks Collected Near Granite Falls, Washington as Part of an Arsenic-in-Groundwater Study**Source** USGS Open File Report 89-148

<b>Volume</b>	<b>Number</b>	<b>Date</b>	<b>Pages</b>
		1989	

**Summary**

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**Article ID 82****Author** Welch, Alan H. and Michael S. Lico**Title** Arsenic in an Alluvial-Lacustrine Aquifer, Carson Desert, Western Nevada**Source** Metals in Ground Water

<b>Volume</b>	<b>Number</b>	<b>Date</b>	<b>Pages</b>
			E13-E18

**Summary**



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**Article ID** 83

**Author** Korte, Nic E. and Quintus Fernando

**Title** A Review of Arsenic (III) in Groundwater

**Source** Critical Reviews in Environmental Control

**Volume** 21                      **Number** 1                      **Date** 1991                      **Pages** 1-39

**Summary**

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**Article ID** 84

**Author** Michel, Jacqueline

**Title** Relationship of Radium and Radon with Geological Formations

**Source** In: Radon, Radium, and Uranium in Drinking Water, C. Richard Cothem and Paul E. Rebers, eds.

**Volume**                      **Number**                      **Date** 1990                      **Pages** 83-95

**Summary**

**Co-Occurrence of Drinking Water Contaminants Literature Search - Notes**


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<b>Article ID 1</b>	<b>Author</b> Hanshaw, Bruce B. and William Back
<b>Notecard #</b> 01-02	<b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b>	<b>Page #</b> 289-290
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** The distribution of chemical species in groundwater is not random; rather, it is controlled by all the processes and reactions of diagenesis including recrystallization, dolomitization and cementation, by structural activity, by dissolution and reprecipitation of minerals during groundwater movement, and by mass transfer of chemical species. The observed chemical character of water in carbonate aquifers is both a control on the physical parameters just mentioned and in response to them. The chemistry of groundwater is a result of the intimate relationship between mineralogy and flow regime because these determine the occurrence, sequence, rates and progress of reactions. In other words, the mineralogy of an aquifer and its groundwater geochemistry are reflected in each other and change in a systematic and generally predictable way.

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<b>Article ID 1</b>	<b>Author</b> Hanshaw, Bruce B. and William Back
<b>Notecard #</b> 01-03	<b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b> Sulfate	<b>Page #</b> 290-291
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** When carbonate sediments first emerge from the marine environment, they undergo flushing of ocean water by freshwater . . . the dissolved solids content decreases; major ions change from predominantly Na-Cl-Mg-SO<sub>4</sub> to Ca-HCO<sub>3</sub>; sediments are recrystallized, selectively dissolved, cemented and perhaps dolomitized . . .

After carbonate sediments have been transformed into a rock aquifer, many additional chemical changes occur both in groundwater and in aquifer mineralogy. In recharge areas . . . Groundwater is typically of the Ca-HCO<sub>3</sub> type. During its movement downgradient, Mg increases owing to dissolution of dolomite and high-Mg calcite while Ca remains relatively constant; SO<sub>4</sub> increases as gypsum dissolves and HCO<sub>3</sub> remains relatively constant.

(SO<sub>4</sub> concentrations shown to increase in moving from recharge water to downgradient water, decrease slightly during flushing, and decrease significantly during dolomitization (moving to marine water) as well as during the dissolution of Halite (from downgradient to brine).

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<b>Article ID 1</b>	<b>Author</b> Hanshaw, Bruce B. and William Back
<b>Notecard #</b> 01-04	<b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b>	<b>Page #</b> 292
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** Where extensive accumulations of evaporite minerals occur, their dissolution results in highly saline brines (Fig. 1 pathway D -> B). Another common pathway (D -> M) is caused by subsurface mixing of ocean water than has encroached into the deeper parts of coastal aquifers as in Florida; dedolomitization may occur under these circumstances [decreasing SO<sub>4</sub>, Ca and Mg while increasing CO<sub>3</sub>, HCO<sub>3</sub>, Na, and K].

[Dolomite - CaMg(CO<sub>3</sub>)<sub>2</sub>]

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<b>Article ID 1</b>	<b>Author</b> Hanshaw, Bruce B. and William Back
<b>Notecard #</b> 01-05	<b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b>	<b>Page #</b> 303
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** Throughout the geochemical evolution of an aquifer, reactions that result from mixing water bodies of different chemical compositions continue to be a major control on groundwater alteration processes including porosity and permeability redistribution. These reactions occur when bodies of saline and fresh water mix . . . Evidence for occurrence and progress of mixing zone reactions in the subsurface is primarily mineralogic; carbonate petrologists are now able to provide a consistent and convincing interpretation for the origin of various cements, textures and crystal morphologies. Mixing owes its significance to the non-linearity of mineral solubility as a function of variables such as salinity, partial pressure of carbon dioxide, temperature and activity (effective concentration).

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<b>Article ID 1</b>	<b>Author</b> Hanshaw, Bruce B. and William Back
<b>Notecard #</b> 01-06	<b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b>	<b>Page #</b> 304-305
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** Even without mixing, any process (e.g., changes in temperature, pH, CO<sub>2</sub> content) that alters the activity of ions will affect the equilibrium conditions of a solution relative to one or more minerals. One such process associated with the zone of dispersion is the CO<sub>2</sub> flux. Any influx of CO<sub>2</sub>, such as from root respiration, decomposition of lignite in an aquifer, or decomposition of organic material in intruding ocean water, will cause additional solution of calcite. Conversely outgassing, which commonly occurs when groundwater discharges at the surface, will prevent further solution and may, under certain conditions, cause precipitation of calcareous cements.

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<b>Article ID 1</b>	<b>Author</b> Hanshaw, Bruce B. and William Back
<b>Notecard #</b> 01-07	<b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b>	<b>Page #</b> 310
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** The opposite of dolomitization is dedolomitization which has been demonstrated by mass-transfer calculations to be an important control on the chemistry of groundwater in a Mississippian carbonate aquifer in parts of the western U.S.A. Basically, it has been found that this aquifer behaves similar to other carbonate-rock systems. The evolutionary pathways and the processes that control its chemistry of water are the same as those shown in Fig. 1 and Fig. 2. The recharge area has a high total CO<sub>2</sub> and relatively low total-dissolved solids. As groundwater moves downgradient through the aquifer it begins to dissolve calcite dolomite and gypsum from the mineralogic framework. This results in an increase in the total CO<sub>2</sub> and increases in many of the other chemical constituents, particularly SO<sub>4</sub> (-2), Ca (+2), and Mg (+2). Eventually, equilibrium with respect to calcite is attained and no more calcite is dissolved from the aquifer.

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| <b>Article ID 1</b>                         | <b>Author</b> Hanshaw, Bruce B. and William Back                                       |
| <b>Notecard #</b> 01-01                     | <b>Title</b> Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems |
| <b>Topic</b> Factors Affecting Geochemistry | <b>Date</b> 1979   |
| <b>Constituent</b>                          | <b>Page #</b> 289  |
| <b>Co-Occurrence?</b>                       | <b>Co-Occurrence Notes</b>   |
- Notes** Although some modern carbonate sediments are deposited in the deep sea, the vast bulk of carbonate deposition occurs in warm shallow (less than 12 m depth) seas in the lower latitudes. Furthermore, the final site of accumulation and initial lithification is typically in the inter- to supra-tidal zone which has often been called the "knee-deep" environment. Therefore, our discussion is limited to the carbonate products from shallow normal marine environments, and we further limited our scope by excluding the hydrology of bedded evaporites, salt deposits, and associated subsurface brines.
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| <b>Article ID 2</b>                         | <b>Author</b> Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson       |
| <b>Notecard #</b> 02-03                     | <b>Title</b> Arsenic Species as an Indicator of Redox Conditions in Groundwater |
| <b>Topic</b> Factors Affecting Geochemistry | <b>Date</b> 1979  |
| <b>Constituent</b> Arsenic                  | <b>Page #</b> 376   |
| <b>Co-Occurrence?</b> No                    | <b>Co-Occurrence Notes</b>  |
- Notes** Although conceptually the redox-pair approach to the acquisition of pE or Eh data is attractive, its applicability to natural waters has been severely restricted because of two factors: (1) many of the important redox reactions (those involving N, S, or C) are biologically mediated, with irreversibility as a characteristic feature; and (2) in the pE-pH domain of natural waters, the concentration of one of the species in a redox pair is commonly below the limits of analytical detection, for example S(2-) or HS(-) in the SO<sub>4</sub>(2-)-HS(-) pair, or Fe(3+) in the Fe(3+)-Fe(2+) pair.
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| <b>Article ID 2</b>                         | <b>Author</b> Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson       |
| <b>Notecard #</b> 02-02                     | <b>Title</b> Arsenic Species as an Indicator of Redox Conditions in Groundwater |
| <b>Topic</b> Factors Affecting Geochemistry | <b>Date</b> 1979  |
| <b>Constituent</b> Arsenic                  | <b>Page #</b> 375   |
| <b>Co-Occurrence?</b> No                    | <b>Co-Occurrence Notes</b>  |
- Notes** A second approach for measurement of the redox status of natural waters involves analysis of water samples for concentrations of two or more dissolved species containing the same element in different oxidation states. The concentrations are converted to activities using the Debye-Huckel or mean-salt relations and the pE or Eh values are obtained as indicated below . . . With these relations pE or Eh values can be calculated from the results of analytical determination of redox pairs such as SO<sub>4</sub>(2-) and HS(-) or S(2-), HCO<sub>3</sub>(-) or CO<sub>2</sub> and CH<sub>4</sub>, NO<sub>3</sub>(-) and NH<sub>4</sub>(+), Fe(3+) and Fe(2+), or Mn(IV) and Mn(II). For a system at equilibrium, computed redox levels from each of these analytical pairs have the same value.
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<b>Article ID 2</b>	<b>Author</b> Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson
<b>Notecard #</b> 02-04	<b>Title</b> Arsenic Species as an Indicator of Redox Conditions in Groundwater
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b> Arsenic	<b>Page #</b> 381
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The presence or absence of one of the As species, As(III) or As(V) species, can be used as a qualitative indication of redox levels. If only As(V) species are detected in the water, the redox level is above the As window. In this case, at pH>7, HAsO<sub>4</sub>(2-) is the dominant species of As(V) and at pH<7, H<sub>2</sub>AsO<sub>4</sub>(-) is the dominant As(V) species. At redox levels below the redox window, only As(III) species are detectable with H<sub>3</sub>AsO<sub>3</sub> being the dominant species under moderately reducing conditions and AsS<sub>2</sub>(-) being important at very low redox levels.

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<b>Article ID 2</b>	<b>Author</b> Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson
<b>Notecard #</b> 02-05	<b>Title</b> Arsenic Species as an Indicator of Redox Conditions in Groundwater
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** For As to be most useful as a redox indicator it must occur in the water at concentrations that yield a useful width for the redox window. The "maximum contaminant level" set by the USEPA (1975) for As in drinking water is 50 ug/l. From Fig. 5 it is apparent that total As concentrations well below this limit are sufficiently large to produce a redox window of significant width. In a survey of As concentrations in rivers and lakes . . . It was found that of 727 samples analysed, about 20% contained As at levels above 10 ug/l. Ferguson and Anderson (1974) also noted that As is the inorganic constituent that more commonly than any other constituent exceeds the maximum permissible limit for drinking water supplies. Because of the position of its redox window, As should generally be better suited as a redox indicator for use in groundwater than for surface water.

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<b>Article ID 2</b>	<b>Author</b> Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson
<b>Notecard #</b> 02-01	<b>Title</b> Arsenic Species as an Indicator of Redox Conditions in Groundwater
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1979
<b>Constituent</b> Arsenic	<b>Page #</b> 373
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** As a result of recent advances in analytical methods, it is now possible to determine the concentrations of both As(III) and As(V) at sufficiently low levels so that the apparent redox condition, as pE or pH, can be computed from measured concentrations of As (III) and As (V) species. The arsenic pE or Eh domain obtained using published thermodynamic data for As species and the assumption of redox equilibrium, provides a basis for obtaining an indication of redox levels within the central portion of the redox field for natural waters.

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<b>Article ID 3</b>	<b>Author</b> Back, William
<b>Notecard #</b> 03-01	<b>Title</b> Geology and Groundwater Features of the Smith River Plain, Del Norte County, California
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1957
<b>Constituent</b> Other	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Being in an area of extremely high rainfall, both the stream waters and ground waters on the Smith River plain are of low mineral concentration and are excellent for irrigation and domestic use. The only natural detrimental feature of the water is the high content of iron, found locally. Several wells in and around Crescent City have a high nitrate content. This may indicate sewage contamination, for nitrate is commonly an end product of the decomposition of organic matter. The chloride content of water contaminated by sewage also is somewhat higher than that of uncontaminated water from the same aquifer.

One of the notable contrasts between the ground water of this area and the water of most of California is the low pH values, generally ranging from 6.0 to 7.2. These low pH values are presumably due to the presence of carbonic acid from the atmosphere and vegetation and organic acids from vegetation.

Most of the waters are of the magnesium bicarbonate type. The bicarbonate ion is derived in part from carbon dioxide gas from the atmosphere dissolved in rain water. However, in general, the largest amount is from the carbon dioxide gas released by decomposition of vegetative matter. The principal source of the magnesium is the ferromagnesian minerals of the Jurassic rocks, especially serpentine.

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<b>Article ID 4</b>	<b>Author</b> Cowart, J.B.
<b>Notecard #</b> 04-03	<b>Title</b> Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.
<b>Topic</b> Constituent Species	<b>Date</b> 1982
<b>Constituent</b> Uranium	<b>Page #</b> 186
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> radium

**Notes** In addition to these elemental fractionations, separation between the two long lived uranium isotopes, U(234) and U(238), occurs commonly in groundwaters (Cherduntsev, 1971). Thus, although the ultimate parent of radium is U(238), the local source for a radium anomaly may be comprised mostly of Th(230) with little uranium, or U(234) and in-grown Th(230) with little activity, or Th(230), U(234) and U(238) in approximate equilibrium. The mix of these nuclides is a function of the history of the geochemical barrier which causes uranium precipitation.

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<b>Article ID 4</b>	<b>Author</b> Cowart, J.B.
<b>Notecard #</b> 03-02	<b>Title</b> Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.
<b>Topic</b> Constituent Species	<b>Date</b> 1982
<b>Constituent</b> Radium	<b>Page #</b> 185
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> uranium

**Notes** Uranium isotopes have been analyzed in a number of water samples from the groundwater flow system of the Cambro-Ordovician aquifers in the Tri-State region of Missouri, Kansas and Oklahoma, U.S.A. The system consists of sodium chloride water having low uranium content (~0.04 ug/l) which meets westward flowing calcium bicarbonate water having uranium content about an order of magnitude greater in a transitional zone located just to the west of the Missouri-Kansas border. In the area where the waters and then flow southwestward, H<sub>2</sub>S is commonly found in the water. Ra(226) is relatively high and uranium concentration is lower than to the east. It appears that at least part of the dissolved uranium in the westward flowing water is precipitated in the zone of mixing. Because the dissolved uranium has U(234)/U(238) activity ratio of 7-10, any precipitated uranium would have an enhanced capability for generating the daughter Ra(226). However, the distribution of uranium isotopes within the system suggests that the source of radium in the water of the transitional zone is not the inferred present-day zone of uranium accumulation but rather the brines themselves.

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**Article ID 4** **Author** Cowart, J.B.  
**Notecard #** 04-02 **Title** Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.  
**Topic** Factors Affecting Geochemistry **Date** 1982  
**Constituent** Uranium **Page #** 186  
**Co-Occurrence?** Yes **Co-Occurrence Notes** radium

**Notes** Uranium, thorium, and radium tend to fractionate because of chemical differences. Uranium tends to be mobile in oxidizing waters containing complexing bicarbonate, sulfate or phosphate anions; in reducing environments the solubility of uranium is sharply decreased and precipitation occurs. Thorium is virtually immobile under almost all surface conditions. Radium is quite mobile in high-Cl waters but in the presence of sulfate, radium is very insoluble.

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**Article ID 4** **Author** Cowart, J.B.  
**Notecard #** 04-04 **Title** Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.  
**Topic** Geographic Location/Distribution **Date** 1982  
**Constituent** Uranium **Page #** 189-190  
**Co-Occurrence?** Yes **Co-Occurrence Notes** radium

**Notes** The fresh waters of the eastern side of the area of investigation have the highest uranium concentrations (Table II). Along the eastern boundary of the transitional zone, where the freshwaters first encounter the saline H<sub>2</sub>S-bearing waters, the uranium concentration decreases abruptly. In the same general location, the radium concentration begins a progressive increase in a westward direction as does the specific electrical conductivity (Fig. 3). IN the transitional zone the uranium concentration is at least an order magnitude less than in the freshwater zone whereas the radium is about an order of magnitude greater.

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**Article ID 4** **Author** Cowart, J.B.  
**Notecard #** 04-07 **Title** Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.  
**Topic** Source(s) - Natural **Date** 1982  
**Constituent** Radium **Page #**  
**Co-Occurrence?** Yes **Co-Occurrence Notes** uranium

**Notes** This information seems to preclude the present-day precipitation site as the major source of high radium values, so we are left with several alternatives: (1) that the boundary site between the freshwater zone and the transitional zone . . . Was once further west and that it has migrated eastward in the recent geologic past, or (2) that the source of radium is the high-Cl brine . . .

The brine as the major radium source. This source must remain speculative for now as there are not appropriate samples presently available from this area although high radioactivity (presumably radium) has been reported from oil-field wells further west in Kansas (Gott and Hill, 1953) and in Oklahoma (Bloch, 1980). U-isotope analyses of brines from the Gulf of Mexico coast region indicate that the A.R. range is usually 1-2 . . . Brine from one well in Israel is reported to have A.R.'s in the range 10-12 (Kronfeld, et. Al., 1975). If the lower A.R. values are valid for Kansas brines, then the U isotopes measured as far west as locations 16 and 22 must have originated in the freshwater region and not with the high-Ra waters. Thus, in a mixing zone, various nuclides may have different sources even though the nuclides are members of the same decay series; the deciphering of such multisource systems may be best approached by isotopic rather than elemental analyses.

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**Article ID 4** **Author** Cowart, J.B.  
**Notecard #** 04-05 **Title** Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.  
**Topic** Factors Affecting Geochemistry **Date** 1982  
**Constituent** Uranium **Page #** 191  
**Co-Occurrence?** Yes **Co-Occurrence Notes** radium

**Notes** The decrease of uranium concentration, shown in Fig. 3b between locations 12 and 17 and in Fig. 3c between locations 12 and 14, is similar to that observed at other locations where oxidizing waters encounter a decrease in redox potential but the lack of an associated well-defined increase in A.R. is unusual. An increase in A.R. at a redox front has been observed in both sandstones (Cowart and Osmond, 1980) and in carbonates (Cowart, 1980). The decrease in dissolved uranium serves to locate uranium presently accumulating as a coating on the aquifer rocks.

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**Article ID 4** **Author** Cowart, J.B.  
**Notecard #** 04-06 **Title** Uranium Isotopes and Ra(226) Content in the Deep Groundwaters of the Tri-State Region, U.S.A.  
**Topic** Factors Affecting Geochemistry **Date** 1982  
**Constituent** Radium **Page #** 191  
**Co-Occurrence?** Yes **Co-Occurrence Notes** uranium

**Notes** By recoil or selective leaching modes, the A.R. in water can be increased. Direct recoil input is a function of the U(238) present where as selective leaching is strongly influenced by the relative amount of U(234) present. The amount of Ra(226) generated by such a coating is a function of the amount of U(234) (and Th(230)) present but since its geochemistry differs from uranium, the radium is not constrained to remain with the accumulation. Thus, the high-A.R. uranium precipitating at the eastern edge of the transition zone should be an efficient Ra (226) generator, assuming enough time for Th(230) in-growth has lapsed.

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**Article ID 5** **Author** Tyson, A.W., P. Bush, R. Perkins and W. Segars  
**Notecard #** 05-02 **Title** Nitrate occurrence in Georgia's domestic wells  
**Topic** Geographic Location/Distribution **Date** March 5-8, 1995  
**Constituent** Nitrate **Page #** 233  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Statewide, the average nitrate concentrations were 1.16 ppm for shallow wells and 0.48 ppm for deep wells. The Atlantic Coast Flatwoods and the Limestone Valley had the highest average concentration of nitrates in shallow wells at 3.3 ppm each. It is unclear as to whether the problem is actually significantly greater in these areas or if the result could be attributed to the relatively low number of samples received from these areas . . .

Statewide, only 0.9% of deep wells and 3.8% of shallow wells exceeded the drinking water standard.



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<b>Article ID</b> 5	<b>Author</b> Tyson, A.W., P. Bush, R. Perkins and W. Segars
<b>Notecard #</b> 05-01	<b>Title</b> Nitrate occurrence in Georgia's domestic wells
<b>Topic</b> Study Methodology	<b>Date</b> March 5-8, 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 231-232
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The University of Georgia Cooperative Extension Service . . . has offered a water testing program since the early 1980s . . . The routine analysis includes 15 mineral elements by pH and hardness. Other tests such as volatile organics, pesticide residues, and petroleum hydrocarbons are available as needed.

In 1989 the Extension Service received USDA Water Quality Initiative funds to test each sample for NO<sub>3</sub>-N in order to build a database on nitrate contamination. Since 1989 the Agriculture Services Laboratories have conducted between 3,000 and 5,000 routine water tests per year. Of these, only about 25% indicated well depth, which experience has shown to be a significant factor in predicting nitrate contamination. The data addressed in this paper include all samples collected from 1989 through 1993 for which the well depth was specified on the water analysis submission form. There were a total of 3,419 such samples.

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<b>Article ID</b> 5	<b>Author</b> Tyson, A.W., P. Bush, R. Perkins and W. Segars
<b>Notecard #</b> 05-03	<b>Title</b> Nitrate occurrence in Georgia's domestic wells
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> March 5-8, 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 233
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** From 1990 through 1994, the Georgia Environmental Protection Division conducted a similar nitrate study where they sampled 2,568 wells in South Georgia and 2,241 in North Georgia. They tested only wells which were less than 250 feet deep and did not differentiate between shallow wells and deep wells. Also, their samples were collected at random, whereas ours were submitted by clientele at their own discretion. Their results indicated a slightly higher incidence of nitrates in South Georgia than in North Georgia, which might be expected in consideration of the fact that South Georgia generally has sandier soils and has more agricultural activities than North Georgia. Statewide, their results indicated that 95% of wells had less than 5 ppm NO<sub>3</sub>-N, 4% had between 5 and 10 ppm, and 1% exceeded 10 ppm. Overall, our data indicated that 1.8% of the wells tested exceeded 10 ppm.

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<b>Article ID</b> 5	<b>Author</b> Tyson, A.W., P. Bush, R. Perkins and W. Segars
<b>Notecard #</b> 05-04	<b>Title</b> Nitrate occurrence in Georgia's domestic wells
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> March 5-8, 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 234
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** In 1994 the University of Georgia Cooperative Extension Service conducted a survey of 823 wells on farms in counties which were known to have high concentrations of livestock and poultry. Although the results have not yet been fully analyzed, they do implicate livestock and poultry operations in contributing to nitrate contamination. In this survey, 5.1% of the wells had NO<sub>3</sub>-N levels above 10 ppm and, of the wells which were used specifically for livestock and poultry, 7.5% exceeded 10 ppm.

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**Article ID 6****Notecard #** 06-07**Topic** Other**Constituent** Arsenic**Co-Occurrence?** Yes**Author** Chen, Hsiao-wen, and Marc Edwards**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities**Date** 1996**Page #** 3**Co-Occurrence Notes** sulfate

**Notes** The 90th percentile concentrations of other dissolved constituents in high As waters (total As > 2 ppb) were compared to those in low As waters (total As < 2 ppb) to explore possible relations between arsenic and co-occurring constituents (Figure 4). No apparent relations between arsenic and pH, alkalinity, or the soluble aluminum concentration were observed. Sulfate and chloride concentrations for surface waters were much higher in waters with high arsenic than in waters with low arsenic. Since some of the co-occurring constituents are of concern with respect to the U.S. secondary maximum contaminant levels (Table 4), these relations can indicate possible secondary benefits of arsenic regulation.

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**Article ID 6****Notecard #** 06-08**Topic** Other**Constituent** Arsenic**Co-Occurrence?** No**Author** Chen, Hsiao-wen, and Marc Edwards**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities**Date** 1996**Page #** 3**Co-Occurrence Notes**

**Notes** Conventional water treatment methods including coagulation, Fe-Mn oxidation, and softening can also remove arsenic. Fifty-five percent of surface waters and 74% of groundwaters investigated in this study that contained more than 5 ppb of total As would also benefit from treatment for hardness (Table 4 and Figure 5). Thus, a large fraction of utilities impacted by the proposed arsenic regulation could meet the regulation by installing softening treatment processes to also remove hardness. Fe and Mn in groundwater also pose a water quality concern, and 61% of high arsenic groundwaters (total As > 5 ppb) also exceeded either the secondary Fe or Mn MCL (Table 4 and Figures 6 and 7). Consequently, this treatment process could also be installed with multiple benefits at many utilities in response to an arsenic regulation.

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**Article ID 6****Notecard #** 06-09**Topic** Other**Constituent** Arsenic**Co-Occurrence?** Yes**Author** Chen, Hsiao-wen, and Marc Edwards**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities**Date** 1996**Page #** 4**Co-Occurrence Notes** sulfate

**Notes** The selection of advanced arsenic removal technology is strongly dependent on the concentrations of co-occurring species in the influent. For example, sulfate is expected to control run length for anion exchange (Figure 8), which is deemed "nonviable" for arsenic removal when raw water sulfate concentrations are greater than 120 ppm. On this basis, anion exchange is not a feasible option for arsenic removal (total As > 5 ppb) (Figure 8). This will drive up costs of the arsenic regulation since anion exchange cannot be applied at many utilities with high arsenic.

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**Article ID 6** **Author** Chen, Hsiao-wen, and Marc Edwards  
**Notecard #** 06-03 **Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Topic** Source(s) - Anthropogenic **Date** 1996  
**Constituent** Arsenic **Page #** 1  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Mining activities expose arsenic-containing coals or ores, and smelting processes discharge arsenic wastes into natural water systems. Arsenic can also be introduced to the environment through application of arsenical pesticides.

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**Article ID 6** **Author** Chen, Hsiao-wen, and Marc Edwards  
**Notecard #** 06-05 **Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Topic** Other **Date** 1996  
**Constituent** Arsenic **Page #** 2  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Only one out of 189 surface water samples exceeded the current Arsenic MCL while four out of 239 groundwater samples did so. If the arsenic MCL were lowered to 2 ppb, more than 28% of the sampled utilities would exceed the standard.

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**Article ID 6** **Author** Chen, Hsiao-wen, and Marc Edwards  
**Notecard #** 06-06 **Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Topic** Other **Date** 1996  
**Constituent** Arsenic **Page #** 2-3  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Particulate As was more significant than previously suspected and more dominant in groundwater than in surface water. In fact, 16% of the groundwater utilities could achieve 90% arsenic removal simply by filtering particulate As from the raw water. In contrast, surface water utilities could only achieve 80% As removal by filtration at maximum. Coagulation, softening, or anion exchange removes As(V), which was more than half the total arsenic in 40% of the surface waters and ground waters. As(III), the most toxic and difficult to treat soluble arsenic species, dominated (>50% of the total arsenic) in only 25% of the surface waters or groundwaters. The concentrations of As(III) reported in this work are probably an upper bound to the actual concentrations of As(III) present in samples due to interferences from arsenic colloids. Thus, As(III) concentrations appear low in U.S. drinking waters.

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**Article ID 6** **Author** Chen, Hsiao-wen, and Marc Edwards  
**Notecard #** 06-10 **Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Topic** Other **Date** 1996  
**Constituent** Arsenic **Page #** 4  
**Co-Occurrence?** Yes **Co-Occurrence Notes** sulfate  
**Notes** While sulfate is not expected to significantly affect activated alumina performance, the run length is primarily a function of influent As concentrations (Figure 1). For more than 80% of the waters surveyed, activated alumina is predicted to treat more than 20,000 bed volumes before 10% arsenic breakthrough. About 20-30% of the waters surveyed would have benefited from overall total dissolved solids (TDS) reduction and arsenic removal by RP (Figure 9). Although RO treatment efficiency is not controlled by TDS, costs increase markedly in higher TDS waters. An overall cost comparison of RO, anion exchange, and activated alumina will be completed soon by examining these results.

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**Article ID 6**  
**Notecard #** 06-01  
**Topic** Constituent Species  
**Constituent** Arsenic  
**Co-Occurrence?** No  
**Author** Chen, Hsiao-wen, and Marc Edwards  
**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Date** 1996  
**Page #** 1  
**Co-Occurrence Notes**  
**Notes** Particulate arsenic is much more significant and widespread than previously suspected. As(V) dominates soluble arsenic occurrence in most U.S. drinking waters, whereas As (III) is of relatively low significance. Additional benefits may be realized by utilities installing conventional water treatment to remove arsenic since arsenic-containing waters also tend to contain high hardness or soluble Fe and Mn.

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**Article ID 6**  
**Notecard #** 06-02  
**Topic** Source(s) - Natural  
**Constituent** Arsenic  
**Co-Occurrence?** No  
**Author** Chen, Hsiao-wen, and Marc Edwards  
**Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Date** 1996  
**Page #** 1  
**Co-Occurrence Notes**  
**Notes** Naturally occurring arsenic is associated with sedimentary rocks, weathered volcanic rocks, and geothermal water.

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**Article ID 7**  
**Notecard #** 07-06  
**Topic** Source(s) - Anthropogenic  
**Constituent** Microbes  
**Co-Occurrence?** No  
**Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley  
**Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River  
**Date** 1995  
**Page #** 1592  
**Co-Occurrence Notes**  
**Notes** It should be noted that while farms and human sewage contribute to the level of parasites in rivers and lakes, there are other sources, such as the natural fauna, which are also important. Elucidation of the relative importance of each source would require involved mass balance calculations, and the relative importance of each source would probably vary with individual waterways.

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**Article ID 7**  
**Notecard #** 07-02  
**Topic** Source(s) - Anthropogenic  
**Constituent** Cryptosporidium  
**Co-Occurrence?** Yes  
**Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley  
**Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River  
**Date** 1995  
**Page #** 1591  
**Co-Occurrence Notes** giardia  
**Notes** Monitoring of the dairy farm stream (table 2) revealed the occurrence of Giardia and Cryptosporidium in 69% and 77% of the monthly samples, respectively. Mean densities were similar for both parasites and generally higher than ambient densities in the Allegheny indicating that the stream is a potential source of parasites to the river. The dairy farm studied in this survey was chosen for its proximity to the city and not for its size (only 20-25 cattle). It is expected that a larger farm might yield higher parasite numbers and perhaps even more Cryptosporidium oocysts.

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**Article ID 7** **Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley

**Notecard #** 07-03 **Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River

**Topic** Source(s) - Anthropogenic **Date** 1995

**Constituent** Cryptosporidium **Page #** 1591

**Co-Occurrence?** Yes **Co-Occurrence Notes** giardia

**Notes** Monthly analysis of treated effluent from a sewage plant, utilizing secondary treatment, revealed the presence of Cryptosporidium oocysts in 27% of the samples . . . And the occurrence of Giardia cysts in 80% of the samples . . . (Table 2). The greater prevalence and concentration of Giardia in treated sewage may reflect the chronic shedding of cysts by people asymptotically infected with the Giardia parasite. These results suggest that human sewage, while contributing Cryptosporidium to natural bodies of water, may be even more important as a source of Giardia cysts.

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**Article ID 7** **Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley

**Notecard #** 07-04 **Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River

**Topic** Source(s) - Anthropogenic **Date** 1995

**Constituent** Cryptosporidium **Page #** 1592

**Co-Occurrence?** Yes **Co-Occurrence Notes** giardia

**Notes** In addition to monitoring treated sewage discharged into the Allegheny River, a limited attempt was made to evaluate the impact of CSOs (combined sewer overflows) (table 3) . . . The CSO data in this study, one from a grab sample and the other from a composite, both indicate the presence of high levels of Cryptosporidium and even higher levels of Giardia. These results reflect the large concentration of protozoa in raw sewage and suggest that CSOs are an important source of parasite contamination that merits further study.

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**Article ID 7** **Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley

**Notecard #** 07-08 **Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River

**Topic** Source(s) - Anthropogenic **Date** 1995

**Constituent** Cryptosporidium **Page #** 1594-1595

**Co-Occurrence?** Yes **Co-Occurrence Notes** Giardia

**Notes** The following conclusions are drawn from the results of this study:

- 1.) Giardia and Cryptosporidium are frequently present in river water with Cryptosporidium typically being somewhat more prevalent and present in higher numbers.
- 2.) Dairy farms are a source of parasites into natural waterways. Treated sewage, but [particularly untreated sewage, is also a source, especially for Giardia.
- 3.) Conventional drinking water plant clarification and filtration can completely eliminate passage of Giardia cysts into the finished water supply. However, small numbers of Cryptosporidium may occasionally pass through the treatment plant even in the absence of obvious treatment problems.
- 4.) Filter backwash water can contain significant numbers of parasites, especially Cryptosporidium. That these numbers are high, relative to levels typically observed in the raw source water, suggests that recycling of backwash water is a potential source of contamination to the treatment plant intake.

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- Article ID 7** **Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley
- Notecard #** 07-01 **Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River
- Topic** Geographic Location/Distribution **Date** 1995
- Constituent** Cryptosporidium **Page #** 1590-1591
- Co-Occurrence?** Yes **Co-Occurrence Notes** giardia
- Notes** Parasites were observed at approximately the same occurrence rates in the Allegheny and Youghiogheny Rivers (Allegheny: Giardia = 60%, Cryptosporidium = 73%; Youghiogheny: Giardia = 67%, Cryptosporidium = 80% occurrence). The mean densities were also similar. However, in both rivers, Cryptosporidium oocysts were generally more frequently detected, and at higher densities, than were Giardia cysts . . . These results . . . Are similar to earlier findings by other investigators.
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- Article ID 7** **Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley
- Notecard #** 07-07 **Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River
- Topic** Source(s) - Anthropogenic **Date** 1995
- Constituent** Cryptosporidium **Page #** 1594
- Co-Occurrence?** Yes **Co-Occurrence Notes** Giardia
- Notes** Table 5 summarizes the results of monthly assays of filter backwash water. Cryptosporidium oocysts were detected in over 50% of the samples while Giardia cysts were observed in only 13% of the samples. The less frequent occurrence of Giardia may be the result of better removal of the larger Giardia cysts in the preceding plant clarification process. Comparison of the mean density of Cryptosporidium oocysts in backwash water (table 5) with oocyst densities in untreated river water (table 4) indicates that parasite levels in backwash water are substantially higher. This suggests that the practice of recycling untreated filter backwash water can constitute a significant source of parasites, especially Cryptosporidium, to the plant intake.
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- Article ID 7** **Author** States, Stanley, Jan Sykora, Kathleen Stadterman, Denise Wright, Julie Baldizar, and Louis Conley
- Notecard #** 07-05 **Title** Sources, Occurrence, and Drinking Water Treatment Removal of Cryptosporidium and Giardia in the Allegheny River
- Topic** Source(s) - Anthropogenic **Date** 1995
- Constituent** Cryptosporidium **Page #** 1592
- Co-Occurrence?** Yes **Co-Occurrence Notes** giardia
- Notes** Furthermore, comparison of Giardia and Cryptosporidium numbers observed in effluent from secondary sewage treatment (table 2) and diluted raw sewage (table 3) indicates the extent to which conventional sewage treatment is important for controlling parasite levels in natural bodies of water.
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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-05	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 3
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Water from 6 of the 94 shallow wells (6.4 percent) contained nitrate concentrations higher than 10 mg/L.

Nitrate was not detected, at a detection limit of 0.05 mg/L, in 43 percent of the shallow wells.

In contrast to the wells with not detectable nitrate, samples from 29 percent of the shallow wells had nitrate concentrations higher than 3.0 mg/L.

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-06	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 3
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The paired wells in the fluvial deposits show stratification of nitrate concentration with depth (fig. 4). The concentration of nitrate in samples from six of the shallow wells was higher than the concentration in the corresponding deep well. IN the remaining three well pairs, no nitrate was detected in samples from either well . . . Nitrate concentrations are typically higher at the top of the water table than at depth, in part because most nitrate sources originate at the land surface (Hallberg and Keeney, 1993). Nitrate concentrations tend to decrease with depth as recharge water containing nitrate moves downward and mixes with water that is lower in nitrate. Stratification of nitrate concentrations with depth also is influenced by the availability of dissolved oxygen. As dissolved oxygen concentrations decrease with depth, loss of nitrate by denitrification is enhanced.

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-09	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 4
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrate concentrations were below the detection limit in samples from approximately 65 percent of the wells n the till plain and 41 percent of the wells in the glacial lowland (fig. 5). Low concentrations of nitrate in ground water underlying agricultural areas of the till plain and the glacial lowland are common where overlying clay-rich tills retard downward movement of nitrate and oxygen into the water-bearing units. Low concentrations of dissolved-oxygen in the ground water of the till plain and glacial lowland settings enable nitrate to be denitrified, thus lowering nitrate concentrations.

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-08	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic Source(s)</b> - Anthropogenic	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 4
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrate concentrations in samples from three-fourths of the shallow wells in fluvial deposits underlying urban land were above the detection limit; however the nitrate concentration did not exceed 10 mg/L in any of the samples (fig. 5). This widespread, low-level contamination probably is due to (1) the vulnerable nature of the fluvial deposits . . . And (2) the prevalent use of lawn fertilizers in urban settings. Effluent from septic systems and leaky sewers also may contribute lesser amounts of nitrate to the ground water in urban settings.

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-07	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic Source(s)</b> - Anthropogenic	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 3-4
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The largest percentage of shallow wells with a nitrate concentration between 3.1 and 10 mg/L (42 percent) and the largest percentage of shallow wells with a nitrate concentration higher than 10 mg/L (17 percent) were in fluvial deposits underlying agricultural land (figs. 3, 5) . . . Elevated nitrate concentrations are expected in water from the fluvial deposits underlying agricultural land; the primary source of nitrate for this water is nitrogen fertilizers applied to the land. The fluvial deposits are vulnerable to nitrate contamination because water infiltrates through them rapidly (Soller and Ber, 1992). Rapid infiltration allows nitrate to easily move below the root zone where it is not available for uptake by plants. In addition, rapid infiltration replenishes ground water with oxygen-rich recharge water, inhibiting nitrate loss by denitrification.

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-04	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic Study Methodology</b>	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 3
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> Nitrite

**Notes** USGS installed 4 monitoring-well networks in the White River Basin . . . Designed to assess the concentrations and distributions of nitrate in shallow, recently recharged (generally less than 10 years old) ground water in four different environmental settings . . . Well locations were randomly selected . . . [samples were collected] from the 103 monitoring wells in the summers of 1994 and 1995. The USGS National Water Quality Laboratory measured nitrate plus nitrite and nitrite concentrations . . .



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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-01	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 1-2
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The principle land use in the [White River Basin] is agriculture (Fig. 2), which covers about 70 percent of the basin. In 1992, about 22 percent of the basin was planted in corn, and about 18 percent was planted in soybeans. Other cropland comprises a smaller percentage of the basin and includes wheat and hay. Most of the forested land is located in the south-central part of the basin. There is significant industrialization in the cities of Indianapolis, Muncie, and Anderson.

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-02	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 2
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The primary source of nitrate in ground water in the White River Basin is nitrogen fertilizer. Commercial fertilizer applied to agricultural and urban land accounts for approximately two-thirds of the estimated total nitrogen input to the basin (Jeff Martin, U.S. Geological Survey, written commun., 1995). Other important nonpoint sources of nitrogen in the basin include manure, decomposing crop residues, septic systems, atmospheric deposition, and fixation of atmospheric nitrogen (Jeff Martin, 1995).

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<b>Article ID</b> 8	<b>Author</b> Moore, Rhett C. and Joseph M. Fenelon
<b>Notecard #</b> 08-03	<b>Title</b> Occurrence of Nitrate in Ground Water in the White River Basin, Indiana, 1994-95
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 2-3
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrogen in the soil of the White River Basin commonly is in the form of nitrate. The primary mechanism for nitrate removal from the soil is plant uptake. However, nitrate can leach downward into ground water when nitrate concentrations in the soil exceed plant uptake. Where dissolved oxygen concentrations in ground water are low - less than 1 mg/L (milligram per liter) - the excess nitrogen can be removed by denitrification (the biochemical conversion of nitrate to nitrogen gas by bacteria). The potential for nitrate contamination of ground water is generally dependent on the following factors (1) amount of fertilizer and other nitrogen sources input to the soil; (2) amount of rainfall; (3) permeability of the surficial geologic materials; (4) depth to water; (5) depth to aquifer (for confined aquifers); and (6) availability of dissolved oxygen in the aquifer. Ground water is most vulnerable to nitrate contamination in coarse-textured, well-drained deposits where leaching rates are high and dissolved oxygen is present.

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**Article ID** 9 **Author** Wright, Winfield G. and Cathy J. Janik  
**Notecard #** 09-01 **Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Study Methodology **Date** 1995  
**Constituent** Sulfate **Page #** 1  
**Co-Occurrence?** Yes **Co-Occurrence Notes** metals  
**Notes** Water samples were collected from natural springs and streams (. . . Determined to be unaffected by mining) in Topeka Gulch. Water samples also were collected from the drainage of two collapsed mines in Topeka Gulch and three mines in Ohio Gulch . . . Cement Creek was sampled at the streamflow-gaging station . . . Water samples were filtered . . . Properties measured at each site were: pH, specific conductance, dissolved oxygen, alkalinity (if pH was greater than 4.5), and water temperature . . . Water-chemistry analyses included: dissolved major ions, dissolved major and trace metals, sulfur isotopes of dissolved sulfate, oxygen isotopes of water, and hydrogen isotopes of water.

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**Article ID** 9 **Author** Wright, Winfield G. and Cathy J. Janik  
**Notecard #** 09-06 **Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Source(s) - Anthropogenic **Date** 1995  
**Constituent** Nickel **Page #** 3  
**Co-Occurrence?** Yes **Co-Occurrence Notes** barium  
**Notes** Mines in Topeka Gulch . . . Contributed 49 percent of the dissolved barium load and 60 percent of the dissolved nickel load.

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**Article ID** 9 **Author** Wright, Winfield G. and Cathy J. Janik  
**Notecard #** 09-05 **Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Source(s) - Natural **Date** 1995  
**Constituent** Nickel **Page #** 3  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Barium  
**Notes** Naturally occurring dissolved metals can be traced by sampling water from natural springs and streams, analyzing for conservative constituents (constituents that remain dissolved in the water in contrast to constituents that might be attenuated by natural processes), and comparing natural dissolved metal loads to loads in the part of the stream that is affected by mining . . . This procedure was performed for Topeka Gulch; however, the analysis represents only a snapshot of the dissolved metals during the time period of sample collection. Barium and nickel seemed to act as conservative constituents in the study area.

Natural springs and streams in Topeka Gulch contributed 39 percent of the discharge, 51 percent of the barium load, and 40 percent of the nickel load to the mouth of Topeka Gulch . . .

At the streamflow-gaging station on Cement Creek (fig. 1), natural springs and streams in Topeka Gulch contributed 0.42 percent of the discharge, 0.73 percent of the barium load, and 0.47 percent of the nickel load.

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**Article ID 9** **Author** Wright, Winfield G. and Cathy J. Janik  
**Notecard #** 09-07 **Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Factors Affecting Geochemistry **Date** 1995  
**Constituent** Sulfate **Page #** 3  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** In sulfide-mineralized geologic regions that have been mined, such as the Upper Animas River Basin, the oxidation of sulfide minerals produces dissolved sulfate in natural springs and in mine drainage. In some collapsed mines, the dissolved sulfate can be subjected to microbial reduction. The oxygen in dissolved sulfate (SO<sub>4</sub> (2-)) can be affected by several processes: (1) Oxidation of sulfide minerals by oxygen in ground water that has low dissolved-oxygen concentrations (such as natural springs that have deep ground-water flow paths); (2) oxidation of sulfide minerals by atmospheric oxygen in contact with the ore body (such as in an open mine); and (3) oxygen in dissolved sulfate where sulfide minerals were oxidized when water first enters the old mine, then part of the sulfate was subjected to reduction by sulfate-reducing bacteria because of the lack of atmosphere circulation to keep the system in an oxidizing condition.

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**Article ID 9** **Author** Wright, Winfield G. and Cathy J. Janik  
**Notecard #** 09-04 **Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Factors Affecting Geochemistry **Date** 1995  
**Constituent** Other **Page #** 2  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Aluminum, iron, zinc  
**Notes** The concentrations of dissolved aluminum, iron, and zinc were lower (attenuated) at the mouth of Topeka Gulch compared to upper reaches. The metals could have been attenuated by natural adsorption processes by the stream water flowing in and out of the alluvial aquifer at the lower end of the gulch. Metals could be stored in the alluvium and possibly remobilized during high flows such as snowmelt runoff; however, this possibility was not analyzed and warrants further investigation.

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**Article ID 9** **Author** Wright, Winfield G. and Cathy J. Janik  
**Notecard #** 09-03 **Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Source(s) - Natural **Date** 1995  
**Constituent** Other **Page #** 2  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Aluminum, iron, zinc  
**Notes** During the sampling period, natural springs and streams contributed substantial dissolved metal loads (discharge times concentration) to Topeka Gulch. Dissolved aluminum and iron loads (fig. 5) were much larger than the dissolved zinc loads (fig. 6).

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**Article ID 9**  
**Notecard # 09-02**  
**Author** Wright, Winfield G. and Catthy J. Janik  
**Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Geographic Location/Distribution  
**Date** 1995  
**Constituent** Other  
**Page #** 2  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Aluminum, iron, zinc  
**Notes** Concentrations of dissolved aluminum in natural springs, a natural stream, and mines in Topeka and Ohio Gulches ranged from 7 to 22,000 micrograms per liter (ug/L) and concentrations of dissolved iron ranged from 3,600 to 78,000 ug/L. Concentrations of dissolved zinc ranged from 6 to 7,440 ug/L. Water from natural springs and streams had similar aluminum, iron, and zinc concentrations compared to water from mines in Topeka and Ohio Gulches.

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**Article ID 9**  
**Notecard # 09-08**  
**Author** Wright, Winfield G. and Catthy J. Janik  
**Title** Naturally Occurring and Mining-Affected Dissolved Metals in Two Subbasins of the Upper Animas River Basin, Southwestern Colorado  
**Topic** Source(s) - Natural  
**Date** 1995  
**Constituent** Other  
**Page #** 4  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** Water from natural springs and streams in Topeka Gulch . . . Had high concentrations of dissolved metals during the low-flow period of September-October 1994. Natural sources contributed substantial dissolved metal loads to the mouth of Topeka Gulch, and natural sources in Topeka Gulch contributed measurable dissolved metal loads to Cement Creek.

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**Article ID 10**  
**Notecard # 10-03**  
**Author** Pollen, Michael R. and Cindy L. Christian, Craig D. Nordgren, Jonathan D. Pollen  
**Title** Occurrence and Significance of Cryptosporidium parvum and Giardia lamblia in Surface Waters on Alaska's North Slope  
**Topic** Source(s) - Natural  
**Date** August 12-16, 1996  
**Constituent** Microbes  
**Page #** 497  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** Giardia cysts are introduced into the water supply by human or animal excreta. There are several animal reservoirs of Giardia, including beaver, muskrat, bears and dogs.

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**Article ID 10**  
**Notecard # 10-05**  
**Author** Pollen, Michael R. and Cindy L. Christian, Craig D. Nordgren, Jonathan D. Pollen  
**Title** Occurrence and Significance of Cryptosporidium parvum and Giardia lamblia in Surface Waters on Alaska's North Slope  
**Topic** Factors Affecting Geochemistry  
**Date** August 12-16, 1996  
**Constituent** Cryptosporidium  
**Page #** 503-504  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Giardia  
**Notes** The only occurrence of Giardia was associated with the spring thaw, while Cryptosporidium showed two occurrence intervals, spring thaw and shortly after the return of the ice cover. . . .  
  
Samples showed significantly higher turbidity and total particle counts during wind events in which the water quality was influenced by benthic sediments being stirred up into the water column by wind and wave action. The data shows no direct correlation ( $r = 0.1$ ) between higher turbidity and higher Giardia or Cryptosporidium counts.

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**Article ID** 10 **Author** Pollen, Michael R. and Cindy L. Christian, Craig D. Nordgren, Jonathan D. Pollen

**Notecard #** 10-04 **Title** Occurrence and Significance of *Cryptosporidium parvum* and *Giardia lamblia* in Surface Waters on Alaska's North Slope

**Topic** Study Methodology **Date** August 12-16, 1996

**Constituent** *Cryptosporidium* **Page #** 501-503

**Co-Occurrence?** Yes **Co-Occurrence Notes** microbes

**Notes** A raw water sampling and analysis program was completed for nine fresh water sources located near the North Slope Borough (NSB) villages of Atkasuk, Kaktovik, Nuiqsut, Point Hope, Point Lay and Wainwright . . . A total of 8 lakes and one river in six villages were sampled . . .

The second project was with the Barrow Utilities and Electric Co-Operative (BUECI) which operates the drinking water treatment plant in Barrow. The raw water supply is taken from the Isatkoak Reservoir which is located between the City of Barrow and its suburb, Browerville. The reservoir is fed mainly from snow melt and tundra runoff during the spring thaw . . . Samples were collected on a monthly basis to obtain a twelve month picture of how the protozoan population fluctuated throughout the seasons. Figure 9 outlines the results in the Isatkoak Reservoir for *Giardia* and *Cryptosporidium*.

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**Article ID** 10 **Author** Pollen, Michael R. and Cindy L. Christian, Craig D. Nordgren, Jonathan D. Pollen

**Notecard #** 10-01 **Title** Occurrence and Significance of *Cryptosporidium parvum* and *Giardia lamblia* in Surface Waters on Alaska's North Slope

**Topic** Source(s) - Anthropogenic **Date** August 12-16, 1996

**Constituent** *Cryptosporidium* **Page #** 496

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Ingestion of drinking water contaminated with viable oocysts is a major mode of transmission for humans. *Cryptosporidium* is introduced to the water supply via animal excreta containing oocysts. Important reservoirs of the oocysts include cattle, sheep, and pigs . . .

Direct contact with infected animals, particularly calves and lambs, can cause illness in exposed persons. Uncooked, contaminated food can also cause infections.

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**Article ID** 10 **Author** Pollen, Michael R. and Cindy L. Christian, Craig D. Nordgren, Jonathan D. Pollen

**Notecard #** 10-02 **Title** Occurrence and Significance of *Cryptosporidium parvum* and *Giardia lamblia* in Surface Waters on Alaska's North Slope

**Topic** Source(s) - Natural **Date** August 12-16, 1996

**Constituent** *Cryptosporidium* **Page #** 496

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** *Cryptosporidium* is also found in wild animal populations. The organism is most prevalent in ruminants, such as deer, elk, and caribou and is found primarily in neonates of those species.

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<b>Article ID</b> 11	<b>Author</b> Segars, William I.
<b>Notecard #</b> 11-02	<b>Title</b> Nitrates in Groundwater: Some Facts on Occurrence
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> August 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 24
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** High nitrate levels in ground water can arise from a variety of agricultural and nonagricultural activities. Primary agricultural sources of N include fertilizer use, animal waste and breakdown of residual N in soils and crop residues. Non-agricultural sources such as nitrate-bearing minerals, septic tanks and municipal or organic wastes may also contribute to occurrences of nitrates in ground water. Regardless of the source, NO<sub>3</sub>-N can accumulate in subsurface soil horizons or leach into ground water if the unused N exceeds that removed by crops.

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<b>Article ID</b> 11	<b>Author</b> Segars, William I.
<b>Notecard #</b> 11-03	<b>Title</b> Nitrates in Groundwater: Some Facts on Occurrence
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> August 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 24
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Areas most at risk for groundwater contamination generally have sandy, highly permeable soils with little organic matter, have sufficient rainfall or irrigation to promote deep leaching and are located over shallow, unconfined aquifers. Thus, site-specific conditions determine the likelihood of leaching.

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<b>Article ID</b> 11	<b>Author</b> Segars, William I.
<b>Notecard #</b> 11-01	<b>Title</b> Nitrates in Groundwater: Some Facts on Occurrence
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> August 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 24
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** One obvious question is how do the nitrates reach groundwater? The answer is primarily by leaching. Organic N or ammoniacal (NH<sub>4</sub><sup>+</sup>) sources are converted to (NO<sub>3</sub>-N) by a process called nitrification. Because the NO<sub>3</sub>-N ion has a negative charge it is not attracted to negatively charged clays. Thus, any NO<sub>3</sub>-N not utilized by plants or denitrified (converted to gas) by microorganisms, can be leached into groundwater.

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<b>Article ID</b> 11	<b>Author</b> Segars, William I.
<b>Notecard #</b> 11-04	<b>Title</b> Nitrates in Groundwater: Some Facts on Occurrence
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> August 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 25
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Our studies in Georgia have shown that the wells most frequently found contaminated have one or all of the following characteristics: (1) are shallow (<50 ft. deep), (2) are old (>30 years), (3) are located down slope from nitrogen sources, (4) have unprotected well-heads that allow entrance of surface water, and (5) are not grouted or properly cased.

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<b>Article ID</b> 12	<b>Author</b> Kolpin, Dana W. and Donald A. Goolsby
<b>Notecard #</b> 12-05	<b>Title</b> A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1995
<b>Constituent</b> Other	<b>Page #</b> 18
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The frequency of herbicide detection in near-surface aquifers was statistically related to crop irrigation. Water samples from wells located within 3.2 km of irrigated crops had almost double the frequency of herbicide detection (35%) than was observed in water samples from wells without nearby irrigation (19%). Irrigation potentially could provide leaching of chemicals from the land surface to the aquifer throughout the growing season.

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<b>Article ID</b> 12	<b>Author</b> Kolpin, Dana W. and Donald A. Goolsby
<b>Notecard #</b> 12-04	<b>Title</b> A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1995
<b>Constituent</b> Other	<b>Page #</b> 16-17
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Herbicides were detected much more frequently in water from unconsolidated aquifers than in water from bedrock aquifers (Kolpin et. al., 1994). Unconsolidated aquifers may be more susceptible to herbicide contamination because: (a) there is a general absence of overlying low-permeability material. Seventy-eight percent of the unconsolidated aquifers sampled, compared to only 48% of the bedrock aquifers sampled, were unconfined;

(b) unconsolidated aquifers in the study region have a planar geometry that is typically long and narrow. In this geometry, flow paths are generally local with surface-recharge areas in proximity to wells. Conversely, bedrock aquifers typically are more extensive laterally and contain more regional flow paths;

(c) most of the unconsolidated aquifers sampled are alluvial in origin and thus a hydraulic connection between the stream and the aquifer may exist. Streams in the midcontinent have much higher concentrations of herbicides than groundwater (Thurma et. al., 1992). Therefore, recharge to aquifers from streamflow could be a source of herbicide contamination (Squillace et al., 1993).

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<b>Article ID</b> 12	<b>Author</b> Kolpin, Dana W. and Donald A. Goolsby
<b>Notecard #</b> 12-03	<b>Title</b> A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1995
<b>Constituent</b> Other	<b>Page #</b> 15-16
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** A direct relation was determined between tritium content (indicative of the general age of the water) and herbicide contamination. Groundwater having a tritium content of <2 Tritium units (TU) is considered to be generally pre-1953 in age ("old" water). The frequency of herbicide detection is the greatest in the youngest water (Fig. 3). Obviously the general age of the water does not cause herbicide contamination, but simply identifies an aquifer's susceptibility to contamination by indicating the presence of post-1953 recharge water. Herbicides were not detected (at the 0.05 ug/L level) in aquifers which contained pre-1953 water. This age of water predates the first use of the target herbicides to improve crop yields in the midcontinent. However, when an analytical method with much lower reporting limits (down to 0.002 ug/L) was used, a small percentage of the aquifers which contained pre-1953 water were found to contain trace amounts of herbicides (from 0.003 to 0.009 ug/L atrazine). This discrepancy might be caused by small amounts of post-1953 water contaminated with herbicides entering and mixing within an aquifer or well through preferential flowpaths and cause trace concentrations of herbicides to be detected, but still not identify the general age of the water as post-1953. Aquifers found to contain "very recent" water indicated a high susceptibility to herbicide contamination, with almost 80% of these aquifers containing at least one herbicide or herbicide metabolite.

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<b>Article ID</b> 12	<b>Author</b> Kolpin, Dana W. and Donald A. Goolsby
<b>Notecard #</b> 12-02	<b>Title</b> A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1995
<b>Constituent</b> Other	<b>Page #</b> 15
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Twenty-seven different pesticide compounds have been detected in the 810 groundwater samples collected for this study since 1991 . . . Nearly all of the most frequently detected compounds were either herbicides or herbicide metabolites (Table 1). Only one sample had a concentration (alachlor = 4.27 ug/L) that exceeded a USEPA maximum contaminant level for drinking water . . .

Six of the seven most frequently detected compounds from this study were herbicide metabolites (Table 1). Thus, herbicide metabolites are being transported to aquifers and, in some cases, are more persistent and mobile than the parent compound. For example, the alachlor metabolite ethansulphonic acid (ESA) was found more than 10 times as frequently and at much higher concentrations than alachlor itself. Consequently, if herbicide metabolites are not quantified, the effects of herbicide use on groundwater quality would be substantially underestimated.

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<b>Article ID</b> 12	<b>Author</b> Kolpin, Dana W. and Donald A. Goolsby
<b>Notecard #</b> 12-09	<b>Title</b> A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 19
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrate concentration has a strong direct relation to dissolved oxygen concentration (Fig. 5). The larger the dissolved oxygen concentration in the aquifer, the more likely that a sample would have excess nitrate. This relation was expected because nitrate is the dominant nitrogen species under oxidizing conditions and ammonium is the dominant nitrogen species under reducing conditions. The presence of hydrogen-sulphide odour during sampling indicates a strongly reducing environment, which is reflected by a few samples having nitrate concentrations  $\geq 0.05$  mg/L and by no samples having nitrate concentrations  $\geq 3.0$  mg/L.

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<b>Article ID</b> 12	<b>Author</b> Kolpin, Dana W. and Donald A. Goolsby
<b>Notecard #</b> 12-08	<b>Title</b> A Regional Monitoring Network to Investigate the Occurrence of Agricultural Chemicals in Near-Surface Aquifers of the Midcontinental USA
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 19
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrate concentrations were not uniformly distributed in water in near-surface aquifers across the midcontinent (Fig. 4). Concentrations were generally higher in the western portion of the study region than in the eastern portion. Because nitrogen-fertilizers are used intensively throughout the study region, the spatial patterns in chemical use alone are not enough to explain spatial patterns in nitrate occurrence. Other factors affecting nitrate contamination such as the type of soil, climate, irrigation, and type of aquifer also need to be considered to explain the spatial patterns in nitrate occurrence.





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<b>Article ID</b> 13	<b>Author</b> Milvy, Paul and C. Richard Cothem
<b>Notecard #</b> 13-04	<b>Title</b> Scientific Background for the Development of Regulations for Radionuclides in Drinking Water
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1990
<b>Constituent</b> Uranium	<b>Page #</b> 3-4
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Although radionuclides in drinking water are found throughout the United States, certain geographic areas have particularly high levels. The highest levels of radon are observed in the New England states and in the Virginia-Maryland region. High levels of radium in drinking water are measured in the Piedmont region of North Carolina, in South Carolina and Georgia, the mid-western area of Iowa, northern Illinois and southern Wisconsin, and the four corners region in the West. The highest levels of uranium are found in the mountainous regions of the Western United States.

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<b>Article ID</b> 13	<b>Author</b> Milvy, Paul and C. Richard Cothem
<b>Notecard #</b> 13-03	<b>Title</b> Scientific Background for the Development of Regulations for Radionuclides in Drinking Water
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1990
<b>Constituent</b> Radon	<b>Page #</b> 3
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Radon in drinking water is found only in groundwater supplies (the insoluble radon gas quickly degasses in surface water supplies). Smaller water supplies tend to take their water from smaller aquifers, which, in general, have larger granular surface areas and, thus, higher concentrations of radon. . . . It is expected, based upon this trend as well as additional limiting sampling, that radon occurrences in private wells will be a factor of three to ten times higher than concentrations measured in public drinking water supplies.

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<b>Article ID</b> 13	<b>Author</b> Milvy, Paul and C. Richard Cothem
<b>Notecard #</b> 13-02	<b>Title</b> Scientific Background for the Development of Regulations for Radionuclides in Drinking Water
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1990
<b>Constituent</b> Radium	<b>Page #</b> 2
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Although the occurrence of Ra(226) and Ra(228) are independent (they occur in two different radioactive series), in general their nationwide distributions with respect to concentration are somewhat similar.

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<b>Article ID</b> 13	<b>Author</b> Milvy, Paul and C. Richard Cothem
<b>Notecard #</b> 13-01	<b>Title</b> Scientific Background for the Development of Regulations for Radionuclides in Drinking Water
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1990
<b>Constituent</b> Uranium	<b>Page #</b> 1
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> radon

**Notes** The radionuclides in drinking water are members of three natural radioactive series. These are the uranium series, the thorium series, and the actinium series. The specific elements of concern are radium (Ra), radon (Rn), and uranium (U). The isotopes in the uranium series that may pose a health risk because of their presence in drinking water are U(238), U(234), Ra(226), and Rn(222). Radium-228, which occurs in the Thorium series, is also found in drinking water. Very few of the other isotopes in these series have been detected in drinking water. Recently, however, polonium-210 has been detected in the drinking water of east central Florida.

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**Article ID** 30  
**Notecard #** 30-03  
**Author** SAIC  
**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources  
**Topic** Other  
**Date** November 10, 1997  
**Constituent** Microbes  
**Page #** 2-1  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Giardia and Cryptosporidium  
**Notes** Of the 38 samples that had Giardia or Cryptosporidium detections, only 9 (24 percent) had both Giardia and Cryptosporidium present. This low percentage of concurrence may be indicative of the absence of either protozoa in the source water, an artifact of imprecise analytical methods for these organisms, analyst expertise, or perhaps different transport mechanisms for these two protozoa. These data suggest that both cysts and oocysts should be analyzed for when evaluating risk of surface water influence.

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**Article ID** 30  
**Notecard #** 30-02  
**Author** SAIC  
**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources  
**Topic** Source(s) - Natural  
**Date** November 10, 1997  
**Constituent** Microbes  
**Page #** 1-5  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Giardia and Cryptosporidium  
**Notes** Hancock et al. (in press) found that there was no correlation between the distance of the ground water source to adjacent surface water and the occurrence of either Giardia or Cryptosporidium.

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**Article ID** 30  
**Notecard #** 30-04  
**Author** SAIC  
**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources  
**Topic** Other  
**Date** November 10, 1997  
**Constituent** Microbes  
**Page #** 2-4  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Giardia and Cryptosporidium  
**Notes** Generally, the concentrations of Giardia and Cryptosporidium were higher in vertical wells than in horizontal wells. However, fewer horizontal wells were tested than vertical wells.

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**Article ID** 30  
**Notecard #** 30-06  
**Author** SAIC  
**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources  
**Topic** Factors Affecting Geochemistry  
**Date** November 10, 1997  
**Constituent** Microbes  
**Page #** 2-7  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Giardia and Cryptosporidium  
**Notes** Giardia and Cryptosporidium breakthroughs in wells deeper than 300 feet BGS appear to be influenced by the hydrogeologic settings of well sites. Four of the five wells deeper than 300 feet were located in karst settings; no hydrogeologic data are available on one well.

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**Article ID** 30**Author** SAIC**Notecard #** 30-01**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources**Topic** Other**Date** November 10, 1997**Constituent** Microbes**Page #** 1-5**Co-Occurrence?** Yes**Co-Occurrence Notes** Giardia and Cryptosporidium

**Notes** Most recently, Hancock et al. (in press), on a study of 383 ground water samples found that the presence of Giardia correlated with the presence of Cryptosporidium. The presence of both pathogens correlated with the amount of sample examined but not with the month of sampling. There was correlation between source depth and occurrence of Giardia but not Cryptosporidium. There was a correlation between designated general risk categories of low, moderate, and high and Giardia and Cryptosporidium occurrence; in fact, the probability of occurrence increased with repeat samples.

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**Article ID** 30**Author** SAIC**Notecard #** 30-07**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources**Topic** Source(s) - Natural**Date** November 10, 1997**Constituent** Microbes**Page #** 2-12**Co-Occurrence?** Yes**Co-Occurrence Notes** Giardia and Cryptosporidium

**Notes** Analyses of the reported data generally suggest that most Giardia occurrences and Cryptosporidium occurrences are within 200 feet of the nearest surface water, although 16 percent of detections (3 out of 19) were in wells beyond the 200-foot setback distance.

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**Article ID** 30**Author** SAIC**Notecard #** 30-08**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources**Topic** Factors Affecting Geochemistry**Date** November 10, 1997**Constituent** Microbes**Page #** 2-10**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Sixty-three percent of Giardia detections (five out of eight detections) were reported in wells shallower than 100 feet BGS. Two occurrences were in wells extending to 50 feet BGS, and three occurrences were in wells with depths ranging from 51 to 100 feet BGS. Of these five wells, two were horizontal wells (24 feet BGS and 87 feet BGS) presumably located in alluvial aquifers, one vertical well (55 feet BGS) was located in basalt, and another vertical well (90 feet BGS) penetrated fissured bedrock. No data were available on the type of aquifer tapped by the fifth well.

Of the three remaining occurrences, two samples were collected from the same well which was located in a karst setting.

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**Article ID** 30

**Author** SAIC

**Notecard #** 30-09

**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources

**Topic**

**Date** November 10, 1997

**Constituent** Cryptosporidium

**Page #** 2-10

**Co-Occurrence?** No

**Co-Occurrence Notes**

**Notes** . . . Cryptosporidium oocysts generally are not found in wells extending deeper than 100 feet BGS. Only two Cryptosporidium occurrences (13 percent) were reported in wells penetrating to 50 feet BGS. However, nine out of 15 occurrences (60 percent) were in wells between 51 feet BGS and 100 feet BGS. The two horizontal wells were present in this well depth range. One well, extending to 55 feet BGS, is located in basalt while four other wells are located in alluvial aquifers. Data regarding aquifer type were not obtained for the remaining well sites.

Four wells with reported Cryptosporidium detections (27 percent) were deeper than 100 feet BGS. Of these, one well was 110 feet BGS and the other three were greater than 350 feet BGS. No hydrogeologic data were available for the shallowest well (110 feet) or the deepest well (450 feet BGS). Both of the other two deep wells extend to 385 feet BGS, are located in karst terrain, and are hydraulically connected to each other.

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**Article ID** 30

**Author** SAIC

**Notecard #** 30-10

**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources

**Topic** Source(s) - Natural

**Date** November 10, 1997

**Constituent** Microbes

**Page #** 2-15

**Co-Occurrence?** No

**Co-Occurrence Notes**

**Notes** Three Giardia occurrences (43 percent) were present in wells located within 50 feet of the nearest surface water. The wells in this range were the sites of the highest and lowest Giardia cyst concentrations and included both horizontal wells. The third site was a vertical well located in fissured bedrock.

Three other Giardia occurrences (43 percent) were reported in two vertical wells (two occurrences in the same well) located at setback distances between 51 and 100 feet of the nearest surface water. The well with two occurrences was located in karst and the other was drilled into basalt.

Giardia cysts (two per 100 gallons) also were found in a vertical well 360 feet away from the nearest surface water and 29 feet deep BGS. No data are available on the type of aquifer penetrated by the well.

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**Article ID** 30**Notecard #** 30-11**Author** SAIC**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources**Topic** Source(s) - Natural**Date** November 10, 1997**Constituent** Cryptosporidium**Page #** 2-15**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Five Cryptosporidium occurrences (36 percent) were in wells within 50 feet of the nearest surface water. Both horizontal wells were present in this category. Two of the remaining three vertical wells were located in alluvial aquifers. The highest Cryptosporidium concentration (1,453 oocysts per 100 gallons) was reported in the vertical well for which no data are available on the type of aquifer tapped.

Six samples collected from wells located between 51 and 100 feet of the nearest surface water or 43 percent of the data set had positive Cryptosporidium detections. Two occurrences were in wells located in karst, and one well was located in basalt. All other occurrences were in alluvial wells, except for one site for which no data are available.

The two anomalous points in the data set represented wells located at 1,000 feet and 26,400 feet from the nearest surface water body. Cryptosporidium concentrations at these sites were 1 oocyst per 100 gallons and 30 oocysts per 100 gallons respectively. According to Ledbetter (undated), the well which is at a setback distance of 1,000 feet is located in alluvium, and it may have been inundated by floods prior to sampling. The Cryptosporidium detection is suspected to be the result of surface water contamination at the well discharge point. No hydrogeologic information is available for the second well.

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**Article ID** 30**Notecard #** 30-12**Author** SAIC**Title** Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources**Topic** Other**Date** November 10, 1997**Constituent** Microbes**Page #** 3-2**Co-Occurrence?** Yes**Co-Occurrence Notes** Giardia and Cryptosporidium

**Notes** Scatter plots and distribution tables of MPA data by well depth indicate that many of the "high risk" samples are present at depths less than 100 feet BGS. Most Giardia and Cryptosporidium occurrences are reported at depths between 51 feet BGS and 100 feet BGS.

<b>Article ID</b> 30	<b>Author</b> SAIC
<b>Notecard #</b> 30-13	<b>Title</b> Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources
<b>Topic</b> Other	<b>Date</b> November 10, 1997
<b>Constituent</b> Microbes	<b>Page #</b> 3-3
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Data indicate that a higher number of occurrences are associated with the traditionally wet months of the spring (March, April, and May) and with the late Autumn/early Winter months (October, November, December and January). In July, a traditionally dry month, there are no Giardia or Cryptosporidium occurrences and relatively few high risk MPA scores.

However, high precipitation periods may not correspond to the periods of highest aquifer recharge or induced recharge from surface water. Specific hydrogeological studies to obtain data on aquifer recharge need to be conducted at each site. Other factors that may also affect such evaluations include precipitation variations relating to geographical sample locations and sample collection times, analytical limitations, and pathogen releases through surface runoff which are not linked to the seasonal variations. In addition, this study focuses on a small subset of data from horizontal and vertical wells with high MPA scores or protozoa occurrence. As such, this subset is not representative of the data required to evaluate the time and frequency of MPA sampling.

<b>Article ID</b> 30	<b>Author</b> SAIC
<b>Notecard #</b> 30-05	<b>Title</b> Microscopic Particulate Analysis (MPA) Correlations with Giardia and Cryptosporidium Occurrence in Ground Water Under the Direct Influence of Surface Water (GWUDI) Sources
<b>Topic</b> Other	<b>Date</b> November 10, 1997
<b>Constituent</b> Microbes	<b>Page #</b> 2-7
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> Giardia and Cryptosporidium

**Notes** Generally, the distribution table and plots indicate that Giardia cysts and Cryptosporidium oocysts were most frequently found in wells less than 100 feet BGS [Below Ground Surface]. . . In addition, most positive detections were at depths ranging from greater than 50 feet BGS to 100 feet BGS and were in wells located in alluvium.

<b>Article ID</b> 31	<b>Author</b> Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg
<b>Notecard #</b> 31-10	<b>Title</b> A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data
<b>Topic</b> Other	<b>Date</b> September 1997
<b>Constituent</b> Nitrate	<b>Page #</b> 219
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Atrazine was found to co-occur with nitrate and with atrazine metabolites. . . For nitrate, 94% of atrazine positive samples were positive for nitrate, while only 34% of atrazine non-detects were positive for nitrate.

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- Article ID** 31 **Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg
- Notecard #** 31-04 **Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data
- Topic** Other **Date** September 1997
- Constituent** Nitrate **Page #** 207
- Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** . . .the issue of atrazine co-occurring with nitrate. Generally, these contaminants may be expected to co-occur because of the co-occurrence of causal factors: use of herbicides and fertilizers in agricultural settings in Iowa, hydrogeologic and well conditions conducive to leaching, and contaminant properties conducive to leaching. Regarding the latter, nitrate does not degrade and is highly soluble in water while atrazine is moderately persistent and slightly soluble.
- 
- Article ID** 31 **Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg
- Notecard #** 31-05 **Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data
- Topic** Other **Date** September 1997
- Constituent** Nitrate **Page #** 207
- Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** An increased frequency of nitrate in the A+ [wells that tested positive for atrazine (versus a random sample)] wells was observed in this study; 15 of 16 (94%) A+ wells had at least one monthly sample above 10 mg/L as compared to 34 of 67 (51%) 10% [a random population] wells ( $p < 0.01$ ; Chi-squared test). In addition, the average yearly nitrate concentrations found in nitrate positive wells from the 10% population (median = 6.0 mg/L), were significantly lower than the average yearly nitrate concentrations (median = 14.1 mg/L) found in the nitrate positive A+ wells ( $p < 0.05$ , Wilcoxon rank-sum test). Finally, among those wells with nitrate levels above 10 mg/L at any month, the median average yearly nitrate concentration was greater in the A+ population, 19.3 mg/L, than in the 10% population, 12.6 mg/L; this difference was not statistically significant, however.
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- Article ID** 31 **Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg
- Notecard #** 31-06 **Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data
- Topic** Other **Date** September 1997
- Constituent** Nitrate **Page #** 207
- Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** The increased prevalence of nitrate in wells with atrazine is also evident from examining the 10% population by itself. Four of 7 (57%) wells positive for atrazine had nitrate levels above 10 mg/L (at least once) compared to 11 of 60 (18%) of atrazine negative wells ( $p = 0.02$ , Chi-square test). Also, the average yearly nitrate concentrations in these 7 wells in the 10% population were higher (median = 8.9 mg/L) than the average yearly concentrations (median = 0.0 mg/L) in the 60 wells without atrazine ( $p = 0.07$ , Wilcoxon rank-sum test).
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**Article ID** 31 **Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg

**Notecard #** 31-02 **Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data

**Topic** Other **Date** September 1997

**Constituent** Nitrate **Page #** 203

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** A similar lack of seasonal pattern is seen for nitrate in both the 10% [random] and the A+ [wells that tested positive for atrazine] populations. For the 10% population, the range of positive wells [wells in which nitrate occurs at least once above the detection limit over the course of the sampling] and of wells showing an occurrence above 10 mg/L was 68-73%, and 10-18%, respectively. The A+ wells were more impacted by nitrate than the 10% population, but the ranges of positive wells and wells showing an occurrence above 10 mg/L were also narrow at 73-81% and 38-60%, respectively.

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**Article ID** 31 **Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg

**Notecard #** 31-09 **Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data

**Topic** Other **Date** September 1997

**Constituent** Nitrate **Page #** 219

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** There does not appear to be any seasonal variation in the results from the TVAC study as measured by an analysis of monthly sampling from either population of wells studied, 10% or A+, and from either contaminant studied, atrazine or nitrate.

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**Article ID** 31 **Author** Pinsky, Paul, Matthew Lorber, Kent Johnson, Burton Kross, Leon Burmeister, Amina Wilkins, and George Hallberg

**Notecard #** 31-08 **Title** A Study of the Temporal Variability of Atrazine in Private Well Water. Part II: Analysis of Data

**Topic** Other **Date** September 1997

**Constituent** Nitrate **Page #** 218

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** The occurrence frequency for a well found positive for atrazine at least once during the year in the 10% [random] population is 10.4%, and the average concentration in those positive wells is 0.10 ug/L. . . About half of the 10% population had positive occurrences of nitrate; the mean concentration in these positive wells was 12.5 mg/L (median 6.6 mg/L).

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**Article ID** 32 **Author** Waypa, John J., Menachem Elimelech, and Janet G. Hering

**Notecard #** 32-02 **Title** Arsenic Removal by RO and NF Membranes

**Topic** Constituent Species **Date** October 1997

**Constituent** Arsenic **Page #** 103

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** As occurs in both inorganic and organic forms in natural water. Inorganic As may be present in the +V oxidation state as arsenate or in the +III oxidation state as arsenite. Both arsenate and arsenite occur in several protonated forms; at near-neutral pH, the predominant species are H<sub>2</sub>AsO<sub>4</sub>(-) and HAsO<sub>4</sub>(2-) for arsenate and H<sub>3</sub>AsO<sub>3</sub> for arsenite. Organic As species occur in natural water both as a result of in situ production (biomethylation) and through the application of organoarsenical pesticides.

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<b>Article ID</b> 32	<b>Author</b> Waypa, John J., Menachem Elimelech, and Janet G. Hering
<b>Notecard #</b> 32-03	<b>Title</b> Arsenic Removal by RO and NF Membranes
<b>Topic</b> Other	<b>Date</b> October 1997
<b>Constituent</b> Arsenic	<b>Page #</b> 103
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Concentrations of As vary considerably in natural water supplies. In rivers, total As concentrations range from <1 to 40 ug/L with As occurring predominantly as inorganic species. In lakes, methylated species may account for up to 60 percent of the total As concentration. Very elevated As concentrations have been reported in alkaline lakes (17 mg/L in Mono Lake, Calif., and 0.1 mg/L in Pyramid Lake) and in alluvial groundwater (up to 0.4 mg/L).

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<b>Article ID</b> 32	<b>Author</b> Waypa, John J., Menachem Elimelech, and Janet G. Hering
<b>Notecard #</b> 32-04	<b>Title</b> Arsenic Removal by RO and NF Membranes
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> October 1997
<b>Constituent</b> Arsenic	<b>Page #</b> 103
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenate is the thermodynamically stable form of inorganic As in oxic water and generally predominates in surface water. Arsenite is favored under reducing conditions and is commonly observed in anoxic hypolimnetic water and reduced groundwater. Observed coexistence of the oxidized and reduced forms is attributable to a combination of the biological production of arsenite and slow oxidation kinetics and indicates that simple equilibrium calculations are insufficient to explain As speciation. Oxidation of arsenite to arsenate is thermodynamically favorable in oxic water. Manganese oxides appear to be important oxidants of arsenite in natural water.

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<b>Article ID</b> 32	<b>Author</b> Waypa, John J., Menachem Elimelech, and Janet G. Hering
<b>Notecard #</b> 32-01	<b>Title</b> Arsenic Removal by RO and NF Membranes
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> October 1997
<b>Constituent</b> Arsenic	<b>Page #</b> 102
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** A recent study on As occurrence in the United States suggests that groundwater systems in the Southwest will be the most affected by adoption of a new standard for As in drinking water.

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<b>Article ID</b> 33	<b>Author</b> Armon, R. and Y. Kott
<b>Notecard #</b> 33-01	<b>Title</b> Distribution Comparison Between Coliphages and Phages of Anaerobic Bacteria ( <i>Bacteroides fragilis</i> ) in Water Sources, and Their Reliability as Fecal Pollution Indicators in Drinking Water
<b>Topic</b> Other	<b>Date</b> 1995
<b>Constituent</b> Microbes	<b>Page #</b> 216
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** According to the whole data set, no correlation between coliforms and bacteriophage groups was observed; nevertheless a good correlation was found while site grouping was performed.

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**Article ID** 33  
**Notecard #** 33-02  
**Author** Armon, R. and Y. Kott  
**Title** Distribution Comparison Between Coliphages and Phages of Anaerobic Bacteria (*Bacteroides fragilis*) in Water Sources, and Their Reliability as Fecal Pollution Indicators in Drinking Water  
**Topic** Geographic Location/Distribution  
**Date** 1995  
**Constituent** Microbes  
**Page #** 217  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Coliforms and Bacteria  
**Notes** . . . the equivalent sites positive for coliforms and fecal coliforms were also positive for one or a combination of the three bacteriophages tested. In addition some places were positive for bacteriophages without coliforms or fecal coliforms present.

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**Article ID** 33  
**Notecard #** 33-03  
**Author** Armon, R. and Y. Kott  
**Title** Distribution Comparison Between Coliphages and Phages of Anaerobic Bacteria (*Bacteroides fragilis*) in Water Sources, and Their Reliability as Fecal Pollution Indicators in Drinking Water  
**Topic** Other  
**Date** 1995  
**Constituent** Microbes  
**Page #** 217  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** . . . a higher frequency of bacteriophage isolation from well water supply compared with lake and spring sources.

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**Article ID** 33  
**Notecard #** 33-04  
**Author** Armon, R. and Y. Kott  
**Title** Distribution Comparison Between Coliphages and Phages of Anaerobic Bacteria (*Bacteroides fragilis*) in Water Sources, and Their Reliability as Fecal Pollution Indicators in Drinking Water  
**Topic** Other  
**Date** 1995  
**Constituent** Microbes  
**Page #** 218  
**Co-Occurrence?** Yes  
**Co-Occurrence Notes** Coliforms and bacteria  
**Notes** Coliforms were present at those sites presented here concomitantly with bacteriophages.

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**Article ID** 33  
**Notecard #** 33-05  
**Author** Armon, R. and Y. Kott  
**Title** Distribution Comparison Between Coliphages and Phages of Anaerobic Bacteria (*Bacteroides fragilis*) in Water Sources, and Their Reliability as Fecal Pollution Indicators in Drinking Water  
**Topic** Other  
**Date** 1995  
**Constituent** Microbes  
**Page #** 218  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** Well water was found more frequently to harbour bacteriophages possibly showing local surface contamination.

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**Article ID** 34  
**Notecard #** 34-01  
**Author** Wyszomirski, P. and J. Zarebski  
**Title** Uranium in Kaolins and Co-occurring Mining Waters of Some Lower Silesian Kaolin Pits (Poland)  
**Topic** Factors Affecting Geochemistry  
**Date**  
**Constituent** Uranium  
**Page #** 121  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** The uranium content in some Lower Silesian kaolins is higher than the average in clayey rocks amounting to ca. 4.2 ppm. This fact has been stated, among others, for an example of kaolins and weakly kaolinized granites exploited quite recently from "Andrzej" open pit in Zarow. Some mining waters of this deposit are also characterized by an elevated content of this element. The similar situation should be expected at the undertaking of exploitation of neighbouring, "Antoni" kaolin deposit.

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**Article ID** 34  
**Notecard #** 34-02  
**Author** Wyszomirski, P. and J. Zarebski  
**Title** Uranium in Kaolins and Co-occurring Mining Waters of Some Lower Silesian Kaolin Pits (Poland)  
**Topic** Factors Affecting Geochemistry  
**Date**  
**Constituent** Uranium  
**Page #** 121  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** The uranium content in the studied samples from "Andrzej" open pit, determined by means of INAA (instrumental neutron activation analysis), amounts to:  
- 37 +/- 10 ppm – for weakly kaolinized granite  
- 11.3 +/- 2.6 ppm – for residual kaolin  
  
It is possible that the reason for the elevated uranium content in these kaolins is the presence of uranium in minerals of pegmatite veins cutting the kaolinized granite of the "Andrzej" deposit. In the weathering process, uranium of some pegmatitic minerals undergoes the oxidation from U(4+) to U(6+) making mobile and perfectly soluble uranyl ion [UO<sub>2</sub>](2+). The above is the probably reason for the distinctly elevated content of uranium in the mining waters of "Andrzej" pit occurring in the direct neighbourhood of the kaolinized granite (for example ca. 0.5 ppm in samples collected during spring periods).

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**Article ID** 34  
**Notecard #** 34-03  
**Author** Wyszomirski, P. and J. Zarebski  
**Title** Uranium in Kaolins and Co-occurring Mining Waters of Some Lower Silesian Kaolin Pits (Poland)  
**Topic** Other  
**Date**  
**Constituent** Uranium  
**Page #** 121  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** The uranium content [in the mining waters of "Andrzej" pit] is changeable in different seasons of the year, nevertheless, it exceeds remarkably the concentration of this element in most ground waters. The range for the majority of them is from  $5 \times 10^{-12}$  to  $5 \times 10^{-9}$  mol [UO<sub>2</sub>](2+) per litre. Moreover, in summer time, especially in the very hot and rain-free period, when there the majority of mining waters dry up, one can observe the crystallization of secondary sulphate minerals (e.g. copiapite) in which a remarkable concentration of uranium ion exceeding 1 wt.% has been stated.

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<b>Article ID</b> 35	<b>Author</b> Hering, Janet G., Pen-Yuan Chen, Jennifer Wilkie, Menachem Elimelech, and Sun Liang
<b>Notecard #</b> 35-01	<b>Title</b> Arsenic Removal by Ferric Chloride
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> April 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 155
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** US drinking water supplies typically contain less than 5 ug/L arsenic. However, accurate determinations of low-level arsenic occurrence are only now becoming available through intensive efforts by USEPA and water utilities. These findings indicate that arsenic occurrence is highest for groundwater in the southwestern United States.

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<b>Article ID</b> 35	<b>Author</b> Hering, Janet G., Pen-Yuan Chen, Jennifer Wilkie, Menachem Elimelech, and Sun Liang
<b>Notecard #</b> 35-02	<b>Title</b> Arsenic Removal by Ferric Chloride
<b>Topic</b> Source(s) - Natural	<b>Date</b> April 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 156
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Naturally elevated arsenic concentrations are common in groundwaters of the western United States, particularly in geothermal waters and groundwaters in mining areas. Although the concentrations of arsenic in rivers and lakes are usually low (<1-40 ug/L), higher concentrations (up to several hundred micrograms per litre) occur in surface waters influenced by hydrothermal inputs, such as the tributaries to Lake Crowley in Mono County, Calif. Extremely elevated concentrations have been reported in alkaline lakes (e.g., up to 17 mg/L in Mono Lake).

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<b>Article ID</b> 37	<b>Author</b> Back, William
<b>Notecard #</b> 37-01	<b>Title</b> Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1966
<b>Constituent</b> Arsenic	<b>Page #</b> A1
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The ground-water flow pattern is the principal hydrologic control on the chemical character of the water. Within the coastal Plain sediments, the proportions of clay, glauconitic sand, and calcareous material are the principal lithologic controls over the chemistry of the water

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<b>Article ID</b> 37	<b>Author</b> Back, William
<b>Notecard #</b> 37-02	<b>Title</b> Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1966
<b>Constituent</b>	<b>Page #</b> A2
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** In any area the main factors that control the chemical character of ground water are the climate and vegetative cover, the mineral composition and physical properties of the rocks and soil through which the water circulates, and the relief of the land surface. . . . Other factors that affect the chemistry of the water are physical and chemical character of the soils through which the water percolates and the activity of microorganisms.

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**Article ID 37** **Author** Back, William  
**Notecard #** 37-03 **Title** Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain  
**Topic** Factors Affecting Geochemistry **Date** 1966  
**Constituent** **Page #** A2  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** The percentage of clay and the presence or absence of greensand [glauconitic sand] and calcareous sediments are believed to be the dominant controls on the chemistry of the water [of the Northern Atlantic Coastal Plain]. . . the general relationships and the relative amounts of clay, greensand, and calcareous sediments are representative of the regional variations.

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**Article ID 37** **Author** Back, William  
**Notecard #** 37-04 **Title** Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain  
**Topic** Factors Affecting Geochemistry **Date** 1966  
**Constituent** **Page #** A37  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** The primary controls on the dissolved-solids content of ground water are the chemical character of the water as it enters the zone of saturation; the distribution, solubility, and adsorption capacity of the minerals in the deposits; the porosity and permeability of rocks; and the flow path of the water.

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**Article ID 37** **Author** Back, William  
**Notecard #** 37-05 **Title** Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain  
**Topic** Factors Affecting Geochemistry **Date** 1966  
**Constituent** **Page #** A37  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** On the basis of the assumptions that chemical equilibrium has not been attained between the water and the minerals and that an excess of soluble material is available, the dissolved-solids content of the water increases and the chemical system tends to move closer to equilibrium as the flow path lengthens. A constant volume of water and a decrease in grain size of soluble material will result in a higher dissolved-solids content of a particular flow path. An increase in concentration due to smaller grain size results from two different effects: (1) the smaller grains of any soluble material will go into solution more readily than coarse grains of the same material, and (2) the smaller grain size causes a decrease in permeability that requires a longer residence time to traverse the same flow distance. Therefore, in an area of fine-grained material containing abundant soluble minerals, we would expect the water to have higher dissolved-solids content closer to the recharge area than it would have in an area of coarser sediments containing less soluble material.

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**Article ID 37** **Author** Back, William  
**Notecard #** 37-06 **Title** Hydrochemical Facies and Ground-Water Flow Patterns in Northern Part of Atlantic Coastal Plain  
**Topic** Factors Affecting Geochemistry **Date** 1966  
**Constituent** **Page #** A37  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** . . . the dissolved-solids content of water in any area increases when water from a different source, containing more dissolved ions, is introduced either by sea-water intrusion or by seepage of deeper brines.

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**Article ID** 39 **Author** Chen, Hsiao-wen and Marc Edwards  
**Notecard #** 39-02 **Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Topic** Geographic Location/Distribution **Date**  
**Constituent** Arsenic **Page #** 2  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** The highest total As concentrations were found in Alabama (68 ppb) and Oklahoma (117 ppb), respectively. Only one out of 189 surface water samples exceeded the current arsenic MCL while four out of 239 groundwater samples did so. If the arsenic MCL were lowered to 2 ppb, more than 28% of the sampled utilities would exceed the standard.

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**Article ID** 39 **Author** Chen, Hsiao-wen and Marc Edwards  
**Notecard #** 39-01 **Title** Arsenic Occurrence and Speciation in United States Drinking Waters: Implications for Water Utilities  
**Topic** Source(s) - Anthropogenic **Date**  
**Constituent** Arsenic **Page #** 1  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Naturally occurring arsenic is associated with sedimentary rocks, weathered volcanic rocks, and geothermal water. Mining activities expose arsenic-containing coals or ores, and smelting processes discharge arsenic wastes into natural water systems. Arsenic can also be introduced to the environment through application of arsenical pesticides.

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**Article ID** 41 **Author** SAIC  
**Notecard #** 41-15 **Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Topic** Other **Date** June 1, 1998  
**Constituent** Microbes **Page #** 2-13  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Giardia and Cryptosporidium  
**Notes** Environmental conditions contributing to the persistence of Giardia cysts are similar to those described for Cryptosporidium in Section 2.1.5. Surface water sources are more likely to be contaminated with Giardia than are ground water sources (Craun 1990). Marginally treated or untreated surface water supplies result in high risk of transmitting Giardia because cysts can survive for several months in cold waters, and relatively low numbers of Giardia are required for an infective dose (Craun 1990).

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**Article ID** 41 **Author** SAIC  
**Notecard #** 41-19 **Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Topic** Source(s) - Natural **Date** June 1, 1998  
**Constituent** Cryptosporidium **Page #** 5-42  
**Co-Occurrence?** No **Co-Occurrence Notes**

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**Notes** In Oregon, Cryptosporidium oocysts were detected at three sites:

- In a well drilled into basalt, Sebald (1997) reports that Cryptosporidium oocysts were found at 12 oocysts per 100 L. The well is located 80 feet from a river, is 55 feet deep, and is suspected to be linked to the river by a gravel conduit. Microscopic analyses were done after close correlations were observed between pH and turbidity values in the river and the well.
- At an infiltration gallery located 15 feet below a river, 11 presumptive Cryptosporidium oocysts occurrences have been reported (Salis 1997).
- Salis (1997) also reports the presence of Cryptosporidium oocysts (4.5/100 L) in a groundwater sample from a Ranney collector 87 feet deep and 50 feet away from the nearest surface water.

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**Article ID 41****Author** SAIC**Notecard #** 41-23**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule**Topic** Other**Date** June 1, 1998**Constituent** Microbes**Page #** 5-47**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Lee (1993) reported 9 confirmed giardiasis cases and several suspected cases associated with two wells in Lemont, Pennsylvania, in a community water system serving 1200 customers. All eight water samples from both wells were positive for Giardia cysts. One well is 304 feet deep and 95 feet from the stream; the other well is 323 feet deep and 45 feet from the stream. Both wells are drilled in Ordovician medium to thin-bedded limestones and dolomite that may be solution-enhanced (karst). Green algae, diatoms, and rotifers were other surface water indicators found (EPA 1994, Lee 1993).

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**Article ID 41****Author** SAIC**Notecard #** 41-22**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule**Topic** Other**Date** June 1, 1998**Constituent** Microbes**Page #** 5-43**Co-Occurrence?** Yes**Co-Occurrence Notes** Giardia and Cryptosporidium

**Notes** Hancock et al. (1998) performed statistical analyses of another data set [unpublished] to determine if correlations exist between the presence of Giardia, Cryptosporidium, and other surface water indicators in groundwater. A total of 383 groundwater samples were analyzed for Giardia, Cryptosporidium, and other microscopic particulates using EPA recommended [MPA and ICR] procedures. The presence of Giardia correlated with the presence of Cryptosporidium (Hancock et al. 1998). The presence of both pathogens correlated with the amount [of sample] examined but not with the month of sampling. There was a correlation between source depth and occurrence of Giardia but not Cryptosporidium.

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**Article ID 41****Author** SAIC**Notecard #** 41-21**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule**Topic** Other**Date** June 1, 1998**Constituent** Microbes**Page #** 5-43**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** EPA (1997b) reviewed the results of MPA determinations in various hydrogeological settings. Protozoa were detected in alluvial, karst, and other groundwater systems greater than 200 ft from surface water sources, and in basalt, alluvial, karst, and fissured bedrock wells at depths exceeding 200 ft (EPA 1997b).

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**Article ID 41****Author** SAIC**Notecard #** 41-20**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule**Topic** Other**Date** June 1, 1998**Constituent** Cryptosporidium**Page #** 5-43**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** All three boreholes [in a U.K. study] positive for Cryptosporidium were located in chalk aquifers; one was in an urban location, and all were located near rural catchments.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-01	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Source(s) - Natural	<b>Date</b> June 1, 1998
<b>Constituent</b> Cryptosporidium	<b>Page #</b> 2-6
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** . . . cryptosporidiosis infections tend to be seasonal, with a higher prevalence during the warmest, wettest months (Current 1986). In most areas of North America, Cryptosporidium generally becomes a concern in surface waters between March and June, when spring rains increase runoff and many newborn animals are present in the environment to amplify oocyst numbers [www-personal.ksu.edu/~coccidia/(August 1997)]. Microorganisms, along with other particulates that comprise the soil, can be suspended in this surface water and transported as surface runoff. The microorganisms (including parasitic protozoa) can be transported either as individual organisms, aggregates of organisms, or within an aggregate of soil particles and organisms.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-26	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Other	<b>Date</b> June 1, 1998
<b>Constituent</b> Microbes	<b>Page #</b> 5-54
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Diehl (undated) reports 11 occurrences of Giardia in Pennsylvania. Groundwater monitoring data show that detection sites included two vertical wells, one infiltration gallery, and five springs (Lee 1993, Pennsylvania Department of the Environment 1997, Conrad 1997, Deihl 1997, Fridirici 1997). Concentrations at these sites ranged from 0.3 cysts/100 L to 5.5 cysts/100 L. EPA reports Giardia concentrations of 1 cyst/100 gallons from an infiltration gallery, and 3 cysts per 100 gallons in a gravel well that was flooded.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-16	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Seasonal Variation	<b>Date</b> June 1, 1998
<b>Constituent</b> Microbes	<b>Page #</b> 2-13
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Giardia cysts survive relatively long periods in water, particularly at temperatures below 20 oC; above 20 oC, cyst inactivation is rather rapid (Jakubowski 1990). Evidence suggests that Giardia cysts in fresh water survive best at 4 to 8 oC (Jakubowski 1990).

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-14	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Distribution/Transport in Soil Profile	<b>Date</b> June 1, 1998
<b>Constituent</b> Microbes	<b>Page #</b> 2-13
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> Giardia and Cryptosporidium

**Notes** With the exception of the Hancock et al. (1998) investigation discussed in Sect. 2.1.4.2., no information is available to contrast the differing transport of Giardia cysts versus Cryptosporidium oocysts through soils or sediments to groundwater, with or without the presence of macropores, fractures, or conduits. It is likely that the difference in size and any possible difference in charge between the two could affect the relative rate of transport of each through soils, sediments, and aquifer materials. Mikels (1992) found that no Giardia were recovered from collector wells constructed in alluvial river valleys, although Giardia were detected in adjacent rivers. In addition, no insects, other macroorganisms, or other large-diameter pathogens were present in the water from the collector wells.

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**Article ID** 41  
**Notecard #** 41-17  
**Topic** Other  
**Constituent** Microbes  
**Co-Occurrence?** Yes  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #** 4-4  
**Co-Occurrence Notes** Giardia and Cryptosporidium  
**Notes** Studies of North American watersheds have documented background levels of contamination by Cryptosporidium oocysts and Giardia cysts (Ongerth and Stibbs 1987, Rose 1988, Isaac-Renton et al. 1994, Hansen and Ongerth 1991, LeChevallier et al. 1991b, LeChevallier and Norton 1995). Oocyst and cyst concentrations in source waters and treated water have been shown to vary with human activities in the watershed and seasonal variations in storm water runoff and production (shedding) of oocysts by animals of human users of the watershed (Hansen and Ongerth 1991). Even protected watersheds (e.g., reservoirs where human activity is prohibited or limited) will typically contain a low concentration of oocysts and cysts because infected wild animals cannot be excluded from these areas (Hansen and Ongerth 1991).

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**Article ID** 41  
**Notecard #** 41-18  
**Topic** Other  
**Constituent** Cryptosporidium  
**Co-Occurrence?** No  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #** 5-23  
**Co-Occurrence Notes**  
**Notes** Outbreaks of cryptosporidiosis in drinking water supplies using groundwater as a source indicate that these systems were under the direct influence of surface water (EPA 1994). . . In outbreaks where groundwater is not adequately treated, contamination can occur from sewage overflow and seepage, surface water runoff, streams and rivers, and through limestone and fissured rock (Craun and Calderon 1996).

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**Article ID** 41  
**Notecard #** 41-02  
**Topic** Other  
**Constituent** Microbes  
**Co-Occurrence?** Yes  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #** 2-6  
**Co-Occurrence Notes** cryptosporidium and giardia  
**Notes** Recently, LeChevallier et al. (1997a) and Stewart et al. (1997a) studied the effects of runoff events on Cryptosporidium and Giardia density and found the greatest protozoan densities were detected during the "first flush" following a precipitation event or peak source water turbidity spike.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-06	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Distribution/Transport in Soil Profile	<b>Date</b> June 1, 1998
<b>Constituent</b> Cryptosporidium	<b>Page #</b> 2-8
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** To understand the likelihood that oocysts could be transported through soil to groundwater, Mawdsley et al. (1996) studied transport of *Cryptosporidium parvum* oocysts through three soil types. Oocysts were detected in leachate (water collected from the bottom of the soil column) from intact soil columns following a 21-day irrigation period. Although most (72.8 percent) of the oocysts were found in the top 2 cm of soil, 5.36 percent were found at soil depths of 30 cm. *C. parvum* transport through soil was greater in a silty loam and a clay loam soil than in a loamy sand soil. Evidence suggests that the extent of adsorption is greater and the size of micropores is smaller in clay than in sandy soils, so the results suggest that factors other than adsorption and micropore size influenced the oocyst movement. . . [The authors] conclude that the rapid flow of water through macropores, which are representative of natural field conditions, largely bypasses the filtering and adsorptive effects of the soil, greatly increasing the risk of pathogen transport to groundwater (Mawdsley et al. 1996).

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-13	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Source(s) - Natural	<b>Date</b> June 1, 1998
<b>Constituent</b> Microbes	<b>Page #</b> 2-12
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** . . . *Giardia* are ubiquitous in the environment, have a number of mammalian reservoir hosts in addition to humans, and are resistant to environmental exposures. Their occurrence and persistence in surface water, even pristine water samples, allow transport significant distances by entrainment within flowing water (Hurst 1997, Roach et al. 1993).

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-12	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Distribution/Transport in Soil Profile	<b>Date</b> June 1, 1998
<b>Constituent</b> Microbes	<b>Page #</b> 2-12
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> <i>Giardia</i> and <i>Cryptosporidium</i>

**Notes** The factors that influence the transport of *Giardia* in the environment are the same as those affecting *Cryptosporidium*: adsorption, filtration, and sedimentation. The other main feature affecting transport of *Giardia*, especially in soil and aquifer materials, is its size. The *Giardia* cyst size is 8 to 12  $\mu\text{m}$  in diameter, larger than the 4- to 6- $\mu\text{m}$  *Cryptosporidium* oocyst. The larger size of the cyst potentially restricts movement through some soils and aquifer materials, except in the presence of natural pathways such as macropores, fractures, and conduits. As with *Cryptosporidium*, *Giardia* cysts in feces deposited on soil surfaces are readily transported during rainfall by surface runoff into surface water and, perhaps, in some hydrogeologic settings, to groundwater.

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|-----------------------------|--|
| <b>Article ID</b> 41        | <b>Author</b> SAIC   |
| <b>Notecard #</b> 41-11     | <b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule |
| <b>Topic</b> Other          | <b>Date</b> June 1, 1998   |
| <b>Constituent</b> Microbes | <b>Page #</b> 2-10   |
| <b>Co-Occurrence?</b> No    | <b>Co-Occurrence Notes</b>   |
- Notes** Microorganisms are inactivated in soil at rates that vary with the degree of predation by other microorganisms, the amount of sunlight, and the physical and chemical composition of the soil, including moisture content, pH, and temperature (Gerba et al. 1975, Kowal 1985).
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|---|--|
| <b>Article ID</b> 41                                | <b>Author</b> SAIC   |
| <b>Notecard #</b> 41-10                             | <b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule |
| <b>Topic</b> Distribution/Transport in Soil Profile | <b>Date</b> June 1, 1998   |
| <b>Constituent</b> Cryptosporidium                  | <b>Page #</b> 2-9  |
| <b>Co-Occurrence?</b> No                            | <b>Co-Occurrence Notes</b>   |
- Notes** Damault et al. (1997) are studying preferential flow paths of *C. parvum* through several different media: glass bead columns, sand columns, and disturbed and undisturbed soil columns. Results indicate that *C. parvum* can flow rapidly through the vadose zone (Damault et al. 1997).
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| <b>Article ID</b> 41                                | <b>Author</b> SAIC   |
| <b>Notecard #</b> 41-09                             | <b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule |
| <b>Topic</b> Distribution/Transport in Soil Profile | <b>Date</b> June 1, 1998   |
| <b>Constituent</b> Microbes                         | <b>Page #</b> 2-9  |
| <b>Co-Occurrence?</b> No                            | <b>Co-Occurrence Notes</b>   |
- Notes** Harvey et al. (1995) modeled the transport of protozoa in groundwater systems, using free-living flagellates (2 to 3 um in situ) and microspheres 0.7 to 6.2 um in size. They noted that physical straining was not of major importance in porous media, such as coarse sands, with grain diameter greater than 100 um. Adsorption or adherence to surfaces appeared to be reversible.
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|-----------------------------|--|
| <b>Article ID</b> 41        | <b>Author</b> SAIC   |
| <b>Notecard #</b> 41-24     | <b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule |
| <b>Topic</b> Other          | <b>Date</b> June 1, 1998   |
| <b>Constituent</b> Microbes | <b>Page #</b> 5-51   |
| <b>Co-Occurrence?</b> Yes   | <b>Co-Occurrence Notes</b> Giardia and Cryptosporidium   |
- Notes** Rose (1988) detected Giardia cysts at a concentration of 0.29 cysts/L in 1 of 6 samples collected at a protected watershed with poor water quality based on standard indicators (turbidity and total coliforms). A second watershed of better water quality based on the indicators contained only 0.006 cysts/L (Rose 1988). Giardia cysts were also detected in 12 of 39 samples collected during a biweekly survey of a watershed in the western United States over a 1-year period (Rose et al. 1988 a,b). Sampling was conducted in a lake receiving sewage effluents, and in a river downstream from the lake running through an area where there were a number of cattle pastures. Mean cyst concentrations by season were 0.35, 0.31, 0.007, and 0.001 cysts/L, for the summer, fall, winter, and spring, respectively. Giardia cyst concentrations were significantly correlated with Cryptosporidium oocyst levels, but there were no significant correlations observed between cyst concentrations and either total or fecal coliforms or turbidity.
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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-07	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Distribution/Transport in Soil Profile	<b>Date</b> June 1, 1998
<b>Constituent</b> Cryptosporidium	<b>Page #</b> 2-8
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** . . . little information is available to identify which hydrogeologic settings are sensitive to [Cryptosporidium] oocyst contamination because groundwater flow and oocyst transport through fractures or dissolution conduits effectively bypass the protective action of most of the aquifer matrix.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-25	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> June 1, 1998
<b>Constituent</b> Microbes	<b>Page #</b> 5-54
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Hacock et al. (1997) sampled groundwater from 199 sites located in 23 of the contiguous 48 states in the U.S. They detected Giardia in 1 percent (2/149) of the vertical wells; 14 percent (5/35) of the springs; 25 percent (1/4) of the infiltration galleries; and 36 percent (4/11) of the horizontal wells. Rosen et al. (1996) reported 2 of 17 samples positive for Giardia in sources classified as GWUDI. Hibler (1998) found Giardia in 14 percent (5/36) of springs, 5 percent (2/40) of wells, and 31 percent (5/16) of infiltration galleries.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-05	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Other	<b>Date</b> June 1, 1998
<b>Constituent</b> Cryptosporidium	<b>Page #</b> 2-7
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The tendency of microorganisms to adsorb onto suspended particles facilitates the sedimentation of those organisms during periods of low water flow or low runoff. Those sediments then serve as reservoirs from which the organisms can be resuspended during periods of intense rainfall and/or flooding (Wilkinson et al. 1995). For example, oocysts in feces deposited on soil surfaces are readily transported during rainfall by surface runoff into surface water. In addition, during periods of increased source water turbidity and elevated flow, source water densities of Cryptosporidium were elevated compared with normal conditions (LeChevallier et al. 1997a). Whether this was due to runoff or resuspension of sediment from scouring effects was not determined, but the results suggest the potential for contribution of Cryptosporidium oocysts by sediment resuspension.

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<b>Article ID</b> 41	<b>Author</b> SAIC
<b>Notecard #</b> 41-04	<b>Title</b> Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule
<b>Topic</b> Distribution/Transport in Soil Profile	<b>Date</b> June 1, 1998
<b>Constituent</b> Cryptosporidium	<b>Page #</b> 2-6
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Cryptosporidium can be transported not only in surface runoff, but also through soil and groundwater or land drains to surface water (Mawdsley et al. 1996, Hurst 1997). Movement of Cryptosporidium parvum through soil and groundwater is influenced by filtration, adsorption to soil and aquifer matrix particles by processes that are governed primarily by the magnitude and distribution of the electrical charge on the organism and the surrounding soil and aquifer matrix, and sedimentation within soil or aquifer pores.

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**Article ID 41**  
**Notecard # 41-03**  
**Topic** Source(s) - Anthropogenic  
**Constituent** Cryptosporidium  
**Co-Occurrence?** No  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #** 2-6  
**Co-Occurrence Notes**  
**Notes** Surface transport of oocysts is affected by rainfall and other seasonal factors. The character (topography, plant cover) and uses (urban, farming) of a watershed also influence the occurrence or concentration of Cryptosporidium in surface water (Hansen and Ongerth 1991). For example, a mountainous forested watershed with little or no human activity had the lowest surface water oocyst concentrations and oocyst production, while downstream sample sites influenced by dairy farming and urban runoff had oocyst concentrations and production rates almost 10 times higher than the upstream sites (Hansen and Ongerth 1991).

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**Article ID 41**  
**Notecard # 41-29**  
**Topic**  
**Constituent**  
**Co-Occurrence?**  
**Notes**  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #**  
**Co-Occurrence Notes**

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**Article ID 41**  
**Notecard # 41-28**  
**Topic** Other  
**Constituent** Microbes  
**Co-Occurrence?** No  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #** 5-57  
**Co-Occurrence Notes**  
**Notes** IN Massachusetts, Smith (1997) reported two Giardia occurrences in wells. At one site, 3.1 cysts per 100 gallons were found in a caisson well 24 feet deep and 50 feet away from surface water. At another location, one unconfirmed cyst per 100 L was found in a rock well 90 feet deep and 50 feet away from the nearest surface water body.

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**Article ID 41**  
**Notecard # 41-27**  
**Topic** Other  
**Constituent** Microbes  
**Co-Occurrence?** No  
**Author** SAIC  
**Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Date** June 1, 1998  
**Page #** 5-54  
**Co-Occurrence Notes**  
**Notes** Giardia cysts also were found at three sites in Oregon with Cryptosporidium oocyst occurrences previously discussed in Section 5.2.2.2. These three sites were a 55-foot deep basalt well, an infiltration gallery, and a Ranney collector. In the basalt well, Giardia cysts were detected at 4 cysts per 100 gallons (Sebald 1997). Two samples collected from the infiltration gallery were found to have presumptive Giardia cysts (2/100 L and 22.6/100 L), and the Ranney collector had an unconfirmed occurrence of 9.1 Giardia cysts per 100 gallons (Salis 1997).



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**Article ID** 41 **Author** SAIC  
**Notecard #** 41-08 **Title** Cryptosporidium and Giardia Occurrence Assessment for the Interim Enhanced Surface Water Treatment Rule  
**Topic** Other **Date** June 1, 1998  
**Constituent** Microbes **Page #** 2-8  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Giardia and Cryptosporidium

**Notes** Hancock et al. investigated the correlation of Cryptosporidium and Giardia occurrence in groundwater with surface water indicators. The presence of Giardia correlated with the presence of Cryptosporidium. Occurrence of Giardia was correlated with source depth, but there was no correlation between Cryptosporidium occurrence and source depth. There was a correlation between general risk categories of low, moderate, and high and the occurrence of Cryptosporidium and Giardia [data not yet available]. However, there was no correlation between the distance of the groundwater source from adjacent surface water and either pathogen.

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**Article ID** 42 **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard #** 42-16 **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic** Source(s) - Natural **Date** 1973  
**Constituent** Arsenic **Page #** 264  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Probably all plants and animals contain arsenic, but the levels are normally low. . .

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**Article ID** 42 **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard #** 42-07 **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic** Factors Affecting Geochemistry **Date** 1973  
**Constituent** Arsenic **Page #** 253  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Among the igneous rocks there is relatively little difference in the arsenic content between the various types. . . Among the sedimentary rocks the shales and argillites contain the most arsenic. This is particularly true of the pyritiferous types and phosphorites. Iron-rich rocks show wide variations in their arsenic content. . . The arsenic content of iron-rich rocks appears to depend on the availability of arsenic in the waters supplied to the basins of sedimentation.

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**Article ID** 42 **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard #** 42-08 **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic** Other **Date** 1973  
**Constituent** Arsenic **Page #** 255  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Stream, river, and lake sediments vary widely in their arsenic contents, depending essentially on their proximity to arsenic-bearing rocks and deposits. Some representative values from Canadian occurrences. . . higher than 25 ppm As are invariably associated with arsenic-bearing rocks and deposits. In Recent stream, river, and lake sediments, there is often a direct relationship between the arsenic content and the iron oxide and organic (carbon) content, the first a result of strong adsorption and absorption processes and the second probably due to chelation and/or metal-organic binding of arsenic.

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<b>Article ID</b> 42	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard #</b> 42-10	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 258
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<b>Notes</b> . . .sediments, particularly the graphitic and pyritiferous types, contain the largest amounts of arsenic, and that most igneous rocks are relatively low in the element. In these studies we have found that the bulk of arsenic in igneous, sedimentary, and metamorphic rocks occurs in pyrite.	

<b>Article ID</b> 42	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard #</b> 42-11	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 262
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<b>Notes</b> The arsenic content of normal soils and glacial materials is low except in the vicinity of deposits containing the element.	

**Final Draft**

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**Article ID 42** **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard # 42-13** **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic Source(s) - Natural** **Date** 1973  
**Constituent Arsenic** **Page #** 264  
**Co-Occurrence? No** **Co-Occurrence Notes**  
**Notes** The oceans and seas average about 2 ppb As. The nature of this arsenic is poorly characterized.

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**Article ID 42** **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard # 42-21** **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic Other** **Date** 1973  
**Constituent Arsenic** **Page #** 278  
**Co-Occurrence? Yes** **Co-Occurrence Notes** Arsenic, cadmium, mercury, uranium, antimony, nickel, selenium

**Notes** Arsenic is a particularly good indicator in most types of geochemical surveys, not only for deposits containing the element as an economic product, but also for many other types of mineral deposits enriched in a great variety of metals. The most common elemental associates of arsenic are Cu, Ag, Au, Zn, Cd, Hg, U, Sn, Pb, P, Sb, Bi, Mo, W, Fe, Co, Ni, Pt metals, Se, and S. There is a particularly marked coherence between arsenic and gold in practically all types of gold deposits. This coherence also extends to silver in all of its deposits and is greatly accentuated in the native silver variety containing nickel and cobalt (Cobalt type). There is frequently a close relationship between arsenic, antimony, and bismuth in many deposits. Arsenic may accompany copper, zinc, mercury, tin, lead, molybdenum, tungsten, iron, cobalt, nickel, and the platinum minerals in most types of their deposits and can often serve as a valuable indicator for those metals. Certain types of uranium deposits, particularly those enriched in the Ni-Co arsenides (Jachymov-Great Bear Lake type) are markedly enriched in arsenic. Even some uranium deposits in sandstones (Colorado Plateau type) have higher than average amounts of arsenic, mainly in pyrite.

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**Article ID 42** **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard # 42-15** **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic Source(s) - Natural** **Date** 1973  
**Constituent Arsenic** **Page #** 264  
**Co-Occurrence? No** **Co-Occurrence Notes**  
**Notes** The content of arsenic in rainwater and snow averages about 1 ppb, much of which is contributed by the burning of coal, petroleum products, and smelting processes in domestic and industrial areas. . . Volcanic gases tend to be rich in arsenic and these contribute considerable amounts of the element to the atmosphere in volcanic belts.

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**Article ID 42** **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard # 42-02** **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic Other** **Date** 1973  
**Constituent Arsenic** **Page #** 252  
**Co-Occurrence? No** **Co-Occurrence Notes**  
**Notes** The element most commonly associated with arsenic in nature is sulphur.

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<b>Article ID</b> 42	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard #</b> 42-17	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 268
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic is widely diffused in many types of mineral deposits in trace, minor, and major amounts. It tends to be concentrated in those deposits containing sulphides, either as separate arsenic minerals or as a minor or trace constituent of a great number of sulphides and sulpho-salts.

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<b>Article ID</b> 42	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard #</b> 42-18	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 268
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The principal types of deposits in which arsenic is a constituent are as follows:

- (1) Copper shale, argillite, and schist deposits (Kupferschiefer-White Pine-Zambia type). . .
- (2) Copper (uranium, vanadium, silver) sandstone deposits ('Red bed' type). . .
- (3) Lead-zinc deposits in carbonate rocks (Mississippi Valley-Pine Point type). . .
- (4) Pyritiferous quartz-pebble conglomerates and quartzites enriched in one or more of gold, silver, uranium, thorium, and rare earths (Witwatersrand-Blaine River type). . .
- (5) Native copper deposits in or associated with amygdaloidal basalts (Keweenaw, Michigan type). . .
- (6) Skarn type deposits. . .
- (7) Pegmatites and pegmatite-like bodies enriched in one or more of Sn, W, Nb, Ta, Bi, Mo, and U. . .
- (8) Massive bodies, mantos, lodes, veins and stockworks. . .
- (8a) Massive nickel-copper sulphide bodies commonly associated with basic rocks (Sudbury type). . .
- (8b) Massive Cu-Zn-Pb sulphide bodies in volcanic and sedimentary terranes (Noranda-Flin Flon-Bathurst type). . .
- (8c) Veins, lodes, and stockworks principally in granitic rocks and associated sediments and greatly enriched in one or more of Sn, W, Bi, and Mo. . .
- (8d) Various polymetallic veins, stockworks, mantos, and lodes containing essentially Cu, Ag, Pb, Au, and Fe sulphides and sulpho-salts. . .
- (8e) Veins greatly enriched in Ni, Co, As, Sb, Ag, Bi, and U (Cobalt-Great Bear Lake-Jachymov type). . .
- (8f) Gold-quartz veins, stockworks, and silicified zones. . .
- (8g) Realgar-orpiment deposits. . .
- (9) Mercury deposits. . .
- (10) Disseminated bodies in various rocks. . .
- (10a) Disseminated gold deposits, mainly in sedimentary rocks. . .
- (10b) Disseminated (porphyry) copper and/or molybdenum deposits. . .

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<b>Article ID</b> 42	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard #</b> 42-19	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 272
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** In endogene processes arsenic and arsenic compounds may reach their sites of deposition in fractures, faults, and chemically receptive rocks, in the vapour state, in solutions, or by a variety of diffusion mechanisms.

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<b>Article ID 42</b>	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard # 42-01</b>	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Other	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 251
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> Arsenic, cadmium, mercury, uranium, antimony, selenium, nickel

**Notes** Arsenic is widely diffused in nature and is concentrated in many types of mineral deposits, particularly those containing sulphides and sulpho-salts. It accompanies many elements in their deposits including Cu, Ag, Au, Zn, Cd, Hg, U, Sn, Pb, P, Sb, Bi, S, Se, Te, Mo, W, Fe, Ni, Co, and Pt metals. Arsenic is, therefore, a good indicator in geochemical prospecting for some twenty elements of commercial importance.

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<b>Article ID 42</b>	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard # 42-20</b>	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 275
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** During the weathering of rocks and deposits containing arsenic the element enters the exogene (surficial) cycle mainly as soluble arsenates in which the element is in the (V) oxidation state.

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<b>Article ID 42</b>	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard # 42-05</b>	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 253
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The principal carrier of arsenic in rocks and in many types of mineral deposits is pyrite, FeS<sub>2</sub>. This mineral may contain up to 6,000 ppm or more As, the element being apparently present in lattice sites substituting for sulphur.

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<b>Article ID 42</b>	<b>Author</b> Boyle, R.W., and I.R. Jonasson
<b>Notecard # 42-04</b>	<b>Title</b> The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting
<b>Topic</b> Constituent Species	<b>Date</b> 1973
<b>Constituent</b> Arsenic	<b>Page #</b> 252
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The principal arsenic minerals in endogene (hypogene) deposits are arsenopyrite, niccolite, cobaltite, tennantite, enargite, native arsenic, orpiment, realgar, and proustite. . . The principal supergene minerals, formed as a result of oxidation of the hypogene sulphides, sulpho-salts, etc., are scorodite, beudantite, olivenite, mimetite, arsenolite, erythrite, and annabergite.

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**Article ID** 42 **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard #** 42-14 **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic** Other **Date** 1973  
**Constituent** Arsenic **Page #** 264  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** With respect to pH, both acid and alkaline waters contain arsenic, mainly because of the amphoteric nature of the element.

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**Article ID** 42 **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard #** 42-03 **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic** Factors Affecting Geochemistry **Date** 1973  
**Constituent** Arsenic **Page #** 252  
**Co-Occurrence?** Yes **Co-Occurrence Notes** arsenic, sulfate (?), mercury  
**Notes** Native arsenic is relatively common in certain types of mineral deposits despite the fact that the element has a marked chalcophile character forming sulphides and a great variety of sulpho-salts, particularly with the metals Cu, Ag, Zn, Hg, Pb, and Fe. The most common of these sulpho-salts is tetrahedrite-tennantite with the complex formula  $(\text{Cu, Fe, Zn, Cd, Bi, Hg, Ag})_{12}(\text{Sb, As, Bi})_4\text{S}_{13}$ . Arsenic forms oxides and complex oxides in nature, and other complex oxygen salts of the element. The biophile character of arsenic is manifest by its presence, usually in small amounts, in a wide variety of living organisms and their fossil equivalents.

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**Article ID** 42 **Author** Boyle, R.W., and I.R. Jonasson  
**Notecard #** 42-06 **Title** The Geochemistry of Arsenic and Its Use as an Indicator Element in Geochemical Prospecting  
**Topic** Other **Date** 1973  
**Constituent** Arsenic **Page #** 253  
**Co-Occurrence?** Yes **Co-Occurrence Notes** arsenic and antimony  
**Notes** The terrestrial abundance of arsenic and antimony is of the order of 3 ppm and 0.7 ppm respectively as calculated from the available data. The As/Sb ratio in terrestrial rocks is therefore, approximately 4.3.

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**Article ID** 43 **Author** Steinheimer, Thomas R., Kenwood D. Scoggin, and Larry A. Kramer  
**Notecard #** 43-02 **Title** Agricultural Chemical Movement through a Field-Size Watershed in Iowa: Subsurface Hydrology and Distribution of Nitrate in Groundwater  
**Topic** Factors Affecting Geochemistry **Date** April 15, 1998  
**Constituent** Nitrate **Page #** 1043  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** During the past 25 years, numerous studies have shown a direct relationship between nitrate concentration in groundwater and nitrogen fertilization rates and/or fertilization history on agricultural landscapes. Nitrate concentration in groundwater under forest, unfertilized (or low-level fertilized) landscapes, pastures, meadows, and grasslands are generally cited as <2 mg/L nitrate and often <1 mg/L, whereas nitrate concentrations beneath fertilized crops and/or animal production areas are commonly >10 mg/L and may range to >100 mg/L.

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**Article ID** 43 **Author** Steinheimer, Thomas R., Kenwood D. Scoggin, and Larry A. Kramer

**Notecard #** 43-03 **Title** Agricultural Chemical Movement through a Field-Size Watershed in Iowa: Subsurface Hydrology and Distribution of Nitrate in Groundwater

**Topic** Factors Affecting Geochemistry **Date** April 15, 1998

**Constituent** Nitrate **Page #** 1043

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Mitigation of the nitrate-nitrogen load in soil and groundwater may be achieved through combinations of heterotrophic denitrification, autotrophic denitrification, or dissimilatory nitrate reduction to ammonium ion. Heterotrophic and autotrophic bacteria are distinguished by their source of electron-donor species; heterotrophs requiring organic carbon and autotrophs utilizing inorganic species. Dissimilatory nitrate reduction produces ammonium ion as the end product. It is regulated by oxygen and usually only observed in electron-rich environments.

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**Article ID** 43 **Author** Steinheimer, Thomas R., Kenwood D. Scoggin, and Larry A. Kramer

**Notecard #** 43-01 **Title** Agricultural Chemical Movement through a Field-Size Watershed in Iowa: Subsurface Hydrology and Distribution of Nitrate in Groundwater

**Topic** Factors Affecting Geochemistry **Date** April 15, 1998

**Constituent** Nitrate **Page #** 1043

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** The high concentration of nitrate at the 6-8 m depth in the unsaturated loess of the ridge top suggests that substantial leaching occurs beneath these landscape positions. The mid-valley, toe-slope position (L3-3) generally shows the highest concentration nearer the surface at the 3 m depth. At L3-3 the soil-pore water nitrate concentration was appreciably lower than that at the ridge tops at the 4-6 m depth. The lysimeter nest in the valley position (L3-2), which is nearest to the shallow water table, reveals the lowest nitrate concentration. At depths below the root zone, the distribution of nitrate in soil pore water varies by landscape position. Maxima at depths below 6 m on both ridge tops suggests that soil pore water is a major source of the nitrate-nitrogen load transported to the headcut in groundwater.

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**Article ID** 43 **Author** Steinheimer, Thomas R., Kenwood D. Scoggin, and Larry A. Kramer

**Notecard #** 43-05 **Title** Agricultural Chemical Movement through a Field-Size Watershed in Iowa: Subsurface Hydrology and Distribution of Nitrate in Groundwater

**Topic** Factors Affecting Geochemistry **Date** April 15, 1998

**Constituent** Nitrate **Page #** 1046

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Many variables influence the resultant concentration of nitrate detected in groundwater beneath intensively fertilized agricultural landscapes. However, over the long-term, three seem to be dominant: the amount of source nitrogen that is available, the amount of infiltrating or percolating water (determined by the hydraulic properties of the soil), and the potential for reduction of nitrate and/or denitrification. The first variable is determined by application rate together with the amount deposited by rainfall less that removed in runoff; the second factor is governed by the transmissivity and water-storage capacity of the soil; and the third is determined largely by the soil biomass.

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- Article ID 43** **Author** Steinheimer, Thomas R., Kenwood D. Scoggin, and Larry A. Kramer
- Notecard # 43-04** **Title** Agricultural Chemical Movement through a Field-Size Watershed in Iowa: Subsurface Hydrology and Distribution of Nitrate in Groundwater
- Topic** Seasonal Variation **Date** April 15, 1998
- Constituent** Nitrate **Page #** 1045
- Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** Variability of nitrate concentration at the same sampling time among all seven wells results from the differences in the time lag required for the movement of a parcel of percolated water and by the timing of fertilizer application. Early spring or late fall infiltration from snowmelt or light rainfall may move only a portion of the mass of nitrate-nitrogen through the vadose zone into the saturated loess. Conversely, rainfall following a mid-spring application of fertilizer could infiltrate an appreciable fraction of it through the unsaturated zone.
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- Article ID 44** **Author** Wilkie, Jennifer A., and Janet G. Hering
- Notecard # 44-02** **Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada
- Topic** Factors Affecting Geochemistry **Date** 1998
- Constituent** Arsenic **Page #** 659
- Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** The in-stream oxidation rate observed along Hot creek is substantially greater than those reported for other nongeochemical systems. On the basis of the estimated flow velocity of 0.4 m/s, a pseudo-first-order half-life of 0.3 h was calculated for As(III) oxidation. Oxidation observed in sediment and water samples collected from nongeochemical systems has been attributed to both biological and abiotic processes. In general, calculated pseudo-first-order half-lives for As(III) oxidation ranged from 6 to 13 h, however, a value on the order of 0.5 h was observed for one soil isolate of bacteria. Abiotic oxidation has been attributed to manganese oxides in several natural systems. Rates reported for As(III) oxidation by synthetic manganese oxides varied widely with half-lives between 0.15 and 203 h. Rapid oxidation of As(III) has previously been reported in the Azure Spring drainage in Yellowstone National Park and in pipelines at geothermal power stations but these rates were not quantified.
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- Article ID 44** **Author** Wilkie, Jennifer A., and Janet G. Hering
- Notecard # 44-06** **Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada
- Topic** Other **Date** 1998
- Constituent** Arsenic **Page #** 661
- Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** The lack of oxidation found in batch studies conducted after sterile filtration of the sample or after the addition of antibiotics to the reactor strongly suggests that bacteria attached to submerged macrophytes are mediating As(III) oxidation in Hot Creek Below the gorge boundary where the plants are abundant.
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**Article ID** 44 **Author** Wilkie, Jennifer A., and Janet G. Hering  
**Notecard #** 44-04 **Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada  
**Topic** Other **Date** 1998  
**Constituent** Arsenic **Page #** 659  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Spatial variations in simultaneously collected samples were examined at several locations along Hot Creek. Within the gorge, significant cross-sectional variations were observed for total As concentrations, which ranged from 1.14 to 2.04 uM. This result is consistent with geothermal inputs in the stream bed. Variability in Cl concentration paralleled total As with values between 0.50 and 0.76 mM. The fraction of As(III), however, was relatively constant among the samples at 41%.

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**Article ID** 44 **Author** Wilkie, Jennifer A., and Janet G. Hering  
**Notecard #** 44-05 **Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada  
**Topic** Other **Date** 1998  
**Constituent** Arsenic **Page #** 660  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** These results suggest that aquatic macrophytes or some component associated with the plants are responsible for the rapid As(III) oxidation occurring within Hot Creek.

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**Article ID** 44 **Author** Wilkie, Jennifer A., and Janet G. Hering  
**Notecard #** 44-01 **Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada  
**Topic** Factors Affecting Geochemistry **Date** 1998  
**Constituent** Arsenic **Page #** 657  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** The concentration and speciation of As in the aquatic environment are governed by numerous biogeochemical processes, which may be abiotic or biologically mediated. Inorganic As species usually predominate in surface waters, although methylated species may become dominant in epilimnetic waters overlying a suboxic hypolimnion. Of the inorganic species, As(V) is thermodynamically stable under oxic conditions, and As(III) predominates under reducing conditions. As(III), however, may be present as a metastable species in oxic environments as a result of slow oxidation kinetics and biologically mediated reactions.

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**Article ID** 44 **Author** Wilkie, Jennifer A., and Janet G. Hering  
**Notecard #** 44-03 **Title** Rapid Oxidation of Geothermal Arsenic (III) in Streamwaters of the Eastern Sierra Nevada  
**Topic** Factors Affecting Geochemistry **Date** 1998  
**Constituent** Arsenic **Page #** 659  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Variable As(III)/As(V) ratios have been observed in other geothermal systems and attributed to processes including cooling, mixing with surficial water, and water-rock interactions; however, no clear correlation could be made between %As(III) and temperature. Our data are consistent with the extent of oxidation being related to residence time within the hot spring pool with lower pool temperatures associated with longer residence time and an increased fraction of oxidized As.

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**Article ID** 45**Notecard #** 45-01**Topic** Other**Constituent** Arsenic**Co-Occurrence?** No**Author** Frey, Michelle M. and Marc A. Edwards**Title** Surveying Arsenic Occurrence in US Drinking Water**Date** March 1997**Page #** 107**Co-Occurrence Notes**

**Notes** Arsenic is a naturally occurring contaminant and exhibits localized trends in occurrence based on specific geophysical and chemical properties of a region. Thus, the likelihood of arsenic occurrence in water supplies must consider both the geographic location and the type of water source (i.e., groundwater versus surface water).

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**Article ID** 45**Notecard #** 45-02**Topic** Other**Constituent** Arsenic**Co-Occurrence?** No**Author** Frey, Michelle M. and Marc A. Edwards**Title** Surveying Arsenic Occurrence in US Drinking Water**Date** March 1997**Page #** 111**Co-Occurrence Notes**

**Notes** In general, groundwater systems had higher levels of arsenic than did surface water supplies. For groundwater sources, the fraction of PSWs finding arsenic concentrations >5 ug/L ranged from 16 to 46 percent, whereas surface water sources rarely found arsenic concentrations >5 ug/L (0 - 11 percent). The majority of PWSs sampled – 53 - 71 percent of groundwater sources and 61 - 68 percent of surface water sources – had arsenic concentrations <2 ug/L.

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**Article ID** 45**Notecard #** 45-04**Topic** Other**Constituent** Arsenic**Co-Occurrence?** No**Author** Frey, Michelle M. and Marc A. Edwards**Title** Surveying Arsenic Occurrence in US Drinking Water**Date** March 1997**Page #** 116**Co-Occurrence Notes**

**Notes** -Overall, higher concentrations of arsenic are present in groundwater sources compared with surface water sources. Nonetheless, surface water supplies detected arsenic more frequently than groundwater systems.  
-Low-level arsenic occurrence in US source waters is prevalent, with more than half of the groundwater and surface water sources showing detectable arsenic (>0.5 ug/L). The majority of water sources – 53-71 percent of groundwater sources and 61 - 88 percent of surface water sources – were found to have arsenic present below 2 ug/L.  
-Regional trends in arsenic occurrence were found for both surface water and groundwater sources, with higher concentrations of arsenic in the south central and more western states.

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**Article ID** 45**Notecard #** 45-03**Topic** Geographic Location/Distribution**Constituent** Arsenic**Co-Occurrence?** No**Author** Frey, Michelle M. and Marc A. Edwards**Title** Surveying Arsenic Occurrence in US Drinking Water**Date** March 1997**Page #** 112**Co-Occurrence Notes**

**Notes** Consistent with their assigned NOF [natural occurrence frequency] levels, the East Coast and southeastern regions experienced only low-level arsenic occurrence for both surface water and groundwater sources. Although surface water supplies in the Midwest (region 4) were found to have arsenic levels <5 ug/L, a higher fraction of those sources exceeded 1 ug/L than did sources in regions 1-3 [New England, Mid-Atlantic, and Southeast]. Surface water sources in regions 5 [South Central], 6 [North Central], and 7 [Western] had substantially higher proportions of elevated arsenic occurrence compared with the rest of the nation.

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**Article ID** 46 **Author** Wilkison, Donald H. and Randall D. Maley  
**Notecard #** 46-03 **Title** Occurrence of Herbicides, Nitrite Plus Nitrate, and Selected Trace Elements in Ground Water from Northwestern and Northeastern Missouri, July 1991 and 1992  
**Topic** Geographic Location/Distribution **Date** 1994  
**Constituent** Arsenic **Page #** 11  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Arsenic concentrations detected in water samples from all wells [in northwestern Missouri] ranged from less than 5 to 9 ug/L.

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**Article ID** 46 **Author** Wilkison, Donald H. and Randall D. Maley  
**Notecard #** 46-01 **Title** Occurrence of Herbicides, Nitrite Plus Nitrate, and Selected Trace Elements in Ground Water from Northwestern and Northeastern Missouri, July 1991 and 1992  
**Topic** Geographic Location/Distribution **Date** 1994  
**Constituent** Nitrate **Page #** 11  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Nitrite plus nitrate, as nitrogen, concentrations in water samples from wells ranged from less than 0.05 to 63 mg/L in samples from 129 wells in northwestern Missouri in July 1991. The mean nitrite plus nitrate concentration in water samples from wells was 8.9 mg/L. Water samples from 31 wells (24 percent) had nitrite plus nitrate concentrations that were greater than or equal to the Missouri drinking-water supply criteria of 10 mg/L (Missouri Department of Natural Resources, 1992).

Water samples in northwestern Missouri that had nitrite plus nitrate concentrations greater than or equal to 10 mg/L had a mean well depth of 38.0 ft and a mean well diameter of 30.7 in. Wells that had nitrite plus nitrate concentrations less than the detection limit of 0.05 mg/L had a mean depth of 72.7 ft and a mean diameter of 20.2 in.

[Hydrogeology in northwestern Missouri, from pp. 5-9]

Most of the wells sampled in northwestern Missouri. . .were screened in glacial drift aquifers.

Extensive alluvial deposits of Holocene age are associated with major streams in the study area: The Grand, Nodaway, and Platte Rivers in northwestern Missouri. . .Twenty-two alluvial wells were sampled in northwestern Missouri. . .

Cyclic Pennsylvanian sediments of limestone, shale, sandstone, coal, and underclays thicken to the north and west coincident with the regional dip (McQueen and Greene, 1938). Wells completed in Pennsylvanian rocks are usually shallow, hand-dug wells lined with rocks or bricks. . .Twenty-one of the wells sampled in northwestern Missouri were completed in Pennsylvanian rocks. . .

The sampled wells withdraw water from the alluvium, glacial drift, and Pennsylvanian rocks.

Most of the sampled wells in northwestern Missouri were augered and cased with concrete tiles.

**Article ID 46****Author** Wilkison, Donald H. and Randall D. Maley**Notecard #** 46-02**Title** Occurrence of Herbicides, Nitrite Plus Nitrate, and Selected Trace Elements in Ground Water from Northwestern and Northeastern Missouri, July 1991 and 1992**Topic** Geographic Location/Distribution**Date** 1994**Constituent** Nitrate**Page #** 11**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** In July, 1992, nitrite plus nitrate concentrations in water samples from 144 wells in northeastern Missouri ranged from less than 0.05 to 60 mg/L with a mean concentration of 5.8 mg/L. The nitrite plus nitrate concentrations were greater than or equal to 10 mg/L in water samples from 28 wells (19 percent). Wells in northeastern Missouri that had nitrite plus nitrate concentrations greater than or equal to 10 mg/L had a mean well depth of 78.5 ft as compared to 237 ft for those wells that had nitrite plus nitrate concentrations less than the detection limit of 0.05 mg/L. The mean well diameter for wells with nitrite plus nitrate concentrations greater than or equal to 10 mg/L was 24.1 in. as compared to 7.8 in. for those wells that had nitrite plus nitrate concentrations less than 0.05 mg/L.

[Hydrogeology in northeastern Missouri, from pp. 5-9]

...four wells in northeastern Missouri were screened in glacial drift aquifers. . .

Extensive alluvial deposits of Holocene age are associated with major streams in the study area ; . .the Fox, Mississippi, Salt, and Wyaconda Rivers in northeastern Missouri. . .15 [alluvial wells] were sampled in northeastern Missouri. . .

Cyclic Pennsylvanian sediments of limestone, shale, sandstone, coal, and underclays thicken to the north and west coincident with the regional dip (McQueen and Greene, 1938). Wells completed in Pennsylvanian rocks are usually shallow, hand-dug wells lined with rocks or bricks. . .25 of the wells sampled in northeastern Missouri were completed in Pennsylvanian rocks. . .

Mississippian rocks. . .crop out extensively in northeastern Missouri. These rocks are cherty limestone, dolostone, and shale. Well-developed solution channels are common in the Burlington and Keokuk Limestones. . .Wells completed in Mississippian formations were sampled in northeastern Missouri.

A sequence of Lower Mississippian, Devonian, Silurian, and Upper Ordovician shale and limestone formations serves to separate the Ordovician and Cambrian formations from the overlying sediments. The Ordovician and Cambrian formations are composed of a series of permeable and semi-permeable sandstones and dolostones. . .Twenty-four wells completed in the Ordovician and Cambrian formations were sampled in northeastern Missouri.

The sampled wells in northeastern Missouri withdraw water from alluvium, glacial drift, Pennsylvanian, Mississippian, and Ordovician rocks.

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**Article ID 48****Author** Reid, Joe**Notecard #** 48-02**Title** Arsenic Occurrence: USEPA Seeks Clearer Picture**Topic** Geographic Location/Distribution**Date** September 1994**Constituent** Arsenic**Page #** 48**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** According to USEPA officials, occurrence trends based on the state and regional data continue to show that arsenic occurs primarily in groundwater sources, with the highest concentrations found west of the Mississippi River, and that it affects primarily smaller systems, with most of the exposure occurring in systems serving fewer than 10,000 people.

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<b>Article ID</b> 48	<b>Author</b> Reid, Joe
<b>Notecard #</b> 48-03	<b>Title</b> Arsenic Occurrence: USEPA Seeks Clearer Picture
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> September 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 50
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The MWDSC [Metropolitan Water District of Southern California] survey indicated that higher arsenic concentrations are found in the western and southwestern United States, with lower concentrations in the eastern states. . .

According to the MWDSC report, "The data suggest that exposure to arsenic increases west of the Mississippi River, and a majority of the West Coast population surveyed is currently drinking water with arsenic levels >2 ug/L."

The highest concentrations of arsenic in raw water were found in USEPA regions VI, VII, and IX. A majority of the population in region IX was exposed to arsenic concentrations between 2 and 20 ug/L.

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<b>Article ID</b> 48	<b>Author</b> Reid, Joe
<b>Notecard #</b> 48-01	<b>Title</b> Arsenic Occurrence: USEPA Seeks Clearer Picture
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> September 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 45
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Existing occurrence data indicate that arsenic occurs primarily in groundwater systems in the western United States. . However, USEPA recently released information indicating that arsenic occurrence at levels approaching 2 ug/L may also be prevalent as well in the eastern United States.

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<b>Article ID</b> 49	<b>Author</b> Wilkison, Donald H. and Randall D. Maley
<b>Notecard #</b> 49-12	<b>Title</b> Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 23
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** This study focused on nitrate and pesticides in samples from domestic wells and shallow ground water in the State [Missouri]. Based on the results of this study, as many as 80,000 domestic wells (24 percent) in the State may have elevated nitrate concentrations larger than the drinking-water criterion or have detectable concentrations of one or more pesticides. The data indicate the presence of elevated nitrate and pesticide concentrations in ground water within the State, although they are primarily associated with practices that occur near the wellhead. Results of this study indicate that elevated nitrate and pesticide concentrations are likely to be localized and limited to shallow ground water. However, continued use of agricultural chemicals could increase the amount of nitrate and pesticides present in ground water. . .

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**Article ID 49****Notecard # 49-11****Topic** Source(s) - Anthropogenic**Constituent** Nitrate**Co-Occurrence?** No**Author** Wilkison, Donald H. and Randall D. Maley**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94**Date** 1996**Page #** 22**Co-Occurrence Notes**

**Notes** The frequency of elevated nitrate concentrations (greater than 3 milligrams per liter) in ground water indicates that anthropogenic sources are contributing to the high nitrate concentrations. If the widespread application of fertilizer resulted in elevated nitrate concentrations in ground water, then increases in county fertilizer use and in the percentage of surrounding row crops would be expected to be predictors of increased nitrate concentrations. Neither of these is true. Nitrate concentration is inversely related to county-wide fertilizer use, which indicates that other sources apparently are more important in the transport of nitrate to ground water. Nitrogen-isotope and land-use data indicate that animal wastes were the predominant source of nitrate in ground water in west-central Missouri.

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**Article ID 49****Notecard # 49-10****Topic** Source(s) - Anthropogenic**Constituent** Nitrate**Co-Occurrence?** No**Author** Wilkison, Donald H. and Randall D. Maley**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94**Date** 1996**Page #** 11**Co-Occurrence Notes**

**Notes** Nitrate concentrations were significantly related to the distance of a well from a feedlot (Kruskal-Wallis test;  $p < 0.001$ ). A feedlot was defined as any present, or historical, confined animal enclosure. Water samples from wells with a feedlot less than 0.25 mi away had significantly higher NO<sub>3</sub> concentrations than samples from wells with a feedlot more than 0.25 mi away (Tukey's test;  $\alpha = 0.05$ ). The highest median concentration of NO<sub>3</sub> (3.7 mg/L) was detected in samples from wells located within 100 ft of a feedlot; samples from wells located between 100 ft and 0.25 mi from a feedlot had only a slightly less median NO<sub>3</sub> concentration (3.5 mg/L). Samples from wells that were located more than 0.25 mi from a feedlot had the lowest median concentration of NO<sub>3</sub> (0.6 mg/L).

Animal manure can be a substantial source of NO<sub>3</sub> to ground water (Madison and Brunett, 1985). Nitrogen isotope ratios can be useful in identifying sources of NO<sub>3</sub>. Nitrogen isotope data from selected wells in west-central Missouri (Wilkison, 1993) indicate that animal wastes are the predominant source of NO<sub>3</sub> in ground water of that area.

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**Article ID 49****Notecard # 49-04****Topic** Other**Constituent** Nitrate**Co-Occurrence?** No**Author** Wilkison, Donald H. and Randall D. Maley**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94**Date** 1996**Page #** 2**Co-Occurrence Notes**

**Notes** Paraphrased from info pp. 2-4:

A significant percentage of samples (12.6% - 23.8%) from domestic wells in several Missouri studies exceeded 10 mg/L nitrate. In contrast, a survey of all public drinking water wells in Missouri revealed only three wells whose samples exceeded 10 mg/L nitrate. These wells tend to be "screened at much deeper intervals than domestic wells because of the yields needed to supply large quantities of potable water."

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<b>Article ID</b> 49	<b>Author</b> Wilkison, Donald H. and Randall D. Maley
<b>Notecard #</b> 49-09	<b>Title</b> Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 11
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrate concentrations were significantly related to the water-level depth below the land surface (Kruskal-Wallis test:  $p < 0.001$ ). Water samples from wells in which the water level was less than 50 ft. from the land surface had significantly higher NO<sub>3</sub> concentrations than samples from wells with water levels deeper than 50 ft below the land surface (Tukey's test;  $\alpha = 0.05$ ). The median NO<sub>3</sub> concentration in samples from wells was 2.1 mg/L where the water level was less than 10 ft below land surface, 4.3 mg/L where it was 10 to 25 ft below land surface, 4.0 mg/L where it was 25.1 to 50 ft below land surface, 0.31 mg/L where it was 50.1 to 100 ft below land surface, and 0.14 mg/L where it was deeper than 100 ft below the land surface. Depth to water generally is an indicator of susceptibility of the aquifer to contamination from surface applications of agricultural chemicals. An extremely shallow water table – less than 10 ft. – can be favorable to lower NO<sub>3</sub> concentrations, especially in areas with poorly drained soils that often have low dissolved oxygen concentrations. Where these conditions occur, ammonia, and not NO<sub>3</sub>, tends to be the dominant species in ground water.

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<b>Article ID</b> 49	<b>Author</b> Wilkison, Donald H. and Randall D. Maley
<b>Notecard #</b> 49-05	<b>Title</b> Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 9
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Water samples from shallow, large-diameter wells completed in glacial drift or Pennsylvanian rocks and from wells where the water table was within 50 ft of the land surface, within 0.25 mi of a feedlot, or within 100 ft of a chemical mixing area were more likely to have elevated NO<sub>3</sub> concentrations. Elevated NO<sub>3</sub> concentrations were not significantly related to the percentage of row crops within a 0.25-mi radius from the well and were inversely related to county-wide fertilizer usage.

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<b>Article ID</b> 49	<b>Author</b> Wilkison, Donald H. and Randall D. Maley
<b>Notecard #</b> 49-07	<b>Title</b> Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1996
<b>Constituent</b> Nitrate	<b>Page #</b> 10
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nitrate concentrations were significantly related to well depth (Kruskal-Wallis test;  $p < 0.001$ ) Water samples from wells less than 75 ft deep had significantly higher concentrations than those samples from wells that were deeper than 75 ft (Tukey's test;  $\alpha = 0.05$ ). Water from wells completed in shallow aquifers is more susceptible to contamination because of shorter flow paths and less time for degradation and denitrification to occur. Median NO<sub>3</sub> concentrations were highest (3.9 mg/L) in samples from wells less than 25 ft deep and consistently declined for increasing well depth. The median NO<sub>3</sub> concentration was 2.4 mg/L for samples from wells 25 to 50 ft deep, 1.8 mg/L for wells 50.1 to 75 ft deep, and 0.05 mg/L (the analytical detection limit) for wells deeper than 75 ft.

**Article ID 49****Author** Wilkison, Donald H. and Randall D. Maley**Notecard #** 49-08**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94**Topic** Factors Affecting Geochemistry**Date** 1996**Constituent** Nitrate**Page #** 11**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Nitrate concentrations were significantly related to well diameter (Kruskal-Wallis test;  $p < 0.001$ ). Water samples from wells with diameters less than or equal to 6 in. had significantly lower concentrations of NO<sub>3</sub> than did those samples from wells with diameters greater than 6 in. (Tukey's test;  $\alpha = 0.05$ ). This relation probably exists because wells with diameters 6 in. or less were most likely to be completed in either alluvial, Mississippian/Springfield Plateau, or Cambrian-Ordovician/Ozark aquifers. Wells completed in glacial drift and Pennsylvanian rocks were significantly larger in diameter (Tukey's test;  $\alpha = 0.05$ ) and many are poorly cased or constructed. Median NO<sub>3</sub> concentration in samples from wells 6 in. or less in diameter was 0.05 mg/L, 6.25 to 24 in. in diameter was 2.35 mg/L, 24.5 to 36 in. in diameter was 3.45 mg/L.

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**Article ID 49****Author** Wilkison, Donald H. and Randall D. Maley**Notecard #** 49-02**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94**Topic** Factors Affecting Geochemistry**Date** 1996**Constituent** Nitrate**Page #** 1**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** The percentage of row crops within a 0.25-mile radius of the well was not related to NO<sub>3</sub> concentrations. . . Nitrate concentrations in ground water were inversely related to estimated fertilizer-use rates.

Nitrate concentrations were significantly higher in samples with pesticide detections than for those without detections. Wells less than 0.25 mile from a feedlot had significantly higher NO<sub>3</sub> concentrations than other wells, however, NO<sub>3</sub> concentrations were not related to the well distance from a septic system.

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**Article ID 49****Author** Wilkison, Donald H. and Randall D. Maley**Notecard #** 49-01**Title** Occurrence and Distribution of Nitrate and Selected Pesticides in Ground Water in Missouri, 1986-94**Topic** Factors Affecting Geochemistry**Date** 1996**Constituent** Nitrate**Page #** 1**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** [in Missouri] Ground water from glacial drift or Pennsylvanian rocks had significantly higher concentrations of nitrate and more frequent pesticide detections than did ground water from alluvial, Mississippian/Springfield Plateau, or Cambrian-Ordovician/Ozark aquifers. Water samples from wells less than 75 feet deep, greater than 6 inches in diameter, and where the water level was within 50 feet of the land surface had significantly higher nitrate concentrations. . . than samples from other wells.



<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-08	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> January 1996
<b>Constituent</b> Barium	<b>Page #</b> 9
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<b>Notes</b> the Ba compounds are used in several industrial activities: petroleum wells, paints and paper pulp, bituminous products, medicine and others (WHO, 1986-1993; Underwood, 1977).	

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**Article ID 52**  
**Notecard # 52-16**  
**Topic Source(s) - Natural**  
**Constituent Chromium**  
**Co-Occurrence? Yes**

**Author** Galvin, Rafael Marin  
**Title** Occurrence of Metals in Waters: an Overview  
**Date** January 1996  
**Page # 11**  
**Co-Occurrence Notes** chromium, sulfate, cyanide

**Notes** Chromium is found in the mineral chromite. The Cr(2+) ions form amine and cyanide complexes; the Cr(3+) ions form complexes not only with chlorides, but also with fluorides, sulphates, ammonium salts, cyanides, sulphocyanides, oxalates and citrates; chromates are complexed by H<sub>2</sub>O<sub>2</sub>; the chromates of the alkali metals, and also ferric, cupric, manganous and magnesium chromates are soluble, but the majority of the chromates of the other metals are insoluble (Pourbaix, 1966).

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**Article ID 52**  
**Notecard # 52-27**  
**Topic Geographic Location/Distribution**  
**Constituent Selenium**  
**Co-Occurrence? No**

**Author** Galvin, Rafael Marin  
**Title** Occurrence of Metals in Waters: an Overview  
**Date** January 1996  
**Page # 16**  
**Co-Occurrence Notes**

**Notes** Concentrations of [selenium] in surface waters as SeO<sub>3</sub>(2-) (selenite), SeO<sub>4</sub>(2-) (selenate) and dimethyl selenium typically do not exceed 10 ug/L (WHO, 1993). Underground waters, conversely, can contain up to 1 mg/L, especially in waters which drain volcanic land; as for example, in certain zones of the USA (Catalan Lafuente, 1981; WHO, 1986).

Furthermore, a recent study carried out in the USA (Liu and Narasimhan, 1994) demonstrated that Se exhibits a trend in depth in lakes and reservoirs, similar to Al, Fe, and Mn; this is due to chemical, electrochemical and microbiological factors.

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**Article ID 52**  
**Notecard # 52-26**  
**Topic Source(s) - Natural**  
**Constituent Selenium**  
**Co-Occurrence? No**

**Author** Galvin, Rafael Marin  
**Title** Occurrence of Metals in Waters: an Overview  
**Date** January 1996  
**Page # 16**  
**Co-Occurrence Notes**

**Notes** Selenium is an essential element being widely spread in nature, especially in volcanic zones, but in small amounts; it is associated with Cu, S, and B.

From a chemical point of view, the selenides, selenites and selenates of metals other than the alkali metals are generally insoluble; moreover, Se forms complexes such as selenophosphoric acid PSe(OH)<sub>3</sub>, chromoselenite acid, cobaltiselenic complexes and complexes derivatives of uranic acid and nitrosylsulphuric acid.

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**Article ID 52**  
**Notecard # 52-25**  
**Topic Constituent Species**  
**Constituent Nickel**  
**Co-Occurrence? No**

**Author** Galvin, Rafael Marin  
**Title** Occurrence of Metals in Waters: an Overview  
**Date** January 1996  
**Page # 16**  
**Co-Occurrence Notes**

**Notes** Nickel salts are reasonably soluble in water, except the ferri- and ferrocyanides, sulphide and Ni-dimethylglyoxime. Likewise, the existence of the following complexes of Ni is known: hydrochloric, and sulphuric (very stable), amine (fairly stable), oxalic, thiocyanide, metaphosphoric, pyrophosphoric and cyanide complexes (Pourbaix, 1966).

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-24	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> January 1996
<b>Constituent</b> Nickel	<b>Page #</b> 15
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** [Nickel] is used in the melting process of metallic alloys, as catalyst and in pesticide formulations.

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-23	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Constituent Species	<b>Date</b> January 1996
<b>Constituent</b> Nickel	<b>Page #</b> 15
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nickel is naturally found as the arsenate and sulphide.

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-22	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Source(s) - Natural	<b>Date</b> January 1996
<b>Constituent</b> Mercury	<b>Page #</b> 15
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Mercury is a typical element which experiences biotransformation processes in the environment (Leed, 1972; USEPA 1977; ECC, 1979; Standard Methods, 1989) which increases its toxic potential. In this way, Hg in waters is found both in inorganic form as Hg(+) chloride and hydroxide, and in organic compounds such as the very toxic methyl, dimethyl and phenyl. Likewise, some Hg(2+) inorganic compounds can be detected in waters as HgCl<sub>2</sub>(2+) (WHO, 1990).

Oxidation of Hg(+) compounds in well-oxygenated waters and especially those with pH lower than 5.0 is rapid, yielding Hg(2+). Later, Hg(2+) can react according to two processes:

-Reduction to metallic Hg carried out by *Pseudomonas* and other water micro-organisms. Once Hg is formed, it might be evaporated to the atmosphere, and later, it is deposited in rain.

-Formation of very toxic organo-mercury compounds such as methyl mercury and dimethyl mercury. In this way, Hg(2+) is either associated with organic particles, or with microorganisms, or even with the bottom sediments of natural water systems, experiencing a process of methylation in both oxygenated and anoxic media.

In the oxygenated medium, the process yields firstly mercuric methionin which later breaks own to produce methyl derivatives. If the pH of water is low, the formation of methyl mercury is favoured against dimethyl mercury.

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| <b>Article ID</b> 52             | <b>Author</b> Galvin, Rafael Marin                       |
| <b>Notecard #</b> 52-21          | <b>Title</b> Occurrence of Metals in Waters: an Overview |
| <b>Topic Source(s)</b> - Natural | <b>Date</b> January 1996                                 |
| <b>Constituent</b> Mercury       | <b>Page #</b> 15   |
| <b>Co-Occurrence?</b> No         | <b>Co-Occurrence Notes</b>                               |
- Notes** The main sources of Hg in the environment are natural volcanic emissions followed by effluents rich in Hg discharged by certain industries, cement production, fuel combustion, batteries, sodium hydroxide and chlorine production. Moreover, Hg can also be used in pesticide formulations.
- The following compounds of monovalent mercury are sparingly soluble: the halide, the chromate and the sulphide. Divalent mercury forms the following sparingly soluble compounds: iodide, thiocyanic and sulphide. Moreover, Hg(2+) forms a large number of complexes which are often quite stable: chloride, hydrobromic, hydroiodic, thiocyanic, hydrocyanic, amine, sulphurous and thiosulphuric complexes (Pourbaix, 1966). On the other hand, Hg levels in waters are generally very low not exceeding more than 1 ug/L (USEPA, 1977; Catalan Lafuente, 1981; Garcia Garrido, 1986). However, in highly polluted waters in Germany, up to 0.40 mg/L have been detected in a few cases only (WHO, 1986).
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| <b>Article ID</b> 52                   | <b>Author</b> Galvin, Rafael Marin                       |
| <b>Notecard #</b> 52-20                | <b>Title</b> Occurrence of Metals in Waters: an Overview |
| <b>Topic Source(s)</b> - Anthropogenic | <b>Date</b> January 1996                                 |
| <b>Constituent</b> Mercury             | <b>Page #</b> 15   |
| <b>Co-Occurrence?</b> No               | <b>Co-Occurrence Notes</b>                               |
- Notes** Mercury usually occurs in the earth's crust as the sulphide while at the same time being found in some mines as the liquid. The main sources of Hg in the environment are natural volcanic emissions followed by effluents rich in Hg discharged by certain industries, cement production, fuel combustion, batteries, sodium hydroxide and chlorine production. Moreover, Hg can also be used in pesticide formulations.
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| <b>Article ID</b> 52                        | <b>Author</b> Galvin, Rafael Marin                       |
| <b>Notecard #</b> 52-19                     | <b>Title</b> Occurrence of Metals in Waters: an Overview |
| <b>Topic</b> Factors Affecting Geochemistry | <b>Date</b> January 1996                                 |
| <b>Constituent</b> Chromium                 | <b>Page #</b> 11   |
| <b>Co-Occurrence?</b> No                    | <b>Co-Occurrence Notes</b>                               |
- Notes** The concentrations of Cr in natural unpolluted waters are not higher than 25 ug/L (ECC, 1979): nevertheless, these levels increase for waters with low pH values (pH 6.0) as well as for very hard waters.
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|---|--|
| <b>Article ID</b> 52                          | <b>Author</b> Galvin, Rafael Marin                       |
| <b>Notecard #</b> 52-06                       | <b>Title</b> Occurrence of Metals in Waters: an Overview |
| <b>Topic</b> Geographic Location/Distribution | <b>Date</b> January 1996                                 |
| <b>Constituent</b> Arsenic                    | <b>Page #</b> 9  |
| <b>Co-Occurrence?</b> No                      | <b>Co-Occurrence Notes</b>                               |
- Notes** While the majority of European surface waters present As values of less than 5 ug/L, rarely exceeding 10 ug/L (EUREAU, 1994), higher As levels in groundwaters have been reported from many parts of the world, e.g. 0.6 to 2.0 mg/L in Taiwan, 3.0 mg/L in Japan, 0.9 to 3.4 mg/L in Argentina and up to 1.7 mg/L in the USA (Dutta and Chaudhuri, 1991).
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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-17	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> January 1996
<b>Constituent</b> Chromium	<b>Page #</b> 11
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** From a chemical point of view, the Cr(6+) salts (HCrO<sub>4</sub>(-), CrO<sub>4</sub>(2-), and Cr<sub>2</sub>O<sub>7</sub>(2-)) are more soluble than the Cr(3+) compounds, especially the hydroxide. Oxidation of trivalent Cr to hexavalent Cr can be carried out electrochemically and, also, biologically. This implies a complex equilibrium between dissolution and precipitation of Cr compounds in natural water media. In this sense, the reductive action of organic matter on the Cr(6+) compounds to yield Cr(3+) organics complexes is well known (ECC, 1979; WHO, 1993).

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-02	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Source(s) - Natural	<b>Date</b> January 1996
<b>Constituent</b> Antimony	<b>Page #</b> 9
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> antimony and arsenic

**Notes** The source of Sb in the water medium is the dissolution of sulphide minerals which contain the element. In this way, Sb is also associated with arsenic minerals as impurity.

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-15	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> January 1996
<b>Constituent</b> Cadmium	<b>Page #</b> 10
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Form and fate of Cd in water depend upon its chemical speciation which is determined by the pH of the water and the hardness as well as the presence of ligands and co-existing metal cations. So, the solubility of Cd in water is a function of the pH value: the lower the pH value the higher the solubility. In this way, surface waters commonly show <1 ug/L (Catalan Lafuente, 1981; Hiat and Juff, 1975). Furthermore, the waters rich in humic compounds contain the lowest Cd levels because of the high stability of the Cd-humic substances complexes generated there (Standard Methods, 1989).

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-14	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Source(s) - Natural	<b>Date</b> January 1996
<b>Constituent</b> Cadmium	<b>Page #</b> 10
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> cadmium, nitrate, sulfate, cyanide

**Notes** [Cadmium] is a trace element in the earth's crust which is generally associated with zinc minerals (i.e. greenockite, a cadmium sulphide found associated with zinc sulphide). . .

Cadmium forms several complexes with anions: halides, nitrate, sulphate, thiosulphate, ammonia and cyanide, generally not very stable. A large number of salts and basic salts of Cd are sparingly soluble or very sparingly soluble, i.e., carbonate, cyanide, phosphate and sulphide (Pourbaix, 1966).

<b>Article ID 52</b>	<b>Author</b> Galvin, Rafael Marin
<b>Notecard # 52-12</b>	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> January 1996
<b>Constituent</b> Beryllium	<b>Page #</b> 10
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<b>Notes</b> In continental waters, the mean Be concentrations range from 10(-2) to 1.1 ug/L, while in drinking waters it can be detected only at very low levels, commonly less than 1 ug/L and showing a mean level near to 0.2 ug/L (WHO, 1993).	

<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-11	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic Source(s)</b> - Natural	<b>Date</b> January 1996
<b>Constituent</b> Beryllium	<b>Page #</b> 10
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<p><b>Notes</b> [Beryllium] is commonly associated with feldspars although it can also be found in a typical mineral such as "beryl" (USEPA, 1980). On the other hand, Be is uncommon in natural waters but it is sometimes found as the chloride, nitrate and sulphate salts. These compounds are relatively soluble in water in the following sequence: Cl&gt;NO3&gt;SO4. Beryllium also forms soluble complexes with anions such as citrate, tartrate, oxalate, fluoride and phosphates.</p>	

<b>Article ID 52</b>	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-10	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> January 1996
<b>Constituent</b> Barium	<b>Page #</b> 10
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<b>Notes</b> Ba is found relatively frequently in waters at levels of less than 0.1 mg/L. Likewise, certain volcanic thermal waters can contain up to 10 mg/L (USEPA, 1977). On the other hand, the Ba concentration in drinking water does not exceed 1.0 mg/L and is commonly about 0.10 to 0.40 mg/L for USA and Russian drinking waters (WHO, 1986).	

<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-09	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic Source(s)</b> - Natural	<b>Date</b> January 1996
<b>Constituent</b> Barium	<b>Page #</b> 10
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>
<b>Notes</b> Salts of Ba sparingly soluble are the carbonates, oxalates, sulphates, phosphates and chromates while certain complexes such as polymetaphosphates and organic hydroxyl compounds are more soluble (Pourbaix, 1966).	

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**Article ID 52** **Author** Galvin, Rafael Marin  
**Notecard #** 52-07 **Title** Occurrence of Metals in Waters: an Overview  
**Topic Source(s)** - Natural **Date** January 1996  
**Constituent** Barium **Page #** 9  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** The amount of Ba in the earth's crust is about 0.5 g/kg, especially found in certain minerals such as barite (barium sulphate) and witherite (barium carbonate).

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**Article ID 52** **Author** Galvin, Rafael Marin  
**Notecard #** 52-05 **Title** Occurrence of Metals in Waters: an Overview  
**Topic Source(s)** - Anthropogenic **Date** January 1996  
**Constituent** Arsenic **Page #** 9  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** the main contribution of arsenic to waters is actually industrial, because of production of As as a by-product in the metallurgical processing of other metals.

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**Article ID 52** **Author** Galvin, Rafael Marin  
**Notecard #** 52-04 **Title** Occurrence of Metals in Waters: an Overview  
**Topic Source(s)** - Natural **Date** January 1996  
**Constituent** Arsenic **Page #** 9  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Arsenic is common in a great variety of minerals, as well as sulphides, specially in those of Cu, Co, Pb, and Zn. The mean concentration of As in the earth's crust is about 2 mg/kg. The presence of As in waters is due to both soluble salts and organic complexes emanating from volcanic emissions. In this way, tartrates, molybdates and tungstates from complexes with arsenic. The alkali metal arsenites and arsenates are very soluble; the other arsenites and arsenates are soluble only in acid solutions. In particular, triargentic arsenate and magnesium ammonium arsenate are sparingly soluble in water (Pourbaix, 1966). Moreover, under moderately oxidising conditions, arsenic is found as As(3+), while a higher oxidising medium promotes the oxidation toward As(5+).

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**Article ID 52** **Author** Galvin, Rafael Marin  
**Notecard #** 52-03 **Title** Occurrence of Metals in Waters: an Overview  
**Topic Source(s)** - Anthropogenic **Date** January 1996  
**Constituent** Antimony **Page #** 9  
**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Likewise, Sb can occur in some raw waters due to discharges from dye factories, mining effluents and certain other industries (Standard Methods, 1989; EUREAU, 1994)

According to the data available (WHO, 1993; EUREAU, 1994) Sb in drinking waters is usually less than 4 ug/L (as ions or organic complexes), while in certain parts of England and Wales the concentrations can be as high as 12 ug/L. Where antimony-tin solder replaces lead solder, exposure to Sb may increase.

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<b>Article ID</b> 52	<b>Author</b> Galvin, Rafael Marin
<b>Notecard #</b> 52-18	<b>Title</b> Occurrence of Metals in Waters: an Overview
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> January 1996
<b>Constituent</b> Chromium	<b>Page #</b> 11
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The main sources of Cr to the environment are industrial effluents emanating from the production of corrosion inhibitors and pigments.

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<b>Article ID</b> 53	<b>Author</b> Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray
<b>Notecard #</b> 53-05	<b>Title</b> The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study
<b>Topic</b> Other	<b>Date</b> Winter 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 147
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Occurrence of all agricultural chemicals was higher in the Effingham County study area when

- Agricultural chemicals were stored within 500 feet of the well ( $\alpha < .001$ )
- Agricultural chemicals were used for nonagricultural uses, such as on lawns and gardens ( $\alpha = .001$ )
- Well depth was less than 30 feet ( $\alpha = .01$ )
- Specific conductance of the samples water was greater than or equal to 500 umhos/cm ( $\alpha = .01$ )
- Temperature of the sampled water was less than 12.5 C ( $\alpha = .025$ )
- Wells were within 500 feet of surface water ( $\alpha = .025$ )
- Samples were collected during the winter or spring ( $\alpha = .05$ )

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<b>Article ID</b> 53	<b>Author</b> Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray
<b>Notecard #</b> 53-02	<b>Title</b> The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> Winter 1995
<b>Constituent</b> Nitrate	<b>Page #</b> 145
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The study areas in Effingham and Piatt counties have no know aquifer material within the uppermost 50 feet; however, wells in the two areas tap very different sources of water. In the Effingham County study area, large-diameter wells generally drain water from thin, discontinuous layers of sand and gravel or fracture zones interspersed in the low hydraulic conductivity tills at an average depth of 35 feet (11m). These geologic materials are too thin and/or discontinuous to satisfy our definition of aquifer materials. In Piatt County, small-diameter wells tap water from a sand and gravel aquifer at an average depth of 111 feet (34 m). These differences in the source of water and well depth were thought to be responsible for the observed difference in occurrence.

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**Article ID** 53 **Author** Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray

**Notecard #** 53-04 **Title** The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study

**Topic** Other **Date** Winter 1995

**Constituent** Nitrate **Page #** 146.

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** the rejection of the null hypothesis for all occurrences, nitrate occurrences, and pesticide occurrences indicated that these occurrences were a function of both well type and depth to the uppermost aquifer material. The results of hypothesis testing showed that well type and depth to the uppermost aquifer material can help predict all occurrences, pesticide occurrences, and the occurrence of some individual agricultural chemicals, such as nitrate or atrazine, but it was not useful for picloram.

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**Article ID** 53 **Author** Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray

**Notecard #** 53-03 **Title** The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study

**Topic** Distribution/Transport in Soil Profile **Date** Winter 1995

**Constituent** Nitrate **Page #** 145

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** the stratification variable can generally be used to predict the occurrence of agricultural chemicals in rural private wells. However, the first two classes (0 to 5 feet and 5 to 20 feet) may be combined because the difference is not statistically significant.

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**Article ID** 53 **Author** Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray

**Notecard #** 53-06 **Title** The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study

**Topic** Other **Date** Winter 1995

**Constituent** Nitrate **Page #** 147

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** Occurrence of all agricultural chemicals was higher in the Kankakee County study area when

- Specific conductance of the sampled water was greater than or equal to 500 umhos/cm ( $\alpha=.01$ )
- Bedrock elevation increased ( $\alpha=.05$ )
- The surficial geology was thin till over Silurian dolomite bedrock ( $\alpha=.05$ )

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**Article ID** 53 **Author** Mehnert, E., S.C. Schock, M.L. Barnhardt, M.E. Caughey, S.F.J. Chou, W.S. Dey, G.B. Dreher, and C. Ray

**Notecard #** 53-01 **Title** The Occurrence of Agricultural Chemicals in Illinois' Rural Private Wells: Results from the Pilot Study

**Topic** Geographic Location/Distribution **Date** Winter 1995

**Constituent** Nitrate **Page #** 144

**Co-Occurrence?** No **Co-Occurrence Notes**

**Notes** The number of all occurrences, nitrate occurrences, and pesticide occurrences was highest in the Effingham County study area, followed by Kankakee, Mason, Livingston, and Piatt counties. Nitrate occurrences were greater than pesticide occurrences for the study areas in Effingham, Kankakee, and Mason counties.

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-05	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic Source(s)</b> - Anthropogenic	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 145
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Anthropogenic sources of As include: (1) atmospheric release through the use of fossil fuels and smelting operations, (2) leaching from mining waste tailings piles, (3) historic use of As as an embalming agent in corpses, (4) oil field brine disposal activities, (5) leaching from pesticide/herbicide production facilities, and (6) direct application through agricultural use of pesticides/herbicides (Welch et al., 1988; Korte and Fernando, 1991; Fetter, 1993).

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-10	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 150
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The predominance of dissolved As occurs in the eastside groundwater sources from Sierran surface flows. Because surface water from the Kern river enters the flow path with only ~0.003 mg/L dissolved As, the increase in dissolved As must be coming from a source along the groundwater flow path. Summaries of point count analyses from sediment collected at subsurface sites along the groundwater flow path indicate that intermediate volcanics range from 1 to 76% and granitic lithic fragments range from 12.6 to 51% in the three slides (Swartz, 1995). Arsenic concentrations in granite and intermediate volcanics range from 0.5 to 5.8 mg/kg and 0.18 to 15 mg/kg, respectively (Welch et al., 1988). Dissolution of these grains along the flow path could be a potential source of dissolved As.

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-09	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic Factors Affecting Geochemistry</b>	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 150
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The average As concentration in anthro-west groundwater is 0.023 mg/L, whereas the maximum dissolved As concentration from these wells is 0.039 mg/L. These figures are well below the As concentrations in eastside groundwaters.

[From p. 149, chemistry of Anthro-west Groundwaters]

Groundwaters in the six other westside wells are termed anthro-west groundwaters because of possible anthropogenic alteration. These waters contain mainly Na and Cl. Previous work suggests that many waters along the base of Elk Hills have been altered by disposal, mixing with evaporatively concentrated surface waters from Buena Vista Lake overflow, or movement of connate waters from formations in Elk Hills (California Department of Water Resources, 1990). The hydrogeology of the study area near Elk Hills is not sufficiently understood to conclude the cause of alteration. However, surface disposal of produced brine along the eastern base of Elk Hills is documented (White, 1993). These waters have an average TDS concentration of 1373 mg/L, with a range from 394 to 3210 mg/L. Elevated Cl and Br concentrations indicate possible input from brine associated with oil field activities. Observed Cl:Br ratios suggest mixing of local oil field water with local surface waters. Nitrate levels are typically below the detection limit of 0.1 mg/L, suggesting these waters are relatively unaltered by agricultural activities.

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-08	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 150
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Dissolved As in westside groundwater is extremely low; two wells have As below the detection limit of 0.001 mg/L, and the remaining two wells have a dissolved As concentration of 0.002 mg/L.

[From p. 147, chemistry of Westside Groundwaters]

Four wells contain groundwater with high amounts of SO<sub>4</sub> and Na or Ca along the western boundary of the project area that closely resembles naturally occurring westside groundwater described by Wood and Davis (1959) and Dale et al. (1966). These waters are sourced from westside ephemeral streams from the Coast Ranges and are found along the base of Elk Hills adjacent to the western study area boundary. These waters have an average TDS of 810 mg/L, and range from 297 to 1890 mg/L. Nitrate levels are typically below the detection limit of 0.1 mg/L, suggesting that these waters are relatively unaltered by agricultural activities..

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-06	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 150
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic concentrations in eastside groundwater average 0.036 mg/L. Spring 1993 values of dissolved As range from 0.002 to 0.163 mg/L in eastside groundwater. All seven wells with As concentrations exceeding 0.05 mg/L in the spring sampling round contain eastside groundwater.

[From p. 14, chemistry of Eastside Groundwaters]

The Ha-HCO<sub>3</sub> waters are termed eastside groundwaters because of their similarity to Kern River water which recharges the aquifer from the east. These groundwaters are similar to Kern River water with respect to TDS values and general water chemistry (high HCO<sub>3</sub>, low SO<sub>4</sub> and Cl), except that Kern River water has Ca and Na in nearly equivalent amounts with considerable Mg, whereas Na is clearly dominant in the Ha-HCO<sub>3</sub> water. The difference in cation composition is probably the result of cation exchange along the aquifer flow path. This would cause the loss of Mg and Ca, while replacing those constituents with equivalent amounts of Na. This is a common groundwater evolution pattern observed in deep alluvial aquifers with restricted atmospheric contact (Drever, 1988; Appelo and Postma, 1993).

Thirty-two of the 57 wells sampled are of the Na-HCO<sub>3</sub> water type. Spring 1993 analyses of Na-HCO<sub>3</sub> water have an average TDS of 128 mg/L, with none of the waters exceeding 200 mg/L. The pH of the Na-HCO<sub>3</sub> waters ranges from 8.2 to 9.2 and averages 8.75. The very low TDS and nitrate concentrations, typically below the detection limit of 0.1 mg/L, indicate these waters have been relatively unaltered by human activities.

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-11	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 151
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Available data strongly suggest that As is naturally occurring and is likely sources from dissolution of igneous aquifer materials as the water moves along an extensive flow path within the Kern River alluvial fan.

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-04	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 145
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Volcanic activities are the primary natural source of As to the environment. Volcanic atmospheric emissions result in average As concentrations in precipitation from oceanic air masses of 0.019 ug/L and terrestrial air masses of 0.46 ug/L (Andreae, 1980). As is associated with volcanic glasses, geothermal areas, and mineral deposits because arsenic minerals are not formed until the pneumatolytic and hydrothermal stages of magmatic cooling (Robertson, 1989).

As can readily substitute for silicon, ferric iron, and aluminum in aluminosilicate minerals; therefore, it is commonly present in a variety of igneous rocks. Marine mudstone and claystone tend to have elevated As associated with sulfides (pyrite) and organic matter, whereas nonmarine sedimentary shales/clays tend to be elevated in As as a result of sorptive processes (Welch et al., 1998). Therefore, igneous rocks or the Sierra Nevada, Coast Range marine rocks, and nonmarine clay beds associated with Buena Vista and Kern Lakes are potential natural sources of As in the KFE [Kern Fan Element].

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-03	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Constituent Species	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 145
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic occurs in the +5, +3, +1, 0, -3 valence states. In natural waters, dissolved As typically has a valence of +5 (arsenate) or +3 (arsenite), depending on Eh and pH conditions. Arsenate exists in the oxyanionic form as either  $\text{H}_2\text{AsO}_4^-$ ,  $\text{HAsO}_4^{2-}$ , or  $\text{AsO}_4^{3-}$ ; arsenite is  $\text{H}_2\text{AsO}_3^-$  (Edwards, 1994).

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-02	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 144
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Several oil field and agricultural operations are located within and around the study area. Evidence shows that these activities have altered groundwater composition. Therefore, human activities could be the source of dissolved As; however, our research indicates otherwise.

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<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-01	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 143
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Welch et al. (1988) noted a variety of occurrences of elevated As throughout the West [United States], along with many natural and human activities acting as potential sources.

<b>Article ID</b> 54	<b>Author</b> Swartz, Robert J., Geoffrey D. Thyne, and Janice M. Gillespie
<b>Notecard #</b> 54-07	<b>Title</b> Dissolved Arsenic in the Kern Fan, San Joaquin Valley, California: Naturally Occurring or Anthropogenic?
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 150
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The average dissolved As concentration for anthro-east groundwater is 0.002 mg/L. Samples from three of the wells contain dissolved As below the detection limit of 0.001 mg/L and were not used in the average.

[From p. 150, chemistry of Anthro-east Groundwaters]

The remaining 15 shallower wells in the central and eastern portions of the study area have a wide variety of water types, show indications of alteration by human activities, and are termed anthro-east groundwaters. These waters are likely of a Kern River origin that have been altered by activities including agriculture, oil field produced-water disposal operations, and artificial recharge. The average TDS of these waters is 348 mg/L with a maximum TDS of 1680 mg/L. The average pH of these waters is 8.0 with a range from 7.3 to 8.4. Chloride concentrations as high as 724 mg/L are seen in some groundwater samples, indicating possible mixing with brine associated with oil field activities. Nitrate concentrations in these waters average 11.5 mg/L, with a range from 1.2 to 41 mg/L, indicating likely alteration by agricultural activities.

<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-06	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 302
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The available data indicate that the geothermally active Jemez Mountains area is a major source of arsenic to the Middle Rio Grande. The concentration of arsenic in the Jemez River is an average of one order of magnitude higher than that of the Rio Grande just above their confluence.

<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-10	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 304
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic is a naturally occurring element in the Middle Rio Grande. Sources of arsenic to the river include:

- The geothermally active Jemez Mountains area
- The Rio Puerco/Rio San Jose system which drains the Grants Mineral Belt and a portion of the Jemez Mountains.
- The portion of the Middle Rio Grande valley below Socorro.
- Discharge of arsenic in wastewater effluent from municipalities located along the Middle Rio Grande which depend on arsenic-containing groundwater for public water supplies.
- Irrigation return flow of arsenic-containing groundwater.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-09	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 304
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic is a naturally occurring element in the Middle Rio Grande. Sources of arsenic to the river include:

- The geothermally active Jemez Mountains area
- The Rio Puerco/Rio San Jose system which drains the Grants Mineral Belt and a portion of the Jemez Mountains.
- The portion of the Middle Rio Grande valley below Socorro.
- Discharge of arsenic in wastewater effluent from municipalities located along the Middle Rio Grande which depend on arsenic-containing groundwater for public water supplies.
- Irrigation return flow of arsenic-containing groundwater.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-08	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 302
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The elevated levels of arsenic in the Rio Grande below Socorro may be due to discharge of groundwater containing arsenic associated with known geothermally active areas in the region or the past volcanic history of the area. These elevated arsenic levels may also be due to surface enrichment of arsenic rock in the area due to moderate and advanced potassium metasomatism of the region associated with alkaline, saline brines in a playa lake environment (Dunbar et al. 1994).

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-07	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic Source(s)</b> - Anthropogenic	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 302
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The Rio Puerco/Rio San Jose system also contributes significant amounts of arsenic to the Middle Rio Grande. Mining activity at the Grants Mineral Belt may have mobilized some of this arsenic into the environment.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-05	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic Source(s)</b> - Anthropogenic	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 301
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Sources of arsenic to the Middle Rio Grande include tributary streams originating in areas of geothermal and mining activity and the discharge of groundwater containing arsenic. Arsenic in groundwater reaches the Middle Rio Grande both through natural discharge in areas where the river is a gaining stream and through groundwater pumping for municipal water supplies and subsequent discharge via wastewater effluent as well as pumping for irrigation with subsequent return flow.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-04	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 301
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Sources of arsenic to the Middle Rio Grande include tributary streams originating in areas of geothermal and mining activity and the discharge of groundwater containing arsenic. Arsenic in groundwater reaches the Middle Rio Grande both through natural discharge in areas where the river is a gaining stream and through groundwater pumping for municipal water supplies and subsequent discharge via wastewater effluent as well as pumping for irrigation with subsequent return flow.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-03	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 295
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Major sources of human-related release include smelting of ores and use of arsenic containing pesticides. Additional sources from commercial and industrial processes include use of arsenic-containing wood preservatives and paints and pigments.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-01	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 295
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic occurs in the earth's crust at an average concentration of 1.8 micrograms per gram (ug/g) (Krauskopf 1979) and at a concentration of 2.6 micrograms per liter (ug/l) in seawater (Maidment 1993). The average concentration of arsenic in the atmosphere in areas where major emission sources are absent has been estimated at 3 nanograms per cubic meter (USEPA 1980). The average concentration of arsenic in fresh surface waters is 3 ug/l (Boyle and Jonasson 1973). A nationwide study of trace metals in waters throughout the United States found arsenic to be present at a concentration greater than 5 ug/l in 5.5 percent of the samples (Kopp and Kroner 1968). The Agency for Toxic Substances and Disease Registry (ATSDR 1990) reported on a 1970 study which found that up to 1 percent of the water supplies in the United States had concentrations of arsenic exceeding 10 ug/l.

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<b>Article ID</b> 55	<b>Author</b> Flanigan, Kevin G.
<b>Notecard #</b> 55-02	<b>Title</b> Arsenic in the Middle Rio Grande: Occurrence and Regulatory Standards
<b>Topic</b> Source(s) - Natural	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 295
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Natural sources of arsenic include arsenic gases and compounds formed as a result of volcanic and geothermal activity and weathering of minerals and ores containing arsenic.

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<b>Article ID</b> 56	<b>Author</b> Chapin, Charles E. and Nelia W. Dunbar
<b>Notecard #</b> 56-06	<b>Title</b> A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 270
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The main source of arsenic is water-rock reactions, both low and high temperature. Arsenic concentrations in groundwater vary with the type of rock in contact with the water, the temperatures, residence time, and geochemical parameters such as pH, Eh, salinity, complexing agents, etc. Arsenic concentrations in groundwater are highest in silicic volcanic terranes and lowest in regions underlain mainly by granitic and metamorphic rocks.

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<b>Article ID</b> 56	<b>Author</b> Chapin, Charles E. and Nelia W. Dunbar
<b>Notecard #</b> 56-01	<b>Title</b> A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico
<b>Topic Factors Affecting Geochemistry</b>	<b>Date</b> 1994
<b>Constituent</b> Arsenic	<b>Page #</b> 258
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenic is a metalloid that sublimates to vapor at 613°C. Its enthalpy of vaporization is among the lowest of common elements, being lower than mercury and intermediate between iodine and bromine (Emsley 1991). Arsenic has several valence states, of which +3 (arsenite) and +5 (arsenate) are the most common in nature. Arsenic trioxide (As<sub>2</sub>O<sub>3</sub>) sublimates at only 193°C and the pentasulfide (As<sub>2</sub>S<sub>5</sub>) sublimates at 500°C. Consequently, arsenic is strongly enriched in volcanic gases as compared to magma, with an enrichment factor of 10(3) to 10(6). The crustal abundance of arsenic is estimated at 1500 ppb (Emsley 1991), but its abundance in common rocks varies widely. Of particular importance to ground and surface waters in the western U.S. is the relative abundance and mobility of arsenic in silicic volcanic rocks, in volcanoclastic sediments derived from them, and in the hydrothermal systems commonly associated with silicic volcanism.

Arsenic has chalcophile, siderophile, and oxyphile characteristics, meaning that it tends to follow sulfur, iron, and oxygen in geochemical processes. In aqueous systems, the two common oxidation states are arsenite (+3) and arsenate (+5). Arsenite is the common form under reducing conditions, such as in deep groundwater and magmatic and hydrothermal systems, whereas arsenate dominates in most surface waters and shallow groundwater. Arsenite is not easily sorbed onto any compound or mineral and is thus very mobile. Arsenate, however, is easily sorbed onto iron, manganese, and aluminum oxides and fine-grained sediments. The Mn(+4) ion, which is widely distributed as a coating on fracture surfaces and mineral grains, is an efficient oxidizer of As(+3) to As(+5). Note in Table 1 the enrichment of arsenic in iron-rich and clay-rich rocks.

Both arsenite and arsenate are equally soluble in aqueous fluids where they commonly are present as oxyanions. In an oxidizing environment (0.2 - 0.5 V), as in most river waters, both H<sub>2</sub>As<sub>4</sub>(-) and HAsO<sub>4</sub>(-2) occur in appreciable proportions, while under reducing conditions (0 - 0.1 V) H<sub>3</sub>AsO<sub>3</sub> is the dominant species (Mok and Wai 1994). Arsenite forms complex ions with chloride in the pH range 6 to 12 and forms both complex ions and colloids with sulfur in hydrothermal systems. Arsenite also forms complex anions with fluoride. Organic complexed with arsenite can greatly increase its mobility (Mok and Wai 1994).

In rivers such as the Rio Grande, arsenic in unfiltered samples is appreciable higher than in filtered samples because of sorption on, and coprecipitation with, hydrous oxides of iron, manganese, and aluminum as well as attachment to sediment grains. The scavenging power of these particles for arsenic is further evident in the dramatically higher arsenic content of sediment from the river bed. . . Mok and Wai (1994, p. 101) state that, "In a river, arsenic is predominantly bound to sediments." Arsenic can be released from the sediments if the pH becomes acidic or if the pH becomes very high (>8.5). At high pH levels, hydroxide ions compete with arsenic anions for sorption sites. Arsenic can also be released if the Eh becomes reducing. Reduction of ferric ions to ferrous ions liberates sorbed arsenic as As(+3), which is highly mobile.



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**Article ID 56** **Author** Chapin, Charles E. and Nelia W. Dunbar  
**Notecard # 56-02** **Title** A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico  
**Topic** Factors Affecting Geochemistry **Date** 1994  
**Constituent** Arsenic **Page #** 263  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Arsenic, antimony, barium, mercury  
**Notes** . . .two areas with arsenic contents between 20 and 200 ppm are associated with fossil hydrothermal systems. These hydrothermally altered areas contain manganese veins and show enrichment in other elements, such as Sb, Zn, Ba, Au, and Hg, that are typically associated with hydrothermal systems. Arsenic has long been used as a "pathfinder" element in prospecting for hydrothermal gold deposits.

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**Article ID 56** **Author** Chapin, Charles E. and Nelia W. Dunbar  
**Notecard # 56-03** **Title** A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico  
**Topic** Factors Affecting Geochemistry **Date** 1994  
**Constituent** Arsenic **Page #** 263  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Hydrothermal waters in silicic volcanic fields are usually enriched in arsenic which often results in increased concentration in both ground and surface waters.

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**Article ID 56** **Author** Chapin, Charles E. and Nelia W. Dunbar  
**Notecard # 56-04** **Title** A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico  
**Topic** Factors Affecting Geochemistry **Date** 1994  
**Constituent** Arsenic **Page #** 268  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Arsenic, nitrate  
**Notes** A number of geochemical factors are associated with increases or decreases in arsenic concentrations in the Middle Rio Grande Basin (CH2M HILL 1990). Arsenic correlates positively with temperature, depth, fluoride, sodium, chloride, silica, nitrate, alkalinity, and pH of water. Inverse correlations are observed with total water hardness (Ca, Mg) and Eh. Especially significant factors in increased arsenic concentrations are depth, temperature, and fluoride content (CH2M HILL 1990).

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**Article ID 56** **Author** Chapin, Charles E. and Nelia W. Dunbar  
**Notecard # 56-05** **Title** A Regional Perspective on Arsenic in Waters of the Middle Rio Grande Basin, New Mexico  
**Topic** Distribution/Transport in Soil Profile **Date** 1994  
**Constituent** Arsenic **Page #** 268  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Table 4 shows that wells having a total depth less than 1200 ft in the Albuquerque well fields produce mainly Ca-Mg-HCO<sub>3</sub> waters containing less than 20 ppb arsenic with a pH between 7 and 8 and an Eh of approximately 300 mV (CH2M HILL 1990). In contrast, groundwater in wells having a total depth greater than 1200 ft produce mainly alkaline Na-HCO<sub>3</sub> waters containing more than 30 ppb arsenic with higher fluoride contents, higher pH, and considerably less oxidation potential.

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**Article ID** 60**Notecard #** 60-03**Topic** Factors Affecting Geochemistry**Constituent** Nitrate**Co-Occurrence?** No**Author** Bhatt, Kailash**Title** Occurrence and Distribution of Nitrate and Pesticides in Bowdle Aquifer, South Dakota**Date** September 1997**Page #** 237**Co-Occurrence Notes**

**Notes** Approximately thirty-eight percent of analyzed nitrate samples in the aquifer exceeded the 10 mg/l U.S. EPA's maximum contaminant limit. High nitrate fluctuations in selected wells are indicative of high vulnerability in the study areas and non-point source contamination from the agricultural fields which subsequently may vary due to attenuation and dispersion between month to month. Nitrate levels and pesticide detections in most wells decreased with well depth, with minor exceptions. Leaching through the vadose zone is a primary mechanism of nitrate movement to groundwater, with high nitrate concentrations in the upper part of the aquifer. The detection of different pesticides at various depths suggests that soil and pesticide characteristics play a far more important role in pesticide movement than they do for nitrates. Shallow wells in nested sites recorded a higher number of detections than the deeper wells. The absence of micropore connectivity in deeper parts of the aquifer is the major factor for low detection in deeper wells. The transit time for water to move to the upper saturates zone ranges from two to five months after a precipitation event. The number of pesticide detections in area wells increase during periods of heavy and continuous precipitation.

Although a quantitative correlation between the application rate, precipitation and occurrence cannot be drawn due to lack of information on fertilizer and pesticide application rate period, the long term monitoring results can be useful for modelling purposes, where calibration and field verification are needed. The results also can be used as a tool by the local and federal agencies to implement nutrient and pesticide management policies.

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**Article ID** 60**Notecard #** 60-01**Topic** Factors Affecting Geochemistry**Constituent** Nitrate**Co-Occurrence?** No**Author** Bhatt, Kailash**Title** Occurrence and Distribution of Nitrate and Pesticides in Bowdle Aquifer, South Dakota**Date** September 1997**Page #** 230**Co-Occurrence Notes**

**Notes** Shallow wells at some nested sites recorded more than double the nitrate concentrations of the deeper wells. At all nested well sites in the study area, shallow wells had higher nitrate concentrations than the deeper wells, indicating leaching may be a primary mode of nitrate movement. Leaching mechanism of nitrates varies with season and type of crop grown in the field (Theocharopoulos et al., 1993) and was not analyzed in detail in this study. Studies including one conducted by Hall (1992) indicated that there is no relationship between nitrate concentrations in groundwater and either depth to the water table or sampling depth below the water table. He also concluded that relationship between nitrate concentration in groundwater and loading rate of fertilizer were statistically significant. In studying the impacts of agricultural activity in five US regions, Hamilton and Helsel (1995) concluded that in some aquifers the nitrate levels increased with well depth and in others it decreased. Nitrate levels in groundwater are more responsive to nitrogen application in the surface than to the degree and direction of ground water fluctuation. The percolating water from fertilized fields moves through the micropores of the unsaturated zone. Depending upon the site specific properties of geologic medium and time of precipitation in the area, the lag time varied from one well to other well.

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**Article ID** 60 **Author** Bhatt, Kailash  
**Notecard #** 60-02 **Title** Occurrence and Distribution of Nitrate and Pesticides in Bowdle Aquifer, South Dakota  
**Topic** Factors Affecting Geochemistry **Date** September 1997  
**Constituent** Nitrate **Page #** 230  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Wide fluctuations of nitrate levels in individuals wells are indicative of non-point source contribution from fertilized fields. Concentrations variation within month to month sampling also suggest attenuation and dispersion of nitrates and depends on groundwater flow and geologic regime of the study areas.  
  
[Also a series of graphs showing the relationship between nitrate concentrations, water levels and area precipitation in four selected wells]

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**Article ID** 61 **Author** Aceil, S.M.  
**Notecard #** 61-01 **Title** The Study of Naturally Occurring Radioactive Materials (NORM) in Waters of the State of Mississippi  
**Topic** Other **Date** 1996  
**Constituent** Uranium **Page #** 296  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** Transport of NORM in coastal and estuaries can follow Fick's law and diffusion theory. [Gives equations for transport in one dimension, in estuaries, and in rivers, streams, and lakes. Also for subsurface seepage.]

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**Article ID** 61 **Author** Aceil, S.M.  
**Notecard #** 61-02 **Title** The Study of Naturally Occurring Radioactive Materials (NORM) in Waters of the State of Mississippi  
**Topic** Other **Date** 1996  
**Constituent** Uranium **Page #** 297  
**Co-Occurrence?** No **Co-Occurrence Notes**  
**Notes** NORM activities, especially the oil and gas related part, are at their early stages in the state of Mississippi. Lack of public awareness has been the cause of unfortunate incidents in the past. Similar studies in neighboring states and studies in general indicate that the radioactivities of the water and mixed water and minerals could be nil to several thousands of Pico Curie (pCi) per liter of water or gram of scale on the pipes or sludges that resulted from drilling (Greer et al, 1995); Oddo et al.; Fisher 1995; Smith et al 1995; and Fisher 1994)

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**Article ID 62****Notecard # 62-04****Author** Christensen, Victoria G. and Larry M. Pope**Title** Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria during Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996.**Topic** Study Methodology**Date** 1997**Constituent****Page #** 4**Co-Occurrence?****Co-Occurrence Notes**

**Notes** A network of 34 sampling sites was established in the Cheney Reservoir watershed to evaluate spatial variability in concentrations of selected water-quality constituents during low flow. Low flow is streamflow originating primarily as springs or ground-water seepage (including irrigation return flow) or from point-source discharges such as wastewater treatment plants. Low flow does not have a surface-runoff component.

Each of the 34 sampling sites were sampled once during June 11-12, 1996, and again during September 10-11, 1996. Five sampling sites during the June period and six sampling sites during the September period were not sampled because the streams at those sites were either dry or had no streamflow (contained only isolated pools). Physical determinations made onsite included streamflow, specific conductance, pH, air and water temperatures, barometric pressure, and dissolved-oxygen concentration. Samples collected for subsequent laboratory determination included dissolved solids and major ions, nutrients (nitrogen and phosphorus species), atrazine, and fecal coliform bacteria. All samples were collected according to methods presented in Horowitz and others (1994).

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**Article ID 62****Notecard # 62-05****Author** Christensen, Victoria G. and Larry M. Pope**Title** Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria during Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996.**Topic** Source(s) - Anthropogenic**Date** 1997**Constituent** Nitrate**Page #** 7**Co-Occurrence?** Yes**Co-Occurrence Notes** nitrate, microbes

**Notes** Major sources of nutrients include agricultural activities such as the application of synthetic fertilizers and the pasturing and confined feeding of livestock. — It is likely that this statewide trend in increased use of synthetic fertilizers also has occurred in the Cheney Reservoir watershed. — A less significant nonpoint source of nutrients is the bacterial decomposition of plant and animal protein and possible leaching from septic systems. Also, nutrients, particularly ammonia and nitrate, may be components of rainfall; however, because of the predominate agricultural land use in the watershed and the associated potential for distribution of nutrients, it is presumed that rainfall is a relatively minor contributor of nutrients to the watershed. The most substantial point sources of nutrients in the Cheney Reservoir Watershed probably are the municipal wastewater discharges from several small towns within the watershed.

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**Article ID 62****Notecard # 62-03****Author** Christensen, Victoria G. and Larry M. Pope**Title** Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria during Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996.**Topic** Other**Date** 1997**Constituent****Page #** 12**Co-Occurrence?****Co-Occurrence Notes**

**Notes** Water-quality constituents may respond differently to increases in streamflow. For example, concentrations of dissolved solids may be largest during low flow when streams are dominated by ground-water discharges containing relatively large concentrations of dissolved minerals. A previous study (Bevans, 1989) showed inverse relationships between dissolved solids and streamflow for the major streams in Sedgwick County. As streamflow increased, dissolved-solids concentrations decreased. Conversely, concentrations of nutrients, atrazine, and fecal coliform bacteria may be largest during high flow when streams are receiving these constituents with runoff from the watershed (Pope, 1995; Pope and others, 1997; Putnam, 1997). The implication of these relations to long-term water quality in Cheney Reservoir are: (1) the average concentration of dissolved solids in the reservoir probably is less than in streams during low flow, and (2) average concentrations of nutrients and atrazine, and average densities of fecal coliform bacteria in the reservoir may be greater than in streams during low flow.

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**Article ID** 62  
**Notecard #** 62-02  
**Author** Christensen, Victoria G. and Larry M. Pope  
**Title** Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria during Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996.  
**Topic** Source(s) - Anthropogenic  
**Date** 1997  
**Constituent** Other  
**Page #** 11  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** Generally, densities of fecal coliform bacteria in surface water of the Cheney Reservoir watershed appear to be of nonpoint-source origin and presumably associated with livestock production.

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**Article ID** 62  
**Notecard #** 62-01  
**Author** Christensen, Victoria G. and Larry M. Pope  
**Title** Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria during Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996.  
**Topic** Source(s) - Anthropogenic  
**Date** 1997  
**Constituent** Nitrate  
**Page #** 9  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** The larger [nitrite plus nitrate] average concentrations in the watershed appear to be of non-point source origin, presumably from agricultural activities such as livestock production (pasturing or feedlot operations) or fertilizer applications.

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**Article ID** 63  
**Notecard #** 63-02  
**Author** Stackelberg, Paul E., Jessica A. Hopple, and Leon J. Kauffman  
**Title** Occurrence of Nitrate, Pesticides, and Volatile Organic Compounds in the Kikkwood-Cohansey Aquifer System, Southern New Jersey  
**Topic** Other  
**Date** 1997  
**Constituent** Nitrate  
**Page #**  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** The media concentration of nitrate was highest (13.0 mg/l) in samples from agricultural areas, where nitrogen fertilizers are used for crop production. Median nitrate concentrations in samples from the new and old urban areas, where nitrogen sources include domestic fertilizers and sewage wastes, were similar (2.6 and 3.5 mg/l, respectively). Nitrate concentrations were lowest (median 0.07 mg/l) in undeveloped areas, reflecting the lack of human inputs of nitrogen into the subsurface environment in these areas.

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**Article ID** 63  
**Notecard #** 63-01  
**Author** Stackelberg, Paul E., Jessica A. Hopple, and Leon J. Kauffman  
**Title** Occurrence of Nitrate, Pesticides, and Volatile Organic Compounds in the Kikkwood-Cohansey Aquifer System, Southern New Jersey  
**Topic** Study Methodology  
**Date** 1997  
**Constituent** Nitrate  
**Page #**  
**Co-Occurrence?** No  
**Co-Occurrence Notes**  
**Notes** Water samples were collected from a network of 72 shallow monitoring wells to assess the chemical quality of recently recharged ground water in the surficial Kirkwood-Cohansey aquifer system of southern New Jersey. The wells are randomly distributed among agricultural, urban, and undeveloped areas to provide data representative of chemical conditions of ground water underlying each of these land-use settings. Samples were analyzed for nutrients, pesticides, and VOCs.

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- Article ID** 64 **Author** Zeigler, Andrew C., Donald H. Wilkison, and Randall D. Maley  
**Notecard #** 64-04 **Title** Occurrence of Selected Pesticides, Nutrients, Selected Trace Elements, and Radionuclides, in Ground and Surface Water from West-Central Missouri - July 1990-March 1991.
- Topic** Geographic Location/Distribution **Date** 1994  
**Constituent** Nitrate **Page #** 11  
**Co-Occurrence?** No **Co-Occurrence Notes**
- Notes** During 1990, the nutrient analyzed was nitrite plus nitrate, as nitrogen, in milligrams per liter. During 1991, the nutrient analyses included total nitrite plus nitrate, dissolved ammonia, nitrite, nitrite plus nitrate, and orthophosphate. Nitrite plus nitrate concentrations are considered to be nitrate because nitrite concentrations were less than 5 percent of the nitrite plus nitrate concentrations.
- [Table 5 shows summary of nitrate concentrations and sigma 15N values in water samples from wells and well and land-use data]
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- Article ID** 64 **Author** Zeigler, Andrew C., Donald H. Wilkison, and Randall D. Maley  
**Notecard #** 64-01 **Title** Occurrence of Selected Pesticides, Nutrients, Selected Trace Elements, and Radionuclides, in Ground and Surface Water from West-Central Missouri - July 1990-March 1991.
- Topic** Study Methodology **Date** 1994  
**Constituent** **Page #** 2  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Nitrate, Nitrite, Radionuclides, Arsenic
- Notes** Agricultural production is the primary land use in west-central Missouri. The dominant row crops are soy beans, hay, corn, wheat, and grain sorghum. Beef and pork are the principal livestock products. Pesticides and nitrogen fertilizers are used extensively on row crops and may enter ground and surface water. Because ground water is the primary drinking water source for many people in the area, the USGS, in cooperation with the Missouri Dept. of Health, sampled wells, springs, and surface-water sites in west-central Missouri during 1990 and 1991 to determine concentrations of pesticides, nutrients, nitrogen isotopes, radionuclides, arsenic, iron, and manganese in ground and surface water from west-central Missouri. This report contains the results of analyses for pesticides, nutrients, nitrogen isotopes, radionuclides, arsenic, iron, manganese, and selected land-use characteristics for ground- and surface-water samples from Bates, Cass, St. Clair, and Vernon Counties in west-central Missouri.
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- Article ID** 64 **Author** Zeigler, Andrew C., Donald H. Wilkison, and Randall D. Maley  
**Notecard #** 64-02 **Title** Occurrence of Selected Pesticides, Nutrients, Selected Trace Elements, and Radionuclides, in Ground and Surface Water from West-Central Missouri - July 1990-March 1991.
- Topic** Study Methodology **Date** 1994  
**Constituent** **Page #** 6  
**Co-Occurrence?** Yes **Co-Occurrence Notes** Nutrients, Radionuclides, Arsenic
- Notes** During 1990, wells, springs, and surface water sites were selected for sampling in Bates, Cass, St. Clair, and Vernon Counties. Because a random sampling of domestic drinking water was desired, wells were not excluded from sampling if chemicals were mixed near the well. Surface water was sampled from the six largest streams in the area; one pond used for drinking water also was sampled.
- During 1991, wells, springs, and surface water sites were sampled in Bates, Cass, and Vernon Counties. No samples were collected in St. Clair County based on the results of sampling during 1990.
- Land use data were collected in 1990 and 1991, including distance of the well from the chemical-mixing area, distance from feedlot, distance from the septic system, and the percentage of land area with row crops within 0.25 mi of the well
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<b>Article ID</b> 64	<b>Author</b> Zeigler, Andrew C., Donald H. Wilkison, and Randall D. Maley
<b>Notecard #</b> 64-03	<b>Title</b> Occurrence of Selected Pesticides, Nutrients, Selected Trace Elements, and Radionuclides, in Ground and Surface Water from West-Central Missouri - July 1990-March 1991.
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1994
<b>Constituent</b> Nitrate	<b>Page #</b> 6
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The ratio of 15nitrogen to 14nitrogen in nitrate, relative to atmospheric nitrogen (sigma 15N of nitrate), expressed in per mil in ground water can be useful in determining the origin of the nitrogen source. Krietler (1975) reported that the sigma 15N relative to the atmospheric nitrogen standard is largest for nitrate originating from animal wastes. The volatilization of ammonia in animal wastes is the principal factor that controls the ratio (Krietler, 1975). Values of the sigma 15N of nitrate derived from animal waste are greater than + 10 per mil. Values of sigma 15N of nitrate derived from fertilizers or oxidation of soil nitrogen are less than for nitrate derived from feedlot or septic wastes. (Spalding and others, 1982)

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<b>Article ID</b> 65	<b>Author</b> Tuthill, Anna, D.B. Meikle, and Michael C.R. Alavanja
<b>Notecard #</b> 65-05	<b>Title</b> Coliorm Bacteria and Nitrate Contamination of Wells in Major Soils of Frederick, Maryland
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1998
<b>Constituent</b>	<b>Page #</b>
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> microbes, nitrate

**Notes** The relationship between coliform bacteria and nitrate contamination and lot size suggests that septic systems may cause increased levels of well contamination as lot sizes decrease. Installation of adequate septic systems is needed on existing small lots to ensure attenuation of coliform bacteria. A long-range study is needed to determine what changes septic system use causes in nitrate concentrations in wells in a subdivision. Information from such a study could show the long-term nitrate contribution to the groundwater caused by septic systems and could be used in making zoning decisions about minimum residential lot size in unsewered subdivisions.

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<b>Article ID</b> 65	<b>Author</b> Tuthill, Anna, D.B. Meikle, and Michael C.R. Alavanja
<b>Notecard #</b> 65-04	<b>Title</b> Coliorm Bacteria and Nitrate Contamination of Wells in Major Soils of Frederick, Maryland
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1998
<b>Constituent</b> Nitrate	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The negative correlation between lot size and nitrate contamination for all wells and for wells located in three soil groups suggests that nitrate contamination of wells in these soil groups originated from septic systems and was not due to residual nitrogen from past agricultural land use. Studies by Exner and Spalding and Tjostem et al. Suggested that elevated levels of nitrates in groundwater are due to point-source contamination (e.g. barnyards and septic systems) and are not caused by the past agricultural use. The observations of this study indicate that septic systems contribute to the contamination of wells are also supported by Tinker, who found that nitrate levels were higher in wells located on the down gradient side of a subdivision in Wisconsin, and by Ford et al. who found that nitrate levels decreased in wells as their distance from septic systems increased.

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<b>Article ID</b> 65	<b>Author</b> Tuthill, Anna, D.B. Meikle, and Michael C.R. Alavanja
<b>Notecard #</b> 65-03	<b>Title</b> Coliorm Bacteria and Nitrate Contamination of Wells in Major Soils of Frederick, Maryland
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1998
<b>Constituent</b> Microbes	<b>Page #</b> 19
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nine of the 10 soil groups exhibited a negative correlation between lot size and coliform contamination of wells, suggesting that septic systems contributed to coliform contamination of wells on small lots. In addition, the significant negative correlation between lot size and coliform contamination in the Edgemont soil group and the presence of fecal coliform bacteria in wells located on the two smallest lots indicate that the wells in this soil group were particularly vulnerable to contamination. Exner and Spalding also reported that wells located near a point source (intermittently used barnyards) were more frequently contaminated with coliform bacteria. Coliform bacteria attenuation may be increased when shallow disposal systems and sand filters are used on lots less than one acre.

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<b>Article ID</b> 65	<b>Author</b> Tuthill, Anna, D.B. Meikle, and Michael C.R. Alavanja
<b>Notecard #</b> 65-01	<b>Title</b> Coliorm Bacteria and Nitrate Contamination of Wells in Major Soils of Frederick, Maryland
<b>Topic</b> Study Methodology	<b>Date</b> 1998
<b>Constituent</b>	<b>Page #</b> 16
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> microbes, nitrate

**Notes** Specifically, two predictions were tested: (1) A negative correlation between lot size and coliform bacteria and nitrate contamination will exist in unsewered areas; (2) Coliform bacteria and nitrate contamination will decrease with increasing case length. The relationship of coliform bacteria and nitrate levels to lot size and casing length was tested for all wells in unsewered areas. (n=832) and for wells in 10 soil groups in Frederick County, Maryland, to determine if septic system construction or placement contributed to well contamination. Coliform bacteria and nitrate concentration were negatively correlated with lot size. In addition, coliform bacteria levels were negatively correlated with casing length, and there was a trend toward nitrate levels being associated with casing length. The results suggest that septic systems may be a source of coliform bacteria and nitrate contamination of wells. The casing length required in well construction should be increased in areas where wells may be prone to coliform bacteria contamination if the minimum amount of casing is used.



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<b>Article ID</b> 65	<b>Author</b> Tuthill, Anna, D.B. Meikle, and Michael C.R. Alavanja
<b>Notecard #</b> 65-02	<b>Title</b> Coliform Bacteria and Nitrate Contamination of Wells in Major Soils of Frederick, Maryland
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1998
<b>Constituent</b> Nitrate	<b>Page #</b> 19
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> nitrate, microbes

**Notes** A significant negative correlation between coliform bacteria and nitrate contamination and lot size was found only in the Edgemont soil group. The two smallest lots in this soil group were contaminated with fecal coliform bacteria. In nine of the 10 soil groups, however, the correlation coefficient was negative. If there were no overall relationship between lot size and contamination with coliform bacteria, there would be an equal number of positive and negative RHO values.

For three of the soil groups, a significant negative correlation was found between nitrate contamination and lot size. The significant negative correlation found for all wells was probably due primarily to the large sample for the Manor/Glenelg soil group. A negative correlation between nitrate level and lot size was present in seven of the 10 soil groups. In the Manor/Glenelg soil group, nitrate contamination levels clearly decreased as lot size increased. Although nitrate levels in Highfield soil were relatively low, the contamination level may still be related to lot size. In the Penn/Readington/Croton soil group, the pattern of nitrate contamination in relation to lot size was not as tight as in the other soil groups.

A significant negative correlation was found between coliform bacteria and casing length in the Manor/Glenelg soil group. The significant negative correlation found in all wells was also probably due to the large sample size of the Manor/Glenelg soil group. In seven of the 10 soil groups, there was a negative correlation between coliform bacteria contamination and casing length. A negative correlation was found in seven soil groups. When the wells were grouped by casing length regardless of soil type, there was an inverse relationship between the percentage of coliform bacteria contamination and casing length. There was not, however, a significant correlation between nitrates and casing length.

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<b>Article ID</b> 66	<b>Author</b> Moorhead, Daryl L., W. Shane Davis, and Craig F. Wolf
<b>Notecard #</b> 66-01	<b>Title</b> Coliform Densities in Urban Waters of West Texas
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1998
<b>Constituent</b> Microbes	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Playa lakes are an integral part of the surface water management plan for the city of Lubbock, Texas. Most have been enlarged to increase volume. Surrounding streets are designed to direct runoff into local basins, so the once-ephemeral wetlands are now permanent urban impoundments. A variety of recreational activities bring people into contact with these playas. This study found coliform densities 10 to 100 times greater than recommended for human contact (i.e. swimming or wading). Analyses of water quality characteristics and landscape features suggest that total coliform densities are diluted by the greater water inputs of larger watersheds and by overflow from adjacent basins. Both total-coliform and E. coli densities appear to be unrelated to other environmental parameters. The source of coliforms, the reason for such high densities, and factors responsible for their persistence remain uncertain.

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<b>Article ID</b> 66	<b>Author</b> Moorhead, Daryl L., W. Shane Davis, and Craig F. Wolf
<b>Notecard #</b> 66-02	<b>Title</b> Coliform Densities in Urban Waters of West Texas
<b>Topic</b> Study Methodology	<b>Date</b> 1998
<b>Constituent</b> Nitrate	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The authors investigated 20 playa lakes located within the city of Lubbock, Texas, that remain permanently inundated. — Water samples were assayed for concentrations of ammonia, nitrate, orthophosphate, alkalinity, total acidity, and total chlorine using a surface water quality test kit. Landscape features associated with each playa were evaluated according to aerial photographs: total watershed area, total surface area of playa, and total area of adjacent park or open land.

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<b>Article ID</b> 66	<b>Author</b> Moorhead, Daryl L., W. Shane Davis, and Craig F. Wolf
<b>Notecard #</b> 66-03	<b>Title</b> Coliform Densities in Urban Waters of West Texas
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1998
<b>Constituent</b> Microbes	<b>Page #</b> 15
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Observations revealed very high coliform populations in most playas—Although significant relationships were found to exist between some water quality parameters and watershed characteristics, none of the correlation coefficients for bacteria were significant.

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<b>Article ID</b> 66	<b>Author</b> Moorhead, Daryl L., W. Shane Davis, and Craig F. Wolf
<b>Notecard #</b> 66-04	<b>Title</b> Coliform Densities in Urban Waters of West Texas
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> 1998
<b>Constituent</b> Microbes	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** While densities of coliforms in Lubbock playas may pose a threat to public health, their origin is uncertain. Feachem reported that ratios of *E. coli* to total coliforms of less than 4.0 probably derive from nonhuman sources. Values for nontruncated data in the present study ranged from 0.04 to 0.89 and averaged 0.33 (for 12 playas), which implied a source other than human. Both chemical and biological contaminants in urban environments can be traced to many sources, such as waterfowl and pet feces, chemical applications to lawns and gardens, vehicle emissions, and erosion. The sources vary with surrounding land use and the extent of impervious surface areas.

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<b>Article ID</b> 67	<b>Author</b> Valentine, J.L.
<b>Notecard #</b> 67-01	<b>Title</b> Environmental Occurrence of Selenium in Waters and Related Health Significance
<b>Topic</b> Geographic Location/Distribution	<b>Date</b> 1997
<b>Constituent</b> Selenium	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Selenium has been found in appreciable amounts in a few spring and well waters due to high geological occurrence. Scott and Voegeli (1961) found selenium ranging from 1 to 400 ug/l in surface waters from Colorado. Selenium in well waters used by an Ute Indian family near Ignacio, Colorado contained 9000 ug/l (Beath, 1962). Cannon (1964) reported 1000-3000 ug/l in spring water of a uranium-rich area in Grand County, Utah. Valentine et al. (1978) reported 26-1800 ug/l in well water of Grants, New Mexico, which is also a uranium-rich area. Johnson and Roth (1978) reported 92 ug/l selenium in drinking water in Golden, Colorado. Industrial discharges from an electrolytic copper works have been thought to cause increased selenium concentrations (0.2-0.25 mg/l) in river waters in Russia (Pletnikova, 1970). More recently agricultural irrigation waste waters have reported selenium concentrations of 140-4200 ug/l (Fan et al, 1988). Fan et al (1988) state that the major fraction of the selenium was as selenate with some methylated selenium being identified. Domestic wells in the vicinity did not exceed 10 ug/l.

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<b>Article ID</b> 67	<b>Author</b> Valentine, J.L.
<b>Notecard #</b> 67-02	<b>Title</b> Environmental Occurrence of Selenium in Waters and Related Health Significance
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1997
<b>Constituent</b> Selenium	<b>Page #</b> 293
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Selenium in water occurs in various forms depending on the pH and Eh of the medium.

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<b>Article ID</b> 67	<b>Author</b> Valentine, J.L.
<b>Notecard #</b> 67-03	<b>Title</b> Environmental Occurrence of Selenium in Waters and Related Health Significance
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1997
<b>Constituent</b> Selenium	<b>Page #</b> 294
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Even though selenate selenium is found in waters derived from seleniferous soils, it is difficult to predict plant selenium content from soil data. It is also difficult in some cases to predict water selenium content. (Fan et al., 1988; Palmer, 1995)

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<b>Article ID</b> 68	<b>Author</b> Fan, Anna M. and Valerie E. Steinberg
<b>Notecard #</b> 68-01	<b>Title</b> Health Implications of Nitrate and Nitrite in Drinking Water: An Update on Methemoglobinemia Occurrence and Reproductive and Developmental Toxicity
<b>Topic</b>	<b>Date</b> February 1996
<b>Constituent</b>	<b>Page #</b>
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** This article did not provide any useful information.

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<b>Article ID</b> 69	<b>Author</b> Daniel, P.A., N. Dumoutier, V. Mandra, N. Tambo, and T. Kamei
<b>Notecard #</b> 69-01	<b>Title</b> Cryptosporidium: a Risk Assessment
<b>Topic</b> Other	<b>Date</b> 1996
<b>Constituent</b> Cryptosporidium	<b>Page #</b> 388
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The conventional indicators of microbial water quality (e.g. coliforms and heterotrophic plate counts) do not necessarily correlate with the presence or concentrations of Cryptosporidium.

The minimum infective dose is thought to be very low.

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<b>Article ID</b> 71	<b>Author</b> Bright, D.A., M. Dodd, and K.J. Reimer
<b>Notecard #</b> 71-02	<b>Title</b> Arsenic in SubArctic Lakes Influenced by Gold Mine Effluent: The Occurrence of Organoarsenicals and 'Hidden' Arsenic
<b>Topic</b> Constituent Species	<b>Date</b> February 9, 1996
<b>Constituent</b> Arsenic	<b>Page #</b> 166
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> arsenic, antimony

**Notes** Several researchers have recently demonstrated in non-biotic environmental compartments the presence of additional complex arsenicals which are hidden to commonly used hydride generation techniques. These arsenic species have been collectively referred to as 'hidden' or 'refractory'. Hidden arsenic comprised that portion of all arsenicals that does not generate a volatile arsine on reaction with borohydride, unless decomposed to simpler forms. Reimer et al have also detected organoantimony compounds in aquatic plant samples which are hidden to hydride-generation, atomic absorption spectroscopy analysis unless first subjected to microwave digestion with added potassium dichromate. Hidden arsenicals in water or sediment potentially include arsenocholine, arsenobetaine, arsenolipids, and arsenosugars; their metabolites (or precursors); possible sulfur- or thiol-containing arsenicals; and other presently undescribed compounds. In practice, the identity of hidden arsenic in environmental samples has rarely been determined, although hidden arsenic may account for in excess of 50% of the local arsenic budget in marine sediment interstitial water.

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**Article ID 71****Notecard # 71-05****Topic** Source(s) - Natural**Constituent** Arsenic**Co-Occurrence?** No**Author** Bright, D.A., M. Dodd, and K.J. Reimer**Title** Arsenic in SubArctic Lakes Influenced by Gold Mine Effluent: The Occurrence of Organoarsenicals and 'Hidden' Arsenic**Date** February 9, 1996**Page #** 180**Co-Occurrence Notes**

**Notes** Aggett and O'Brien proposed a detailed model of arsenic cycling in lacustrine sediments, and largely discounted earlier hypothetical models by Furguson and Gavis and Weed which emphasized the role of methylarsenical production in controlling the upward remobilization of arsenic from sediments to the water column. The role of inorganic chemical processes, especially of iron- and manganese-oxyhydroxides, in controlling arsenic distributions in aqueous systems has subsequently been emphasized by a large number of researchers. However, recent research on the presence of MMAA and DMAA in lacustrine and marine waters, as well as the dominance of organoarsenicals in the fate and effects of arsenic inputs. The emphasis by most researchers on inorganic arsenic species in examining environmental arsenic cycling is, in part, an artifact of the currently available analytical techniques. This study and research by others have provided evidence of exocellular arsenicals that are hidden to hydride-generation techniques, at concentrations in pore water that can exceed the concentration of arsenate + arsenite by a factor of three or more. Clearly, exocellular organoarsenicals and other hidden arsenic species potentially represent a substantial portion of the total arsenic budget in some ecosystems; the geochemical fate and bioavailability of organoarsenicals has not been clearly elucidated.

Studies undertaken within the last decade of methylarsenic distribution in aquatic environments have emphasized the role of algae as methylators and have focused on the concentrations of arsenite, arsenate, MMAA, and DMAA in the water column. It is becoming increasingly clear, however, that the *de novo* production by bacteria may account for a significant proportion of methylated arsenic levels in aquatic systems, and that arsenic methylation in sediments bears a similarity to mercury methylation. There is no reason to dismiss the role of bacterial arsenic methylation in the photic zone of the water column either.

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**Article ID 71****Notecard # 71-01****Topic** Other**Constituent** Arsenic**Co-Occurrence?** No**Author** Bright, D.A., M. Dodd, and K.J. Reimer**Title** Arsenic in SubArctic Lakes Influenced by Gold Mine Effluent: The Occurrence of Organoarsenicals and 'Hidden' Arsenic**Date** February 9, 1996**Page #** 166**Co-Occurrence Notes**

**Notes** The toxicity of arsenic to aquatic biota is controlled by the type of arsenic species present, as well as the partitioning of arsenicals between environmental compartments.

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**Article ID 71****Notecard # 71-04****Topic** Geographic Location/Distribution**Constituent** Arsenic**Co-Occurrence?** No**Author** Bright, D.A., M. Dodd, and K.J. Reimer**Title** Arsenic in SubArctic Lakes Influenced by Gold Mine Effluent: The Occurrence of Organoarsenicals and 'Hidden' Arsenic**Date** February 9, 1996**Page #****Co-Occurrence Notes**

**Notes** In this study, we have demonstrated that a wide range of methylarsenic compounds occurs in the water column and pore water of freshwater environments near Yellowknife, N.W.T. Depth profiles of EMeAs compounds in sediment cores, along with corroborative evidence from arsenic methylation by anaerobic microbial cultures, indicate that sulfate-reducing bacteria play a role in the arsenic methylation. The results presented here exhibit a strong similarity to recent studies of methylarsenic distributions in marine sediments.

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<b>Article ID</b> 71	<b>Author</b> Bright, D.A., M. Dodd, and K.J. Reimer
<b>Notecard #</b> 71-03	<b>Title</b> Arsenic in SubArctic Lakes Influenced by Gold Mine Effluent: The Occurrence of Organoarsenicals and 'Hidden' Arsenic
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> February 9, 1996
<b>Constituent</b> Mercury	<b>Page #</b> 166
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The biomethylation of mercury in freshwater sediment is directly related to bioavailability and toxicity. The importance of arsenic methylation and demethylation, however, is not known and the factors that control the concentrations of organoarsenicals in water and sediment have not been elucidated. In sediments, bacterial methylation and demethylation as well as microbially-mediated oxidation-reduction reactions might alter the lipophilicity and bioavailability of pore water arsenicals, directly alter arsenic toxicity, and/or alter the rates of arsenic remobilization from and demobilization into the sediment.

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<b>Article ID</b> 72	<b>Author</b> Back, William and Ivan Barnes
<b>Notecard #</b> 72-01	<b>Title</b> Relation of Electrochemical Potentials and Iron Content to Groundwater Flow Patterns
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> undated (circa 1962)
<b>Constituent</b> Other	<b>Page #</b> C11
<b>Co-Occurrence?</b>	<b>Co-Occurrence Notes</b>

**Notes** The greatest amount of iron occurs where the pH is between about 5.0 and 6.5 and the Eh is less than about 200 mv. Note that in water with pH values less than 5, the iron concentrations are not the greatest, but rather have a wide range between  $10^{-3.69}$  and  $10^{-6.75}$ .

The samples from each aquifer tend to cluster according to Eh, pH, or iron content. For instance, the Patuxent samples have pH between 4.5 and 4.8 and iron content between  $10^{-5.17}$  (0.38 ppm) and  $10^{-4.74}$  (1.01 ppm). Most of the samples from the Patapsco Formation have pH between 4.0 and 5.1. The wide range in iron concentration was discussed in an earlier section as a function of the flow path and resulting oxidation potential. With the exception of two samples the water from the Magothy and Raritan Formations has a pH greater than 4.9 and the iron content is more than about  $10^{-4}$  (5.6 ppm). Although the pH of samples from the Aquia greensand ranges from 5.50 to 7.79, the iron content is nearly uniform, ranging from 0.43 to 0.48 ppm. The sample with the lowest pH, 5.50, has the highest oxidation potential, +5.82 mv, and the sample with the highest pH, 7.79, has the lowest Eh, -13 mv; the third sample has an intermediate value for both variables. The equal iron content of all three samples may indicate that this water is in equilibrium with an iron-bearing mineral that was not studied during this investigation.

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**Article ID 72****Author** Back, William and Ivan Barnes**Notecard #** 72-02**Title** Relation of Electrochemical Potentials and Iron Content to Groundwater Flow Patterns**Topic** Factors Affecting Geochemistry**Date** undated (circa 1962)**Constituent** Other**Page #****Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Contact with the atmosphere affects the oxidation potential of the water; oxygenated water tends to have a potential higher than natural water with no oxygen. Within the same aquifer the oxidation potential is higher in areas of recharge than it is in areas of discharge. The oxidation potential is one variable that controls the occurrence and concentration of iron in water. A relationship was found among the oxidation state and amount of iron in water, the groundwater flow pattern, and the mineralogy and organic content of the deposits. This statement probably is a valid generalization for any hydrologic system that contains iron-bearing sediments and oxidizable material.

The difference and changes in Eh within a hydrologic system can be used to substantiate conclusions based on other hydrologic data regarding source and movement of ground water.—Inconclusive evidence suggests that oxidation potentials may show a seasonal variation in shallow aquifers, this would lead to seasonal variation in concentration of iron in water.

Ranges of concentrations of iron in water can be predicted as a function of Eh and pH together. The Eh values measured in the field are between the values predicted from the solubility of  $\text{Fe}(\text{OH})_3$  and the solubility of hematite.

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**Article ID 73****Author** Korte, Nic**Notecard #** 73-04**Title** Naturally Occurring Arsenic in Groundwaters of the Midwestern United States**Topic** Source(s) - Natural**Date** 1991**Constituent** Arsenic**Page #** 137**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Relatively high concentrations of naturally occurring arsenic are common in the US. Most published sites occur in the west and result from weathered volcanic rocks, geothermal areas, irrigation practices, or mineral deposits.

The circumstances at the Missouri study site are very different. The aquifer under investigation is quaternary alluvium underlain by Pennsylvanian strata – mostly limestones and shales. Furthermore, as shown in Figure 1, the occurrences of arsenic within the site are somewhat sporadic. – Indeed, seven years of intensive site characterization have demonstrated that the industrial operation were not a source of arsenic contamination.

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<b>Article ID</b> 73	<b>Author</b> Korte, Nic
<b>Notecard #</b> 73-08	<b>Title</b> Naturally Occurring Arsenic in Groundwaters of the Midwestern United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 140
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The mechanism for elevated arsenic concentrations in midwestern alluvial groundwater systems probably begins with the deposition of iron oxides during streamflow while the alluvium is being deposited. These oxides have a strong affinity for dissolved arsenic and adsorb it from the streamwater. The amount of arsenic adsorbed by the iron oxides is apt to be extremely variable because deposition occurs over a long period of time. Variations in redox conditions, concentrations of dissolved species, and position in the stream all effect the amount of adsorbed arsenic. As the alluvium is buried, it eventually becomes subject to slow groundwater movement. As redox conditions become increasingly reducing, the ferric iron is reduced to ferrous iron, resulting in mobilization of some of the adsorbed arsenic. If conditions are sufficiently reducing long enough, essentially all of the arsenic may be reduced to As(III) (Agget and Kriegman 1988)

Support for this mechanism is available in the literature. Druel and Swoboda 1972 showed in a laboratory that as conditions become more reducing, ferric iron reduces to ferrous and previously sorbed arsenic is reduced and mobilized. This may explain why, at the study site, little correlation existed between the iron and arsenic concentrations in the groundwater. Thus, local variations in Eh and arsenic content demonstrate why the arsenic concentration in midwestern alluvial groundwaters may be significantly elevated yet sporadic and does not correlate with commonly measured groundwater parameters.

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<b>Article ID</b> 73	<b>Author</b> Korte, Nic
<b>Notecard #</b> 73-07	<b>Title</b> Naturally Occurring Arsenic in Groundwaters of the Midwestern United States
<b>Topic</b> Other	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** A review of drilling records revealed that an orange iron oxide stain (described as limonite) was frequently noted on the lithologic logs. Typically, the limonite was noted as a stain on a dark-green reduced clay. The literature contains much discussion of the scavenging of arsenic by iron oxides. Thus, in subsequent drilling operations, some of the limonite was collected and separated from the clay. Analysis of the limonite subsamples showed that some contained as much as 84 mg/kg of arsenic. This finding was significant because a laboratory study demonstrated that sediments having arsenic concentrations similar to those in the limonite could support aqueous concentrations as high as those observed at the study site.

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<b>Article ID</b> 73	<b>Author</b> Korte, Nic
<b>Notecard #</b> 73-05	<b>Title</b> Naturally Occurring Arsenic in Groundwaters of the Midwestern United States
<b>Topic</b> Study Methodology	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 138
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The initial phase of the investigation focused on determining the arsenic species present in the groundwater. Such information was deemed important because: 1) the presence of organic arsenicals might indicate prior usage of pesticides or herbicides, and 2) a determination of arsenic oxidation states would provide additional insight into the redox conditions in the aquifer. In addition, As(III) is generally more toxic than As(V).

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**Article ID 73****Author** Korte, Nic**Notecard #** 73-03**Title** Naturally Occurring Arsenic in Groundwaters of the Midwestern United States**Topic** Geographic Location/Distribution**Date** 1991**Constituent** Arsenic**Page #** 137**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Discussions with state agencies revealed that high concentrations of arsenic occur in aquifers in at least five state in the midwestern US.: Missouri, Iowa, Illinois, South Dakota, and Ohio. In most cases, the appearance of the arsenic could not be correlated with waste disposal, chemical usage, or with the site geochemical and geologic features. Data collected at the Missouri site, however, and a review of information from the various states revealed that similar geochemical conditions prevailed wherever elevated concentrations of arsenic were found in groundwater. A review of some of the data suggested that one reason there had not been much study of this phenomenon is that the arsenic-contaminated water-supply aquifers were relatively low-yield, sufficient for single families but not municipalities. The purpose of this article, therefore, is to describe a common set of hydrogeologic conditions that yield elevated levels of naturally occurring arsenic in groundwaters of the US.

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**Article ID 73****Author** Korte, Nic**Notecard #** 73-02**Title** Naturally Occurring Arsenic in Groundwaters of the Midwestern United States**Topic** Factors Affecting Geochemistry**Date** 1991**Constituent** Arsenic**Page #** 137**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** A recent investigation of the groundwater at an industrial facility in the state of Missouri, USA, revealed the presence of arsenic in concentrations significantly greater than the US EPA drinking water standard of 0.05 mg/l (Korte 1990). Extensive review of the site's history revealed no arsenic usage. More puzzling was the fact that the arsenic concentrations were not correlated to other groundwater parameters. For example, many wells at the site contained tens of parts per million of iron and manganese oxides to adsorb arsenic (Pierce and Moore, 1980) a direct correlation of iron and/or manganese content and arsenic content might have been expected. Instead, water samples containing elevated arsenic typically exhibited elevated levels of iron and manganese, but relative concentrations were so variable that no direct correlation existed.

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**Article ID 73****Author** Korte, Nic**Notecard #** 73-01**Title** Naturally Occurring Arsenic in Groundwaters of the Midwestern United States**Topic** Factors Affecting Geochemistry**Date** 1991**Constituent** Arsenic**Page #** 137**Co-Occurrence?** Yes**Co-Occurrence Notes**

**Notes** High concentrations of naturally occurring arsenic are present in alluvial groundwater systems in the midwestern U.S. These occurrences tend to be sporadic because the arsenic is mobilized only under a narrow range of redox conditions. The reducing conditions must be sufficient to reduce and dissolve iron and manganese but not to produce sulfide. Typically the affected aquifers are relatively high in clay content and of relatively low [word unreadable]. For that reason, many of these occurrences are in aquifers supplying single families. The mechanism by which the arsenic is mobilized begins with the deposition of nonoxides??(word partially missing) during streamflow while the alluvium is being deposited. The oxides have a strong affinity for dissolved arsenic and adsorb it from the streamwater.



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<b>Article ID</b> 73	<b>Author</b> Korte, Nic
<b>Notecard #</b> 73-06	<b>Title</b> Naturally Occurring Arsenic in Groundwaters of the Midwestern United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 139
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The presence of As(II) without detectable As(V) was evidence that conditions at the site were strongly reducing. Other evidence included high concentrations of iron and manganese and little or no dissolved oxygen in the groundwater. However, no simple correlation existed between the arsenic content and the concentrations of iron, manganese, or oxygen. Sulfide was not present, but ample evidence of anaerobic biodegradation (based on transformations undergone by chlorinated solvents present in some portions of the aquifer) was present. This information is important because arsenic is precipitated by sulfide and may be reduced by microorganisms.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-03	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Study Methodology	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 836
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** During 1987-1989, 146 wells penetrating the Permian part of the aquifer were sampled. Water-producing sandstone layers in the test holes were isolated using inflatable packers, and water samples were analyzed.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-11	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Uranium	<b>Page #</b>
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> uranium, arsenic

**Notes** Water with a pH below 8.5 tends to contain only low concentrations of As but may contain very high concentrations of U. Water with a pH less than 8.5 and a high concentration of U tends to be from shallow wells, have over 0.9 mmol/l of exchanged sodium, and have a CO<sub>3</sub><sup>2-</sup> activity higher than waters with the same pH but with only low concentrations of U.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-10	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Uranium	<b>Page #</b>
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> uranium, arsenic

**Notes** In its most oxidized state (U(VI)) U is an oxy-cation (UO<sub>2</sub><sup>2+</sup>) and tends to sorb on negatively charged mineral surfaces. Within the range of water pH in the aquifer, the mobility of U can be enhanced by the complexation of the U oxy-cation with carbonate ions (CO<sub>3</sub><sup>2-</sup>) to form neutral or negatively charged complexes. At a high pH the activity of carbonate ions increases in solution and mobilization of oxidized U is favored. Thus, in waters with a pH above 8.5 high U concentrations occur with dissolved As.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-09	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Arsenate (As(V)) tends to sorb on positively charged iron oxide surfaces. Iron oxides are abundant in this red-bed aquifer, and analyses of the rock-cores has shown arsenic to be associated with yellow-brown goethite. Desorption of arsenate from iron-oxide surfaces is enhanced by increasing pH, which may explain the association between As and pH in the aquifer.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-08	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 838
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> arsenic uranium

**Notes** Data collected for this study show a strong relation between dissolved As and pH, and between dissolved U and the amount of cation exchange the water has undergone. Arsenic is present at high concentration (50-110 ug/l) only in water with a pH at or above 8.5.

Uranium exceeds 20 ug/l only in water containing 0.9 mmol/l or more exchanged sodium and a pH greater than or equal to 7.2. Water with a pH above 8.5 and a high concentration of U (20-318 ug/l) commonly is from a deep well (>300 ft deep). Water with a pH 7.2 to 8.5 and a high U concentration (20-217 ug/l) generally is from a shallow well (<200 ft deep) in the clay-rich part of the aquifer and has a high alkalinity (300-650 mg/l).

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-07	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 837
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> arsenic, selenium, uranium

**Notes** Detectable dissolved oxygen (>1mg/l) is present in most water in the aquifer, indicating an oxic environment (Berner, 1981). Water without detectable oxygen commonly contains As, selenium, or U, which are generally only mobile in post-oxic or oxic environments, and are not mobile in sulfidic and methanic environments. Determination of As oxidation state in this water and in some oxic water showed the As to be present as As(V), the highest oxidation state. This indicates most water in the aquifer resides in post-oxic or oxic environments. The oxic and post-oxic redox environments in the aquifer should allow As and U to be in oxidation states (As(V) and U(VI)) that enhance the mobilization of the elements.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-05	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 836
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The aquifer is composed primarily of fine- and very-fine-grained quartz-litharenite sandstone and lenticularly interbedded with mudstone.

The most notable diagenetic feature of the aquifer is the pervasive red color, which is caused by abundant grain-coating iron oxides and indicates the generally oxidized nature of the rocks. Locally, yellow-brown goethite grain coatings color thick sequences of sandstone. Also notable are the reduced zones, which are white or pale greenish gray in color due to a lack of ferric oxides and which are generally less than five feet thick.

Chemical and mineralogic analyses of the rock core revealed that the highest concentrations of As (up to 62 micrograms per gram) were found in rocks containing abundant yellow-brown goethite grain coatings. No discrete As-mineral phases were found, although two grains of iron pyrite isolated by heavy separation did contain some As. Pyrite is rare in the aquifer.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-02	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Other	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 835
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The Central Oklahoma aquifer underlies approximately 3,000 square miles in central Oklahoma. It is composed of Quaternary alluvium and terrace deposits and the underlying Permian sandstone and mudstone. The alluvium and terrace deposits were not included in this study because they generally do not contain water with high concentrations of As or U. Permian geologic units in the aquifer include the Garber Sandstone, the Wellington Formation, and undivided rocks of the Chase, Council Grove, and Admire Groups.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-01	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 835
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> arsenic, uranium

**Notes** The Central Oklahoma aquifer is a major source of water in central Oklahoma. In the confined part of the aquifer, dissolved arsenic (As) concentrations commonly exceed the Federal drinking water standard of 50 ug/l (USEPA 1986). Dissolved uranium concentrations commonly exceed the proposed standard of 20 ug/l in both the confined and unconfined parts of the aquifer. The high concentrations of As and U were found to be a function of 1) the distribution of As and U in the solid phases of the aquifer 2) the oxidized nature of the aquifer 3) the distribution of sandstone and mudstone in the aquifer, and 4) changes in water chemistry as the water flows through the aquifer. This paper describes water-rock interactions that mobilize As and U.

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<b>Article ID</b> 74	<b>Author</b> Schlottmann, J.L. and G.N. Breit
<b>Notecard #</b> 74-06	<b>Title</b> Mobilization of As and U in the Central Oklahoma Aquifer, USA
<b>Topic</b> Distribution/Transport in Soil Profile	<b>Date</b> 1992
<b>Constituent</b> Arsenic	<b>Page #</b> 837
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> arsenic, uranium

**Notes** Mudstone in the aquifer generally contains a higher concentration of As and generally contains a higher concentration of As and U than does sandstone and may be an important source for these elements.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-09	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Other	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Adsorption or coprecipitation also can be major factor controlling aqueous arsenic concentrations. Phases that may coprecipitate with or adsorb arsenic include hydrous oxides and hydroxides of iron, manganese, clay minerals, and organic matter

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-17	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 342
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** In general, geothermal water has higher arsenic concentrations than nonthermal water that does not drain mineralized areas. The geochemical controls and sources of arsenic in geothermal systems are not well understood, although the relation between chloride and arsenic at Yellowstone and Lassen has led to the interpretation that aqueous arsenic may be derived largely from leaching of the aquifer matrix.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-16	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

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**Notes** The part of eastern Nevada and western Utah underlain by carbonate rocks is one part of the Alluvial Basins groundwater region with characteristically low dissolved aqueous arsenic concentrations.

Ground water from the Columbia Lava Plateau in Washington generally has low arsenic concentrations. This area is dominantly comprised of basaltic volcanic rocks, whereas parts of Oregon and the Western Snake River Plain with more frequent occurrences of intermediate to high arsenic concentrations are commonly underlain by more acidic extrusive rocks similar to the northern part of the Alluvial Basins of western Nevada.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-15	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 342
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Within the Alluvial Basins, both confined and unconfined aquifers with elevated arsenic concentrations (>50 ug/l) are commonly associated with sediments partially derived from volcanic rocks of intermediate to acidic composition. Examples of elevated arsenic concentrations generated from reaction of ground water with nonsedimentary and unmineralized volcanic aquifers have not been found during this investigation. Although the arsenic may ultimately be a result of weathering of volcanic rocks, the elevated arsenic concentrations in the Alluvial Basins may be a result of reactions occurring within volcanically derived sediments. The weathering process may result in the concentration of arsenic onto phases such as ferric oxyhydroxide that are deposited with the sediments. Subsequent dissolution by chemically reduced ground water of the phases containing arsenic could then generate elevated dissolved arsenic concentrations.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-14	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Other	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Some areas that have experienced land subsidence resulting from inelastic or permanent compaction also have notably high arsenic concentrations. Examples include the southern San Joaquin Valley (California Department of Water Resources, 1966) and, possibly the Las Vegas Valley. Whether high arsenic concentrations are caused by inelastic compaction has not been established.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-13	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 339
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Nonthermal water of the Alluvial Basins, Columbia Lava Plateau, and the Colorado Plateau ground water regions have similar log mean, upper and lower quartile values. Within the Alluvial Basins region, very high concentrations of arsenic (>1000 ug/l) occur within shallow ground water (<30 feet below land surface) recharged through agricultural irrigation. Examples include the Carson Desert in western Nevada (located about 50 miles east of Reno) and the Tulare Lake area in the southern San Joaquin Valley of California. In these areas, the shallow ground water flows to agricultural drains and may affect surface water use.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-12	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 339
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Elevated arsenic concentrations are widespread in the western US in nonthermal water that is unaffected by mining. . The arsenic concentrations of water in the western mountain ranges are generally lower than those in the other groundwater regions with data for the Sierra Nevada being sparse. Notable exceptions to the generally low arsenic in the western mountain ranges are found in the vicinity of Eugene, Oregon (Lane County) where concentrations exceeding 50 micrograms per liter (ug/l) occur. The aquifers in the Eugene area include sediments derived from volcanic rocks that are immediate to acidic in composition. In the vicinity of Verdi, Nevada (located about 10 miles west of Reno), which is also in the western mountain ranges, ground water contains elevated arsenic concentrations in an aquifer composed of volcanic rocks of intermediate to acidic composition and their sedimentary derivatives. The association of elevated arsenic with sedimentary aquifers derived from volcanic rocks has also been found within the Alluvial Basins ground water region as discussed later in this section

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-18	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Areas in which some of the highest concentrations in the western US occur are associated with mining.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-10	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 338
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** A survey of literature and an examination of more than 7,000 analyses for arsenic in computerized data bases indicates that the occurrence of elevated arsenic concentrations in ground water can be related to the geochemical environment and regional ground-water hydrology.

<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-01	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** High concentrations of arsenic are generally associated with one of four geochemical environments: 1) basin-fill deposits of alluvial-lacustrine origin, particularly in semiarid areas, 2) volcanic deposits, 3) geothermal systems, and 4) uranium and gold-mining areas.

In the first two environments, arsenic appears to be associated with sediments derived, in part, from volcanic rocks of intermediate to acidic composition. Dissolved arsenic concentrations in water from volcanic aquifers in the same regions, however, may be low (less than 10 micrograms per liter)

Alluvial and lacustrine sedimentary deposits appear to be an important source of arsenic in volcanic areas (such as Lane County, Oregon) and in areas underlain by basin-fill deposits (such as Carson Desert in Nevada and the Tulare Lake basin in California). Mobilization of arsenic in sedimentary aquifers may be, in part, a result of changes in the geochemical environment due to agricultural irrigation. In the deeper subsurface, elevated arsenic concentrations are associated with compaction caused by groundwater withdrawals.

<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-08	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 337
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Mineral precipitation can limit aqueous arsenic concentrations in ground water. Of the more than 320 minerals identified that contain arsenic, few are present in most geochemical environments. The commonly identified arsenic-bearing minerals are realgar (As<sub>2</sub>S<sub>3</sub>), orpiment (As<sub>2</sub>S<sub>3</sub>), arsenopyrite (FeAsS), claudetite (As<sub>2</sub>O<sub>3</sub>), arsenolite (As<sub>4</sub>O<sub>6</sub>), arsenic pentoxide (As<sub>2</sub>O<sub>5</sub>), and scorodite (FeAsO<sub>4</sub> · 2H<sub>2</sub>O). Within this group of minerals, arsenopyrite probably is the most common arsenic mineral. Alkaline-earth and transition-metal arsenates also may control the arsenic concentrations in ground water.

Barium arsenate has been suggested as a possible control on arsenic concentrations on the basis of its low solubility.

<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-11	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Study Methodology	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 339
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The assembled data do not represent a random sampling of ground water in the western US. Most important sources of bias may arise from the designs of the studies generating the data. In studies directed toward resource appraisal, sampling of nonthermal ground water from existing wells may result in a tendency to exclude sources with known water-quality problems, because of avoidance or abandonment of wells where problems have been recognized. An opposite bias may be present in studies directly addressing arsenic contamination as a result of more intensive sampling in areas where arsenic is known to be present at elevated concentrations. Another possible source of bias may be a result of incorrectly identified water as thermal, nonthermal, or from a mined area. Despite these potential problems in using historical data, the broad generalizations presented here are believed to be valid.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-02	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 333
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> arsenic, selenium, antimony

**Notes** Arsenic can serve as an example of the factors that may influence concentrations of other constituents because other oxyanions, such as phosphorus, selenium, molybdenum, antimony, tungsten, and vanadium, are affected by many of the same types of reactions.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-03	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Source(s) - Anthropogenic	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 334
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Higher than average arsenic levels in precipitation are often associated with anthropogenic sources, such as emissions from smelters, and have resulted in abnormally high arsenic concentrations in surface sediments. It is unusual to find high arsenic concentrations in river water without a significant contribution of arsenic from geothermal water or mineralized areas.

The Malheur River, which drains part of southeastern Oregon, is notable for dissolved arsenic concentrations that exceed 50 ug/l during periods of low flow.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-04	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 334
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** An obvious difference in arsenic concentration does not exist among the various types of igneous rocks. Arsenic does, however, concentrate in some minerals. For instance, arsenic readily substitutes for silicon, ferric iron, and aluminum in crystal lattices of silicate minerals. As a result, arsenic concentrations tend to be relatively high in volcanic glass, aluminosilicate materials, and igneous rocks containing iron oxide. Because the arsenic content of metamorphic rocks is dependent primarily on source-rock composition, arsenic concentrations are highly variable within this rock type. Sedimentary rocks generally contain higher arsenic concentrations than igneous and metamorphic rocks. Tourtelot (1964) found that, in general, arsenic in nonmarine shales/clays is present in pyrite and organic matter. Sandstones and carbonate rocks are comparatively low in arsenic, averaging only 1 mg/kg. High arsenic concentrations in phosphorites have been positively correlated with the organic (Gulbrandsen, 1966) and iron content (Stow, 1969) of the rock.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-05	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Other	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Comparisons of the data in tables 1 and 3 indicate that suspended and bottom sediments in most aquatic systems contain much higher arsenic concentrations than those of the water.



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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-06	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b> 335
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** In soils, organic matter can concentrate arsenic in the upper horizons while adsorption onto ferric oxyhydroxide can enrich arsenic at greater depths. Arsenic in certain solid phases within sediments, particularly iron oxides, organic matter, and sulfides, may be the primary source of arsenic in ground water. Elevated concentrations of dissolved arsenic may be expected under conditions where these solid phases are unstable.

Figure 1 on page 335 is illustration of the forms of naturally occurring arsenic found in the environment.

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<b>Article ID</b> 76	<b>Author</b> Welch, Alan H, Michael S. Lico, and Jennifer L. Hughes
<b>Notecard #</b> 76-07	<b>Title</b> Arsenic in Ground Water of the Western United States
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> May-June 1988
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Major processes responsible for observed concentrations of arsenic in ground water include: mineral precipitation/dissolution, adsorption/desorption, chemical transformations, ion exchange, and biologic activity. Factors such as pH, Eh, solution composition, competing and complexing ion, aquifer mineralogy, reaction kinetics, and hydraulics of a ground-water system can all potentially affect the arsenic concentrations.

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<b>Article ID</b> 77	<b>Author</b> Garcia, Kerry T.
<b>Notecard #</b> 77-02	<b>Title</b> Ground-Water Quality in Douglas County, Western Nevada
<b>Topic</b> source(s)	<b>Date</b> 1987
<b>Constituent</b> Nitrate	<b>Page #</b> 40
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Constituent: Nitrate

Source or cause of occurrence: Derived from the atmosphere or may be leached from decaying organic matter, fertilizers, sewage, industrial wastes, or sewage.

Normal range in concentration: 0 to 10 mg/l

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<b>Article ID</b> 77	<b>Author</b> Garcia, Kerry T.
<b>Notecard #</b> 77-03	<b>Title</b> Ground-Water Quality in Douglas County, Western Nevada
<b>Topic</b> source(s)	<b>Date</b> 1987
<b>Constituent</b> Arsenic	<b>Page #</b> 40
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Constituent: Arsenic

Source or cause of occurrence: Associated with volcanic minerals and metallic ore deposits. Common in water of thermal springs.

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**Article ID 77****Author** Garcia, Kerry T.**Notecard #** 77-04**Title** Ground-Water Quality in Douglas County, Western Nevada**Topic** Factors Affecting Geochemistry**Date** 1987**Constituent** Arsenic**Page #** 60**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** A statistical evaluation of constituents in [Douglas County] ground water indicates that sodium, arsenic, iron, manganese, and zinc each have a single statistical "population," whereas dissolved solids, calcium, magnesium, bicarbonate, sulfate, chloride, fluoride, and nitrate each have two discrete "populations." Because of known hydrogeologic conditions in certain areas of Douglas County, the two data distributions may be caused by: water flowing from metasedimentary rocks into alluvial-fan deposits in the Topaz Lake area; water above the clay layers underlying the Douglas County Airport; and geothermal water in the Jacks Valley-Indian Hills and Saratoga Hot Springs areas.

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**Article ID 77****Author** Garcia, Kerry T.**Notecard #** 77-01**Title** Ground-Water Quality in Douglas County, Western Nevada**Topic** source(s)**Date** 1987**Constituent** Sulfate**Page #** 39-40**Co-Occurrence?** No**Co-Occurrence Notes****Notes** [From Table 1]Constituent: Sulfate (SO<sub>4</sub>)

Source or cause of occurrence: Dissolved from rocks and soils containing gypsum and sulfide or sulfate minerals. Commonly associated with coal deposits, metallic ore deposits, and geothermal areas. May be derived from industrial wastes and atmospheric pollution.

Normal range in concentration: Generally ranges from 1 to 1,000 mg/l.

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**Article ID 78****Author** Goolsby, Donald A., R.C. Severson, S.A. Wilson, Kurt Webber**Notecard #** 78-01**Title** Geochemistry of Soils and Shallow Ground Water, With Emphasis on Arsenic and Selenium, in Part of the Garrison Diversion Unit, North Dakota, 1985-1987**Topic** Source(s) - Anthropogenic**Date** unknown (circa 1989)**Constituent** Other**Page #** 1**Co-Occurrence?** No**Co-Occurrence Notes**

**Notes** Recent studies in the western US have focused on important environmental problems associated with irrigating arid and semiarid lands underlain by soils that originated from sediments deposited in a marine environment.—The natural accumulation of potentially toxic elements in the sedimentary rocks makes these lands important remobilization sources for trace elements such as selenium. Results of earlier investigations in the western San Joaquin Valley of California have demonstrated that under intensive irrigation, trace quantities of selenium have been mobilized, transported, and concentrated. This can create a major environmental problem. Changes in environmental conditions, such as those accompanying irrigation in the Garrison Diversion Unit, could result in increased concentrations or remobilization of potentially toxic elements. This in turn could limit water and soil uses and affect the ecological system dependent on the water resource.

Reconnaissance evaluations by the US Department of the Interior's Irrigation Drainage Task Force indicated the probability of such effects at the Kesterson National Wildlife Refuge in the San Joaquin Valley of California, the Tulare Lake Bed area in California, the Salton Sea in southern California, and the Kendrick Irrigation Project in eastern Wyoming. At many of these areas, marine shales of Cretaceous age were the original source of trace elements. Concentration of trace elements commonly was achieved through leaching processes, adsorption on fine-grained or organic-rich materials, evapotranspiration or bioaccumulation.

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**Article ID** 80

**Author** Eccles, Lawrence A.

**Notecard #** 80-02

**Title** Sources of Arsenic in Streams Tributary to Lake Crowley,  
California

**Topic** Factors Affecting Geochemistry

**Date** June 1976

**Constituent** Arsenic

**Page #**

**Co-Occurrence?** No

**Co-Occurrence Notes**

**Notes** According to Willey, O'Neal, and Rapp (1974), the geothermal water is either a sodium bicarbonate or a sodium chloride bicarbonate type. It is characterized in Long Valley by: high concentrations of dissolved solids -- mainly sodium, bicarbonate, chloride, boron, and arsenic; a relatively low concentration of magnesium compared to other native water; and high concentrations of a host of trace elements.

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**Article ID** 80

**Author** Eccles, Lawrence A.

**Notecard #** 80-01

**Title** Sources of Arsenic in Streams Tributary to Lake Crowley,  
California

**Topic** Source(s) - Natural

**Date** June 1976

**Constituent** Arsenic

**Page #**

**Co-Occurrence?** No

**Co-Occurrence Notes**

**Notes** Arsenic enters Lake Crowley primarily from hot springs in Long Valley.

Sixty percent of the arsenic discharged to Lake Crowley is from springs in Hot Creek Gorge.

Other sources of arsenic in Long Valley are from either high volume and low-arsenic concentration springs, such as the springs at Hot Creek Fish Hatchery, or high-concentrations and low-volume springs, such as those found in the vicinity of the Alkali lakes.

Many hot springs and other surface manifestations of geothermal activity occur in Long Valley, Calif. Water from these hot spring has a high concentration of arsenic and other dissolved minerals and blends with surface water that flow into manmade Lake Crowley and subsequently into the Los Angeles city water supply by way of the Los Angeles-Owens River aqueduct. The hot-spring water is the major source of arsenic to Lake Crowley and thence to the aqueduct which supplies 80 percent of the water for the City of Los Angeles.

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**Article ID** 81

**Author** Ficklin, Walter H., David G. Frank, Paul K. Briggs, and Robert E. Tucker

**Notecard #** 81-01

**Title** Analytical Results for Water, Soil, and Rocks Collected Near  
Granite Falls, Washington as Part of an Arsenic-in-Groundwater  
Study

**Topic** Study Methodology

**Date** 1989

**Constituent** Arsenic

**Page #**

**Co-Occurrence?** No

**Co-Occurrence Notes**

**Notes** The arsenic concentration in some domestic water supply wells in the vicinity of Granite Falls, Washington greatly exceeds the maximum allowable concentration for safe drinking water (50 ug/l). We collected ground water samples from several of these wells and also solid phase material from sites adjacent to some of the wells. We also collected samples from in-place vein material that was exposed to the surface at a rock crushing operation near the Wayside mine (abandoned), a mine water sample and a vein sample from the Yankee Boy mine (abandoned), and two sediment samples and a water sample from Gardner Lake. The samples were collected to determine, if possible, the source of the arsenic in the ground water.

Some outcrops of volcanic rocks can be found in the vicinity of Granite Falls, however most of the samples were collected in the areas where surficial alluvial material occurs.

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<b>Article ID</b> 82	<b>Author</b> Welch, Alan H. and Michael S. Lico
<b>Notecard #</b> 82-01	<b>Title</b> Arsenic in an Alluvial-Lacustrine Aquifer, Carson Desert, Western Nevada
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b>
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Elevated arsenic concentrations (>0.01 mg/l) are common in ground water of the western US (Alaska, Arizona, California, Idaho, Nevada, Oregon, and Washington) -- Natural high concentrations of arsenic appear to be associated with one of four geological environments: alluvial-lacustrine deposits, geothermal systems, volcanic deposits and their derivatives, and mineralized (sulfide-rich) areas, notably gold-bearing deposits. The most extensively affected environment, in terms of total area, appears to be the alluvial-lacustrine type, where arsenic concentrations as high as several milligrams per liter are attained.

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<b>Article ID</b> 83	<b>Author</b> Korte, Nic E. and Quintus Fernando
<b>Notecard #</b> 83-06	<b>Title</b> A Review of Arsenic (III) in Groundwater
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 31
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Although few data exist, low-yielding alluvial groundwater systems employed as drinking water supplies may be a significant source of arsenic exposure.

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<b>Article ID</b> 83	<b>Author</b> Korte, Nic E. and Quintus Fernando
<b>Notecard #</b> 83-01	<b>Title</b> A Review of Arsenic (III) in Groundwater
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 1
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Reducing conditions in alluvial aquifers supplying single families may result in significant exposures to naturally occurring As(III).

In general, the mechanism promoting the mobility of As(III) in groundwater is the onset of reducing conditions in alluvium in which iron oxides have sorbed arsenic.

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<b>Article ID</b> 83	<b>Author</b> Korte, Nic E. and Quintus Fernando
<b>Notecard #</b> 83-02	<b>Title</b> A Review of Arsenic (III) in Groundwater
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 2
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The occurrence of arsenic in natural waters is usually associated with sedimentary rocks of marine origin, weathered volcanic rocks, fossil fuels, geothermal areas, mineral deposits, mining wastes, agricultural use, or irrigation practices. With the exception of agricultural practices, occurrences in North America have typically been found in the western US and have been associated with oxygenated environments.

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<b>Article ID</b> 83	<b>Author</b> Korte, Nic E. and Quintus Fernando
<b>Notecard #</b> 83-03	<b>Title</b> A Review of Arsenic (III) in Groundwater
<b>Topic Source(s)</b> - Anthropogenic	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b> 2
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Because of arsenic's reputation as a poison, and its use as a herbicide and pesticide, many occurrences are attributed to anthropogenic use. A number of studies have described arsenic contamination from spills of herbicides, and pesticides. Some of these incidents or usages have resulted in regionally contaminated aquifers.

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<b>Article ID</b> 83	<b>Author</b> Korte, Nic E. and Quintus Fernando
<b>Notecard #</b> 83-04	<b>Title</b> A Review of Arsenic (III) in Groundwater
<b>Topic Source(s)</b> - Natural	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The major natural source of arsenic to the environment appears to be volcanoes.

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<b>Article ID</b> 83	<b>Author</b> Korte, Nic E. and Quintus Fernando
<b>Notecard #</b> 83-05	<b>Title</b> A Review of Arsenic (III) in Groundwater
<b>Topic Factors Affecting Geochemistry</b>	<b>Date</b> 1991
<b>Constituent</b> Arsenic	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The effect of other ions on As(III) mobility has been considered by there is no agreement in the literature

Apparently, only manganese, and not iron, oxidizes As(III), although both reactions are thermodynamically favorable. Cherry et al did report that ferric iron oxidized As(III). The reaction, however, only occurred at low pH (pH=2) and not under near-neutral pH. In addition, oxidation due to carbonate or silicate minerals also does not occur.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-07	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic Factors Affecting Geochemistry</b>	<b>Date</b> 1990
<b>Constituent</b> Radon	<b>Page #</b> 93
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The strong correlation of Rn in groundwater with lithology of the aquifer has been demonstrated in numerous studies.

Granitic-type rock aquifers always have the highest levels of Rn in groundwater. Average levels in water from granites, are usually 8,000 pCi/l or greater.

Basaltic-type rock aquifers are expected to have very low Rn

Metamorphic rocks - the original composition of the rock prior to metamorphism is a more important factor affecting the Rn content of groundwater than just the degree of metamorphism.

Rn levels in crystalline rock aquifers are a function of the U content and distribution of the aquifer, but also the efficiency of transport of Rn from the solid into groundwater. The transport mechanisms are complex, but they result in crystalline rocks tending to have the highest Rn levels of all aquifer types, even when the aquifers have similar mineralogical composition and U content.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-06	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1990
<b>Constituent</b> Radon	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The results of these studies have shown that the small public water supplies and private wells tend to have the highest levels of Rn. This relationship is not due, however, to any functional relationship between system size and Rn concentrations, such as losses to aeration or decay through extensive distribution systems. Rather, the correlation reflects the relationship between system size and aquifer composition or rock type. The apparent relationship between Rn and system size is due to the fact that larger systems obtain groundwater from aquifer types that tend to have lower Rn than those that are used by smaller systems and domestic wells. For example, crystalline rock aquifers generally do not produce enough water to satisfy the needs of large water users, but smaller users could rely on such a source.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-05	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1990
<b>Constituent</b> Radon	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** Rn is of unique concern as a natural radionuclide in drinking water because it is a gas with no chemical affinities and a half-life of 3.8 days. Thus, Rn is not transported any significant distance in groundwater, and its concentration in a well sample is directly controlled by the lithology of the aquifer solids adjacent to the well.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-04	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1990
<b>Constituent</b> Radium	<b>Page #</b> 90
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> radium, uranium

**Notes** 226Ra is easy to measure.

The area with the highest 226Ra was in Illinois/Iowa, where the very old, clean sandstones were high in both Ra isotopes. The highest 226Ra measurements were associated with high TDS, due to desorption of 226Ra from the aquifer solids.

The 226Ra content of groundwater from granitic aquifers was variable but could have a high mean.

Limestone aquifers generally do not have elevated levels of 226Ra, except in Florida, where they are affected by the presence of phosphate deposits that are enriched in U. Studies have shown that elevated 226Ra is due to phosphate mineralization, with no significant differences in levels in similar mining versus unmined areas. 226Ra in limestone aquifers is affected by ionic strength of the water, with regional trends of increasing concentrations of 226Ra in wells with distance from the recharge zone and increases in TDS.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-03	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1990
<b>Constituent</b> Radium	<b>Page #</b>
<b>Co-Occurrence?</b> No	<b>Co-Occurrence Notes</b>

**Notes** The aquifers that generally had high levels of 228Ra were as follows:

- 1) Granitic rock aquifers
- 2) Arkosic sand and sandstone aquifers
- 3) Quartzose sandstone aquifers

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-01	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Other	<b>Date</b> 1990
<b>Constituent</b> Radium	<b>Page #</b> 84
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> radium, radon

**Notes** One conclusion from study of radionuclides in groundwater is that there is little correlation between Ra and Rn levels.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-08	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1990
<b>Constituent</b> Radon	<b>Page #</b> 93
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> radon, uranium

**Notes** The only other types of clastic aquifer having the potential for elevated Rn are those composed of arkosic sediments, especially those derived from the physical weathering of granites where the sediments have not been transported far from the granitic source. However, arkosic sediments are not really extensive and grade with distance into more mature sediments.

Rn levels in groundwater from carbonate aquifers are generally low. A notable exception is the phosphate mining region in central Florida, where U enrichment is associated with the phosphate deposits.

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<b>Article ID</b> 84	<b>Author</b> Michel, Jacqueline
<b>Notecard #</b> 84-02	<b>Title</b> Relationship of Radium and Radon with Geological Formations
<b>Topic</b> Factors Affecting Geochemistry	<b>Date</b> 1990
<b>Constituent</b> Radium	<b>Page #</b>
<b>Co-Occurrence?</b> Yes	<b>Co-Occurrence Notes</b> radium, uranium

**Notes** 228Ra is directly controlled by the distribution of Th in the aquifer solids, and the levels generally do not vary much within an aquifer. Where there has been no secondary enrichment of U, 228Ra is generally the dominant Ra isotope in solution, primarily due to the higher natural abundance of Th over U.

The only water-quality parameter that shows any correlation with Ra is total dissolved solids (TDS). At TDS levels of greater than 1,000 ppm, particularly in clean, quartz sandstones, competition for the few available sorption sites on the aquifer solids is high, and Ra solubility is enhanced by the common-ion effect, a process by which absorbed Ra atoms can be replaced by more common ions in solution. However, this correlation has not been universal for 228Ra, particularly in Illinois.