Hydraulic Fracturing in Colorado: A Public Forum

August 8, 2009
9:00 a.m. to 5:00 p.m.
Glenwood Springs, Colorado
Program
Saturday, August 8, 2009

8:00 a.m. — 9:00 a.m. • Registration

Welcome and Opening Remarks
9:00 a.m. — 9:10 a.m.
Larry Cerrillo, CPG, Moderator - Ingenuity Enterprises International, Inc.
Graham Closs, CPG, Moderator - Professor, Colorado School of Mines

Groundwater Basics
9:10 a.m. — 9:50 a.m.
Robert J. Sterrett, PhD - HCItasca, Denver, Inc.

Basics of Hydraulic Fracturing
9:50 a.m. — 10:10 a.m.
Mike Eberhard, PE - Halliburton Energy Services

10:10 a.m. — 10:30 a.m.
Questions and Answers

10:30 a.m. — 10:45 a.m. • Break

Toxicology
10:45 a.m. — 11:15 a.m.
Scott D. Phillips, MD - Rocky Mountain Poison and Drug Center

Potential Health Effects
11:15 a.m. — 11:45 a.m.
Roxana Zulauf Witter, MD, MSPH, MS - Colorado School of Public Health, University of Colorado Denver

11:45 a.m. — 12:15 p.m.
Teresa Coons, PhD - Western Colorado Math and Science Center

12:15 p.m. — 1:15 p.m. • Lunch (provided)
Program
Saturday, August 8, 2009

Public Relations Aspects
1:15 p.m. — 1:35 p.m.
Doug Hock - EnCana Oil and Gas (USA) Inc.

County, State and Federal Perspectives
1:35 p.m. — 1:55 p.m.
Judith Jordan - Garfield County

1:55 p.m. — 2:15 p.m.
Bruce Bertram, LGD - Delta County

2:15 p.m. — 2:35 p.m.
Mesa County (Will Provide a Statement)

2:35 p.m. — 2:55 p.m.
David Andrews - COGCC

2:55 p.m. — 3:15 p.m.
William Howell, PE - BLM, Glenwood Springs Energy Office

3:15 p.m. — 3:35 p.m.
Nathan Wiser - EPA

3:35 p.m. — 4:00 p.m. • Break

Panel Discussion and Questions/Answers
4:00 p.m. — 5:00 p.m.
All Presenters. Moderated by Larry Cerrillo and Graham Closs

Closing Remarks
5:00 p.m. — 5:10 p.m.
Presenter Biographies

Robert J. Sterrett, PhD - HCItasca, Denver, Inc.
Principal Hydrogeologist with HCItasca Denver, Inc. Dr. Sterrett has over 25 years of experience in the areas of groundwater and contaminant transport analysis, and soil and groundwater remediation. His expertise includes analysis of the fate and transport of chemicals in the vadose zone; and the design and analysis of soil and groundwater remediation systems. He has also undertaken the analysis of mine and construction dewatering systems. Dr. Sterrett was the technical editor and chief contributor to the 3rd edition of Groundwater and Wells.
Email: bsterrett@hcico.com

Mike Eberhard, Professional Engineer (PE) - Halliburton Energy Services
Mike Eberhard is the Rocky Mountain Technical Manager for Halliburton Energy Services located in Denver. He has been with Halliburton nearly 28 years and has worked in various pumping services positions; field engineering, sales, technical team, and management positions. Eberhard holds a BS in mechanical engineering from Montana State University. Mr. Eberhard has authored and co-authored several papers and publications. He is a 2009-10 Society of Petroleum Engineers (SPE) Distinguished Lecturer and is a member of SPE, AADE, DWLA, and is on the IAB for Montana Tech. He is also a registered professional engineer in Colorado.
Email: mike.eberhard@Halliburton.com

Scott D. Phillips, MD (Medical Doctor) - Rocky Mountain Poison and Drug Center
Scott D. Phillips MD, is a sub-specialty board certified medical toxicologist and also board certified in internal medicine. He is an active member of the medical school teaching faculty and is an attending physician on the clinical pharmacology/toxicology consultation service at the University Hospital and Denver Health Medical Center. Currently he holds the rank of Clinical Associate Professor of Medicine at the University of Colorado Denver. Dr. Phillips is a Fellow of the American College of Physicians, the American Academy of Clinical Toxicology and the American College of Medical Toxicology. Dr. Phillips has edited several textbooks in toxicology and authored many publications, virtually all related to clinical toxicology. He is an editor of Critical Care Toxicology: The Diagnosis and Management of the Critically Poisoned Patient and Occupational, Industrial and Environmental Toxicology. Dr. Phillips is on the teaching staff of the Rocky Mountain Poison and Drug Center, and is the Director of the Toxicology Clinic.
Email: scott.phillips@ucdenver.edu

Roxana Zulauf Witter, MD, MSPH, MS (Medical Doctor) - Colorado School of Public Health, University of Colorado Denver
Roxana Z. Witter is a Clinical Instructor of Environmental and Occupational Health, in the Colorado School of Public Health. She has served on the University of Colorado faculty since 2006, initially as a volunteer Clinical Instructor in the Department of Preventive Medicine in the School of Medicine from 2006-2007. In 2008, Dr. Witter was a principal investigator on a project that resulted in a literature review and white paper regarding the potential health impact of oil and gas exploration on this subject. The project involved collection and review of publicly accessible exposure and health impact data for Garfield County, Colorado. She presently teaches in the School of Public Health, co-directing and lecturing in the graduate-level course EHOH6616 “Environmental and Occupational Toxicology”.

Dr. Witter completed her BS (Bachelor of Science) degree at Georgetown University and MS (Master of Science) Degree in Microbiology and Immunology at University of Colorado Medical School, where she studied
and published on the subject of the role of calcium in programmed cell death. She earned her MD (Medical Degree) from University of Colorado School of Medicine and completed her internship at St. Joseph Hospital in Denver, Colorado in Internal Medicine. She completed her residency in Occupational and Environmental Medicine and her MSPH (Master of Science of Public Health) degree at University of Colorado Health Sciences Center/ National Jewish Research Center in Denver, Colorado, where she studied and published on the subject of health effects of methamphetamine lab exposure in law enforcement officers. She has also worked in the community as a clinician in occupational medicine and as Medical Director for a Denver based international corporation. Email: roxana.witter@ucdenver.edu

**Teresa Coons, PhD - Western Colorado Math and Science Center**

Teresa Coons received her undergraduate degree from Colorado State University in physical sciences and a Ph.D. in immunology from the University of New Mexico. She has recently assumed the position of Executive Director for the Western Colorado Math and Science Center, located in Grand Junction, CO. Her research career has spanned the disciplines of basic and clinical research, most recently focusing on occupational and environmental epidemiology. These latter studies have included descriptive studies of childhood asthma in Mesa County, Colorado and studies of respiratory conditions related to mining industry operations. Over the years, Dr. Coons’ research has involved collaboration with federal, state and local governments, industry group, citizen advisory committees and grassroots activist groups. Through community-based, participatory research she has worked with culturally diverse communities to investigate health issues related to environmental impacts. This work has involved the use of focus groups, community health surveys and community action planning to identify and address community concerns. Until January of 2009, Dr. Coons was the Senior Scientist for the Saccomanno Research Institute in Grand Junction, Colorado, where she directed the research programs associated with St. Mary’s Hospital and Medical Center, including participation in multi-institutional collaborations investigating genetic markers of susceptibility to lung cancer, the effects of tobacco smoke components on immune function, and early detection of lung cancer. Dr. Coons was also the organizer and, for six years, the Director of a federally funded medical screening program for former uranium workers under the Radiation Exposure Screening and Education Program. She was also the principal investigator for a study of potential health-related impacts of the natural gas industry in Garfield County, CO.

Dr. Coons is active in the Grand Junction community as a member of the Grand Junction City Council (currently Mayor Pro Tem), the Mesa County Board of Health, the Grand Junction Housing Authority Board, the Mesa County Methamphetamine Task Force, and other local organizations. She holds Adjunct faculty positions at Mesa State College and the University of Colorado Denver Health Sciences Center, and is a member of the University of Colorado Cancer Center and the Dean’s Council for the College of Natural Sciences at Colorado State University. She was appointed by Governor Ritter to the Colorado Air Quality Control Commission in 2007. Email: teresac.masc@bresnan.net

**Doug Hock - EnCana Oil and Gas (USA) Inc.**

Doug Hock is director of public and community relations for EnCana Oil & Gas (USA) Inc. He has worked in public relations for over 20 years, the majority of it with oil/gas and mining companies. He is a past president of the Colorado Chapter of the Public Relations Society of America (PRSA). Doug serves as chairman of the board of Parent Pathways, a Denver-based non-profit that helps teen parents raise healthy families. In addition, he chairs the Resource Allocation Committee for Denver’s Road Home, the city’s ten-year plan to end
homelessness. Doug holds a bachelor’s degree in news/editorial journalism from Drake University.
Email: doug.hock@EnCana.com

**Judith Jordan, Garfield County**
Judy Jordan is the oil and gas liaison for Garfield County, serving as an ombudsman and coordinator between county and other governments, citizens and industry. She attended law school while managing Delaware’s groundwater quality program and while working for DuPont as a hydrogeologist in the 1980s. She later worked as an attorney for the Pennsylvania DEP in their Superfund and Hazardous Sites Bureau, for Brandywine Conservancy, and was executive director of the Pennsylvania Organization for Watersheds & Rivers. She has researched and spoken extensively on water law and watershed management.
Email: jjordan@garfield-county.com

**Bruce Bertram, LGD - Delta County**
Bruce Bertram is a Colorado native from Cedaredge, Colorado. He graduated from the Colorado School of Mines with a Professional Engineering degree in Geology and worked in the petroleum industry. Later, after managing and providing accounting services for a contract blasting company he returned to Delta County where he has been the County Solid Waste Coordinator. Delta County appointed Bruce as its local governmental designee to the Colorado Oil and Gas Commission seven years ago when new oil and gas activity started in the County. While continuing to provide related education for the public and industry; he remains active in County, State, and Federal oil and gas regulatory and enforcement processes.
Email: bertram@tds.net

**David Andrews, PE, PG - Colorado Oil and Gas Conservation Commission (COGCC)**
David Andrews works out of COGCC’s Rifle office as the Northwest Area Engineering Supervisor. COGCC’s engineering group primarily regulates downhole operations in oil and gas wells. Mr. Andrews has been with COGCC for 3 ½ years, performing work in the D-J Basin and the Piceance Basin. Prior to joining COGCC, Mr. Andrews spent nearly 12 years in environmental consulting, performing work mostly for the oil and gas industry. Mr. Andrews earned a BS in Geological Engineering from Michigan Technological University and a MS in Civil Engineering from Wayne State University. He is a licensed Professional Engineer in Colorado, Michigan, and Wyoming, and he is a licensed Professional Geologist in Wyoming.
Email: david.andrews@state.co.us

**William Howell, PE - Bureau of Land Management (BLM), Glenwood Springs Energy Office**
William Howell is a Petroleum Engineer currently working for the Bureau of Land Management in the Glenwood Springs energy office. Mr. Howell has a BS in Petroleum Engineering from Mississippi State University and completed his graduate course work in geohydrology at the University of New Orleans.
Email: william_howell@blm.gov

**Nathan Wiser - Environmental Protection Agency (EPA)**
Nathan Wiser is a 19-year veteran of the EPA’s Underground Injection Control (UIC) program, regulating injection wells as a permit writer, inspector, and compliance officer. His educational background includes a bachelor’s degree in geology from the University of California, Berkeley and a master’s degree in geology from Northwestern University. Mr. Wiser works in the Region 8 (Denver) office of EPA where he is considered a regional expert in the UIC program, and serves as the program lead for UIC deep well enforcement. Mr. Wiser’s
accomplishments include the issuance of many hundreds of UIC permits and enforcement orders, conducting and overseeing thousands of injection well inspections, and he oversees a complex aquifer remediation in the East Poplar Oil Field in northeast Montana.
Email: wiser.nathan@epamail.epa.gov

Larry A. Cerrillo - Ingenuity Enterprises International, Inc.
Larry Cerrillo is a past national and Colorado state section president of AIPG. He has a BS in Geology from Syracuse University and an MS in Hydrogeology from Colorado State University. Larry has worked nationally and internationally on groundwater and environmental projects. In addition to his hydrogeologic background, he has several certificates of training in alternative dispute resolution (ADR) including a certificate of advanced study in ADR from Denver University. He is currently working at his second career as a mediator, facilitator and arbitrator of environmental, public policy, water, and construction disputes.
Email: cerrillo1@mindspirng.com

L. Graham Closs - Professor, Colorado School of Mines
Graham Closs received his A.B. in Geology from Colgate University (1967), his M.S. in Geology from the University of Vermont (1970), and his PhD. in Geological Sciences (1973), specializing in Exploration Geochemistry, from Queen’s University (Canada). He has over 35 years experience in field programs, teaching and applied research. He is a Licensed Professional Engineer (Ontario, Canada) and a Certified Professional Geologist (American Institute of Professional Geologists). Since 1978 he has been on the faculty of the Department of Geology and Geological Engineering, Colorado School of Mines where he is involved in teaching and supervising research in the areas of economic geology, mineral exploration design, metals exploration geochemistry, and geological data analysis.
Email: chezctc@comcast.net
Abstracts

Introduction to Hydrogeology
Robert J. Sterrett, Ph.D.
HCItasca, Denver, Inc.

Groundwater is an important source of water for rural residences and for agriculture. In order to protect this resource there must be a basic understanding of how groundwater flows and how chemicals are transported by it. This talk will provide a basic overview of the occurrence and movement of groundwater. Basic concepts and terms will be explained and examples provided.

Hydraulic Fracturing – What is it?
Mike Eberhard, PE
Halliburton Energy Services

Hydraulic fracturing is used extensively throughout the US to enhance well production in unconventional gas reservoirs; tight gas sandstones, shale gas, and coalbed methane (CBM). Over the last 60 years there have been over 1 million hydraulic fracture treatments completed in North America. There is growing concern that hydraulic fracturing has a potential to contaminate underground sources of drinking water. This presentation will discuss the steps taken to avoid this potential and what hydraulic fracturing is. There will be a brief discussion of what hydraulic fracturing is and the steps taken to avoid the potential problem of contamination.

Potential Health Effects Secondary to Fracing Fluids
Roxana Witter, MD, MS, MSPH,
Colorado School of Public Health, University of Colorado Denver

Liquids and chemicals used for fracturing processes can include potentially toxic substances such as petroleum distillates, diesel fuel, acids, MTBE and BTEX, fatty acid esters and crystalline silica, among other chemicals. Most companies do not disclose the full chemical makeup of specific compounds injected into the ground.

Human exposure to fracturing chemicals can occur by many pathways, including contamination of aquifer and surface drinking water sources, volatile chemical and dust inhalation in contaminated air, and ingestion of foods grown in contaminated soil. Little is known about the levels of these chemicals in water, air, and soil in areas close to the well sites or in local communities. There is also little publicly-available data regarding the levels of contaminants and pollutants that may be affecting water and air on a regional basis.

Human health effects cause by contaminants can vary by chemical, exposure route, dose and duration. Exposures can result in acute or chronic, cancerous or non-cancerous health effects. Heath outcomes can also vary according to the population being exposed, with children, seniors, women of childbearing age, and those with pre-existing diseases generally being more susceptible than the general population to the potential toxic effects of chemical exposure. Furthermore, chemical mixtures may cause health effects that differ from those caused by individual chemicals alone.
Abstracts

Predicting the potential health effects of fracing fluid exposure can be complex because of the uncertainty related to chemical identity and quantity, exposure pathway and environmental levels, and human susceptibility. Despite these unknowns, some statements can be made about the potential health effects of chemicals known to be used in the fracing process. A number of fracing chemicals are known carcinogens and mutagens, some with no known safe level of exposure. Many chemicals are known to cause significant long term health effects, such as neurological, reproductive and renal effects while others are known to cause significant acute illness such as respiratory and cardiac effects and irritant symptoms.

Because information regarding the chemicals themselves and the levels of chemicals in the water, air and soil is incomplete, the potential for the fracing process to impact the health of local and regional human populations remains a possibility, yet the extent of potential impact remains unknown. In the interest of protecting workers and community members, steps should be taken to prevent exposures from occurring while research is conducted to establish exposure levels and possible health consequences.

Abstract
Judith Jordan
Garfield County

The issue of hydraulic fracturing, or “fracing,” has received a lot of attention from environmental groups and recently has drawn congressional scrutiny, largely because in 2005 the Congress, then with a Republican majority, had specifically exempted fracing from regulation under the Safe Drinking Water Act. But does the exemption actually subject water to greater risk of pollution? Is there evidence that fracing causes water pollution? Would rescinding the exemption afford greater protection? This presentation will offer a local government perspective on the issue of fracing and groundwater quality.

Abstract
Bruce C. Bertram, LGD
Delta County

Local government concerns and responses to the oil and gas well Fracing process depends in part on the magnitude of oil and gas activity and the general knowledge of the public within its jurisdiction. There are always common concerns about the physical fracing process and the nature and chemical make up of the fluids used. The process brings with it many questions and apprehensions about its potential impact on the surrounding environment and both ground and surface waters. Local Governments play an important role in helping protect these areas by providing information and answers to questions about the process and establishing local regulations when needed. Local governments also consider the physical impacts the fracing and support equipment may have on their infrastructure such as County roads, etc. Any local regulations are guided by the sometimes questionable regulatory pre-emption boundaries between them and other oil and gas regulatory agencies (state and federal). Education always plays a very important role in this process as does the enforcement of all levels of regulations. In Counties with lesser oil and gas activity or those just beginning to have activity oil and gas, the education process is a two way street. Local government officials, in some cases along with the public, are in need of such knowledge as is a similar need for the industry to know and understand valid local issues.
Abstracts

Abstract
Nathan Wiser
United States Environmental Protection Agency, Region 8

In 2005, hydraulic fracturing was exempted from regulation under the Safe Drinking Water Act (SDWA), except in cases where diesel fuel is used as an additive in hydraulic fracturing fluids. On June 9, 2009 companion bills were introduced in the U.S. House and Senate to regulate oil and gas related hydraulic fracturing under SDWA. Additionally, language in the 2010 Appropriations Bill urges the United States Environmental Protection Agency (EPA) to review the risks that hydraulic fracturing may pose to drinking water supplies, using the best available science, as well as independent sources of information.

A brief history of the federal implementation of the injection well program as it relates to hydraulic fracturing will be presented. In addition, the presentation will cover how federal regulations at the EPA are developed. This could become important if legislative changes to the SDWA occur that necessitate promulgation of new federal regulations.

WHEREAS, US Representatives DeGette and Polis have recently submitted for consideration by Congress the Fracturing Responsibility and Awareness for Chemicals Act of 2009 (FRAC Act) “to repeal the exemption for hydraulic fracturing in the Safe Drinking Water Act, and for other purposes” and

WHEREAS, Congresswoman DeGette represents Colorado’s House District 1 and Congressman Polis represents Colorado’s House District 2 both on the front range of Colorado consisting largely of the Greater Denver Metro and Boulder Area; and

WHEREAS, Representatives DeGette and Polis House Districts have little to no oil and natural gas development activity employing fracings technology and should at least extend the courtesy to fellow Congressmen in districts where this act would be applicable to sponsor it; and

WHEREAS, the United States Congress passed the Safe Drinking Water Act (SDWA) of 1974 to assure the protection of the nation’s drinking water sources; and

WHEREAS, since the enactment of the SDWA, the United States Environmental Protection Agency has never interpreted hydraulic fracturing as constituting "underground injection" within the SDWA; and

WHEREAS, in 2004, the EPA published a final report stating that minimal threat was posed to underground sources of drinking water by hydraulic fracturing; and

WHEREAS, the Ground Water Protection Council (GWPC) is a non-profit organization dedicated to the protection of our Nation’s ground water resources and made up of state ground water protection agencies regulating hydraulic fracturing have produced findings from studies indicating that there are no documented cases of contamination involving hydraulic fracturing technology or fluids; and

WHEREAS, the United States Congress, in the Energy Policy Act of 2005, explicitly exempted hydraulic fracturing from the provisions of the SDWA; and

WHEREAS, hydraulic fracturing has been used more than one million times in the last 60 years in exploration and production activities by the oil and gas industry across the nation with no harm to ground water supplies; and

WHEREAS, the regulation of oil and gas exploration and production activities, including hydraulic fracturing, is strictly regulated by the Colorado Oil and Gas Conservation Commission; and

WHEREAS, the SDWA was never intended to grant to the federal government authority to regulate oil and gas drilling and production operations, such as hydraulic fracturing; and

WHEREAS, the issue of hydraulic fracturing is critical to natural gas exploration and development in Mesa County and the neighboring Piceance Basin; and

WHEREAS, due to the nature of the geology within the surrounding area natural gas fields, natural gas extraction could not efficiently take place without hydraulic fracturing; and
WHEREAS, Mesa County is a regional trade center and is the location of many industrial support companies that service the natural gas industry; and

WHEREAS, onerous new regulations regarding hydraulic fracturing could stymie energy development in Mesa County and surrounding areas, cause detriment to Mesa County residents, increase costs to all consumers and decrease the economic vitality of the State; and

WHEREAS, hydraulic fracturing technology has opened up natural gas basins that would otherwise not be producible and has increased reserves resulting in lower commodity prices for consumers;

WHEREAS, due to the ignorance of elected officials in positions of authority introducing legislation that does nothing for the environment or protect public safety but only raises the cost of production and development of natural resources, we will most certainly be paying higher energy costs in the future impacting hard working men and women of our Country and County the most; and

WHEREAS, we in Mesa County and the Piceance Basin of Colorado have managed to contribute successfully and very significantly to our Nation’s energy demands in a manner respectful of the environment without the added oversight or regulation of Congress; and

WHEREAS, Mesa County has worked diligently on an Energy Master Plan to allow for energy development at the same time respecting our County’s Natural assets, promoting a viable economy while maintaining or increasing the quality of life for County residents; and

WHEREAS, Mesa County supports, encourages and embraces best available technologies such as hydraulic fracturing and best management practices that mitigate the impacts of energy development or any other kind of human activity necessary to maintain our quality of life; and

WHEREAS, Mesa County respects and honors all the hard working men and women of the natural gas industry working, living, recreating, and raising families in Mesa County for providing a vital resource to our County and Nation with no appreciation by any Federal, State or Local elected officials for your innovation, technology and tireless efforts to keep our houses warm and illuminated;

NOW THEREFORE BE IT RESOLVED, that Mesa County urges our federal legislators to maintain the exemption for hydraulic fracturing from the provisions of the SDWA and to not pass unneeded legislation that would negatively impact Mesa County’s economy and increase our Nation’s energy insecurity and dependence of foreign sources. Mesa County urges Congress and specifically Representatives DeGette and Polis to actually visit these areas where this technology is employed and learn about its historical use and current practice before enacting legislation that does nothing but empower government, increase bureaucratic controls, raise commodity prices to consumers and further discourage technology and innovation in an area much needed to promote our Country’s future energy independence and security.

Mesa County Board of County Commissioners

Steven Acquafresca, Chairman

ATTEST:

Clerk and Recorder

[Signature]

[Signature]
Additional Information on Hydraulic Fracturing
Example of Typical Deep Shale Fracturing Mixture Makeup

A representation showing the percent by volume composition of typical deep shale gas hydraulic fracture components (see graphic) reveals that over 99% of the fracturing mixture is comprised of freshwater and sand. This mixture is injected into deep shale gas formations and is typically confined by many thousands of feet of rock layers.

<table>
<thead>
<tr>
<th>Additive Type</th>
<th>Main Compound</th>
<th>Purpose</th>
<th>Common Use of Main Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Hydrochloric acid or muratic acid</td>
<td>Helps dissolve minerals and initiate cracks in the rock</td>
<td>Swimming pool chemical and cleaner</td>
</tr>
<tr>
<td>Antibacterial Agent</td>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water that produce corrosive by-products</td>
<td>Disinfectant; Sterilizer for medical and dental equipment</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium persulfate</td>
<td>Allows a delayed break down of the gel</td>
<td>Used in hair coloring, as a disinfectant, and in manufacture of common household plastics</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>n,N-dimethyl formamide</td>
<td>Prevents the corrosion of the pipe</td>
<td>Used in pharmaceuticals, acrylic fibers and plastics</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Borate salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Used in laundry detergents, hand soaps and cosmetics</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Petroleum distillate</td>
<td>&quot;Slides&quot; the water to minimize friction</td>
<td>Used in cosmetics including hair, make-up, nail and skin products</td>
</tr>
<tr>
<td>Gel</td>
<td>Guar gum or hydroxyethyl cellulose</td>
<td>Thickens the water in order to suspend the sand</td>
<td>Thickener used in cosmetics, baked goods, ice cream, toothpaste, sauces, and salad dressings</td>
</tr>
<tr>
<td>Iron Control</td>
<td>Citric acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Food additives, food and beverages; lemon juice ~7% citric acid</td>
</tr>
<tr>
<td>Clay Stabilizer</td>
<td>Potassium chloride</td>
<td>Creates a brine carrier fluid</td>
<td>Used in low-sodium table salt substitute, medicines and IV fluids</td>
</tr>
<tr>
<td>Oxygen Scavenger</td>
<td>Ammonium bisulfite</td>
<td>Removes oxygen from the water to protect the pipe from corrosion</td>
<td>Used in cosmetics, food and beverage processing and water treatment</td>
</tr>
<tr>
<td>pH Adjusting Agent</td>
<td>Sodium or potassium carbonate</td>
<td>Maintains the effectiveness of other components, such as crosslinkers</td>
<td>Used in laundry detergents, soap, water softener and dish washer detergents</td>
</tr>
<tr>
<td>Proppant</td>
<td>Silica, quartz sand</td>
<td>Allows the fractures to remain open so the gas can escape</td>
<td>Drinking water filtration, play sand, concrete and brick mortar</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Used in household cleaners, de-icer, paints and caulks</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Used to increase the viscosity of the fracture fluid</td>
<td>Used in glass cleaner, multi-surface cleaners, antiperspirant, deodorants and hair color</td>
</tr>
</tbody>
</table>
INTRODUCTION TO TOXICOLOGY

All substances are poisons, it is the dose that differentiates a poison from a remedy.”
Paracelsus, 16th Century

Risk
According to the Environmental Protection Agency (EPA) risk is defined as “the probability of injury, disease, or death under specific circumstances.” When looking at risk in terms of environmental hazard it is a function of two concepts.

Risk = Toxicity (x) Exposure

Toxicity
Is the measure of the poisonous or harmful nature of a substance. Toxicity can be divided into two categories.

• Carcinogenic (cancer causing)
• Non-carcinogenic (all other effects)

Exposure
Is pollutants coming into contact with the body and presenting a potential health threat. Exposure can occur through a variety of pathway routes:

• Ingestion (eating/drinking)
• Inhalation (breathing)
• Adsorption (skin contact)
• Injection

Chemicals of Concern
Are chemicals that the assessor selects to evaluate for their potential to cause health effects.
Information reviewed to determine if a chemical is one of concern is as follows:

• Is it found on and off site?
• Is there a potential for human contact?
• How much was found in the sample?
• Is it found naturally in the environment?
• Are the Laboratory results reliable
• How does the sample results compare to Federal, State, and other appropriate guidelines
• Does the community have a real or perceived concerned about the chemical?

How chemical impact is determined
Any chemical can make you sick. Getting sick will depend on:

• How much you were exposed to (dose)
• How you are exposed (route)
• How long you were exposed (duration)
• How often you were exposed (frequency)
• General Health, Age, Lifestyle
I. TOXICOLOGY

A. Basic Principles of Toxicology

Toxicology — The study of the nature, effects, and detection of poisons and the treatment of poisoning. It is the study of how toxic substances affect organisms.

1. Dose and how it is expressed
   a. All chemical substances can produce harmful effects if taken in excessive amounts
   b. The difference between a toxic effect and no effect is the DOSE (and route of entry or exposure time)
      i. The Dose is the amount of chemical substance to which an organism is exposed. Route is the method of entry into the body.
      ii. Toxins and poisons produce their harmful effects at relatively low dosages.
      iii. How DOSE is expressed
          a. Per unit weight — mg/kg
          b. Per area of skin surface — cm²
          c. Per unit of volume of air inhaled — mg/m³, ppm, mg/l
          d. As a function of the duration of exposure
   c. Routes of Entry or Exposure
      i. Inhalation
      ii. Ingestion
      iii. Absorption
      iv. Injections or cuts in skin

2. Many variables affect what effect a chemical will have on an organism
   a. Factors related to substance
      i. Chemical composition
      ii. Physical characteristics
      iii. Stability and storage
      iv. Carrier
      v. Solubility in body fluids
      vi. Additives
   b. Factors related to exposure
      i. Dose
      ii. Concentration
      iii. Volume
      iv. Route
      v. Rate
      vi. Site
      vii. Duration and frequency
      viii. Administration time.
c. Factors inherent to persons
   i. Gender
   ii. Age
   iii. Weight
   iv. Nutrition
   v. Emotional Status
   vi. Genetics, disease and immunological status.

d. Environmental factors related to persons
   i. Physical factors
   ii. Social factors
   iii. Presence of other chemicals
      a. Additive
      b. Synergistic
      c. Potentiation
      d. Antagonism

3. How toxicity is measured
   a. Toxicity tests incorporate selection of
      i. A test organism
      ii. The response or biological endpoint
      iii. An exposure or test period
      iv. Dose or series of doses.
   b. The objective is to select a test species that is a good model of how a human would respond, look for an end point that is not subjective and can be consistently determined, and choose a test period, which is relatively short.
   c. Sometimes tests must be selected which yield indirect measurements or responses (i.e., determining carcinogenic potential by measuring mutagenic potential).

4. Dose-Response Relationship
   a. A toxicity test exhibits a dose-response relationship when there is a consistent mathematical and biologically plausible relationship between a proportion of individuals responding and a give dose for a given exposure period.
DOSE RESPONSE CURVE

% of Population Responding

5. **Dose-Response Terms**
   a. No Observed Adverse Effect Level (NOAEL) — The concentration (or dose) at which there is no adverse response in the population
   b. Lowest Observed Adverse Effect Level (LOAEL) — The lowest concentration which causes an adverse response in the population
   c. Toxic Dose 50 (TD$_{50}$) — The concentration (or dose) which produces the adverse effect in 50% of the population (Lethal Dose (LD$_{50}$) if killing the population)
   d. Toxic Dose 100 (TD$_{100}$) — The concentration (or dose) which produces the adverse effect in 100% of the population (Lethal Dose (LD$_{100}$) if killing the population)

6. **Use of the Dose-Response relationship**

7. **Limitations of Dose-Response data:**
   a. Terms like toxic or lethal dose fifty are single values and do not indicate toxic effects which may occur at different dose levels;
   b. Most data are derived from acute (single-dose, short term) exposures rather than from chronic exposures (continuous, long term).
   c. Must use data from animal studies which do not perfectly mimic human exposure
B. Routes of Entry
   1. Inhalation
   2. Ingestion
   3. Absorption
   4. Injection

C. Terms
   1. Local vs. systemic effect
   2. Signs vs. symptoms
   3. Acute vs. chronic
   4. Reversible vs. irreversible

D. Body Response to Toxic Chemicals
   1. Respiratory system — Is the only organ system with vital functional elements in constant direct contact with the environment
      a. Function — provides means for exchange of oxygen and carbon dioxide. Three regions:
         i. Nasopharyngeal
         ii. Tracheobronchial
         iii. Alveolar
      b. Effects on lungs:
         i. Asphyxiants (suffocation or lack of O\textsubscript{2})
            a. Simple
            b. Chemical
         ii. Irritants, reversible inflammatory effect on living tissue
         iii. Necrosis producers
         iv. Fibrosis producers
         v. Allergens
         vi. Carcinogens
      c. Systemic effects — direct route for chemicals to reach other organs
   d. How to avoid lung damage

2. Skin
   a. Natural defenses of skin
      i. Epidermis — prevents absorption of chemicals and is physical barrier to bacteria
      ii. Sebaceous gland — bacteriostatic and fungustatic
      iii. Melanocytes (pigments) — prevents UV damage
      iv. Sweat glands — heat regulation
      v. Connective tissue — elasticity
      vi. Lymph/blood — immunologic response
   b. Ability of skin to absorb toxicants depends on:
      i. Properties and health of skin
      ii. Chemical properties
      iii. Environment (vehicle)
   c. Absorption enhanced by:

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i. Breaking or abrasion of skin
ii. Increased hydration
iii. Increased temperature
iv. Increased concentration
v. Alteration of pH of skin
vi. Decrease size of chemical
vii. Surface-active agents (e.g., DMSO)
viii. Polarity of chemical
d. Local effects:
   i. Irritant, necrosis
   ii. Sensitizers
   iii. Phototoxicity
   iv. Cutaneous cancer
e. System effects — toxins can enter body through skin and travel to other organs

3. Central Nervous System (CNS) — brain and spinal cord receives environmental input through the sensory nerves and responds by sending impulses through the motor nerves to the muscles. The CNS supervises and coordinates the entire nervous system and is vital for normal function and survival.
   a. Structural — cell damage due to direct contact with chemical or secondary effects, such as anoxia
   b. Functional — which affects motor functions, sensory functions, learning and memory

4. Liver — largest and metabolically the most complex organ in the body, detoxifies substances and may produce toxic by-products, may have up to 500 functions (Hepatotoxins are liver toxins).
   a. Effects on liver
      i. Acute hepatitis
      ii. Cholestasis
      iii. Chronic hepatitis
      iv. Carcinogenesis
      v. Potentiation

5. Kidneys — remove waste from blood, regulate fluid and salt content (Nephrotoxins are kidney toxins)
   a. Effects on kidneys
      i. Kidney stones
      ii. Nephritis
      iii. Kidney failure

6. Eyes
   a. Effects on eyes
      i. Direct damage
      ii. Systemic absorption
7. Blood — circulatory system damaged by agents that affect blood cell production, the components of blood or Ô2 carrying capacity of red blood cells
   a. Effects on blood
      i. Bone marrow
      ii. Red blood cells
      iii. Oxygen-carrying capacity
      iv. White blood cells
      v. Spleen

8. Reproductive Toxins
   a. Effects on reproduction systems (infertility — may affect either men or women)
      i. Males
         a. Impotence
         b. Sperm number, motility, shape
         c. Impaired testicular integrity
         d. Poor semen quality
         e. Damage chromosomes
      ii. Females
         a. Ovarian integrity
         b. Blockage of oviduct
         c. Menstrual irregularity
         d. Amenorrhea
         e. Anovulatory cycles
   b. Mutagenic
      i. Changes genetic code altering DNA
      ii. Will not be seen until next generation (at the earliest)
   c. Teratogenic
      i. Damages fetus (often in first 8 to 10 weeks)
      ii. Not necessarily from DNA alterations
      iii. Results from disruption of normal fetus development due to biological, chemical, or physical agents

9. Mutagens — can also affect adults

10. Carcinogens
    a. Group A — Human Carcinogens
    b. Group B — Probable Human Carcinogens
    c. Group C — Possible Human Carcinogens
    d. Group D — Not Classified
    e. Group E — No evidence of Carcinogens for Humans
D. Exposure Limits — The maximum safe amount to which a worker can be exposed during a normal work shift

1. Exposure through skin contact and ingestion

2. Inhalation exposure terms
   a. Dose
      i. Threshold Limit Value (TLV); source – ACGIH
      ii. Permissible Exposure Limit (PEL); source – OSHA
      iii. Recommended Exposure Limit (REL); source – NIOSH
   b. Time
      i. Time-Weighted Average (TWA)
      ii. Short Term Exposure Limit (ST or STEL)
      iii. Ceiling (C)

3. Immediately Dangerous to Life or Health (IDLH)—different definitions depending on source. NIOSH definition used to select respirators. Must use supplied air above IDLH concentrations.
CARCINOGENS
Profiles for Agents, Substances, Mixtures or Exposure Circumstances Known To Be Human Carcinogens

Aflatoxins
Alcoholic Beverage Consumption
4-Aminobiphenyl (4-Aminodiphenyl)
Analogic Mixtures Containing Phenacetin
Arsenic and Certain Arsenic Compounds
Asbestos
Azathioprine
Benzene
Benzidine
bis(Chloromethyl) Ether and Technical-Grade Chloromethyl Methyl Ether
1,3-Butadiene
1,4-Butanediol Dimethylsulfonate
Cadmium and Cadmium Compounds
Chlorambucil
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosoure (MeCCNU)
Chromium Hexavalent Compounds
Coke Oven Emissions
Conjugated Estrogens
Cyclophosphamide
Cyclosporin A
Diethylstilbestrol
Dyes that Metabolize to Benzidine:
  • Direct Black 38
  • Direct Blue 6
Environmental Tobacco Smoke

Erionite
Ethylene Oxide
Melphalan
Methoxsalen with Ultraviolet A Therapy (PUVA)
Mustard Gas
2-Naphthylamine
Radon
Silica, Crystalline (Respirable Size):
  • Quartz
  • Cristobalite
  • Tridymite
Smokeless Tobacco
Solar Radiation and Exposure to Sunlamps or Sunbeds
Soots
Strong Inorganic Acid Mists Containing Sulfuric Acid
Tamoxifen
Tars and Mineral Oils
*2,3,7,8-Tetrachlorodibenz-p-dioxin (TCDD)
Thiopeta
Thorium Dioxide
Tobacco Smoking
Vinyl Chloride
Profiles for Agents, Substances, Mixtures or Exposure circumstances Reasonably Anticipated to be Human Carcinogens

<table>
<thead>
<tr>
<th>Agent/Substance/Mixture</th>
<th>Description</th>
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| Acetaldehyde             | 3,3'-Dimethoxybenzidine and 3,3''-
                           | Dimethoxybenzidine Dihydrochloride |
| 2-Acetylaminofluorene    | 4-Dimethylaminoazobenzene |
| Acrylamide               | 3,3'-Dimethylbenzidine |
| Acrylonitrile            | Dimethylcarbamoyl Chloride |
| Adriamycin®              | 1,1-Dimethylhydrazine |
| 2-Aminoanthraquinone     | Dimethyl Sulfate |
| o-Aminoazotoluene        | Dimethylvinyl Chloride |
| 1-Amino-2-methylantraquinone | 1,4-Dioxane |
| Amitrole                 | Disperse Blue 1 |
| o-Anisidine Hydrochloride| Epichlorohydrin |
| Azacytidine              | Estrogens (Not Conjugated): Estradiol-17β |
| Benzetrichloride         | Estrogens (Not Conjugated): Estrone |
| Beryllium and Certain Beryllium Compounds | Estrogens (Not Conjugated): Ethinylestradiol |
| bis(Chloroethyl) nitrosourea | Estrogens (Not Conjugated): Mestranol |
| Bromodichloromethane     | Ethylene Thiourea |
| Butylated Hydroxyanisole | Ethyl Methanesulfonate |
| Carbon Tetrachloride     | Formaldehyde (Gas) |
| Ceramic Fibers (Respirable Size) | Furan |
| Chlorendic Acid          | Glasswool (Respirable Size) |
| Chlorinated Paraffins (C12, 60% Chlorine) | Glycidol |
| 1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea | Hexachlorobenzene |
| Chloroform               | Hexachloroethane |
| 3-Chloro-2-methylpropene | Hexamethylphosphoramide |
| 4-Chloro-o-phenylenediamine | Hydrazine and Hydrazine Sulfate |
| Chloroprene              | Hydrazobenzene |
| p-Chloro-o-toluidine and p-Chloro-o-toluidine Hydrochloride | Iron Dextran Complex |
| Chlorozotocin            | Isopropyl Chloride |
| C.I. Basic Red 9 Monohydrochloride | Kepone® |
| Cisplatin                | Lead Acetate and Lead Phosphate |
| p-Cresidine              | Lindane and Other Hexachlorocyclohexane Isomers |
| Cupferron                | 2-Methylaziridine (Propylenimine) |
| Dacarbazine              | 4,4’-Methylenebis(2-chloroaniline) (MBOCA) |
| Danthron                 | 4,4’-Methylenebis(N,N-dimethylbenzenamine) |
| DDT (Dichlorodiphenyltrichloroethane) | 4,4’-Methylenedianiline and Its |
| 2,4-Diaminoanisole Sulfate | Dihydrochloride |
| 2,4-Diaminotoluene       | Methyl Methanesulfonate |
| 1,2-Dibromo-3-chloropropane | N-Methyl-N’-nitro-N-nitrosoguanidine |
| 1,2-Dibromoethane (Ethylene Dibromide) | Metronidazole |
| 1,4-Dichlorobenzene      | Michler's Ketone |
| 3,3’-Dichlorobenzidine and 3,3’-Dichlorobenzidine Dihydrochloride | Mirex |
| 1,2-Dichloroethane       | Nickel and Certain Nickel Compounds |
| Dichloromethane          | Nitrilotriacetic Acid |
| 1,3-Dichloropropene (Technical Grade) | o-Nitroanisole |
| Diepoxylbutane           | Nitroarenes: |
| Diesel Exhaust Particulates | 1,6-Dinitropyrene |
| Di(2-ethylhexyl) Phthalate | 1,8-Dinitropyrene |
| Diethyl Sulfate          |                         |
| Diglycidyl Resorcinol Ether |                         |
- 6-Nitrochrysene
- 1-Nitropyrene
- 4-Nitropyrene

Nitrofen
Nitrogen Mustard Hydrochloride
2-Nitropropane
N-Nitrosodi-n-butylamine
N-Nitrosodiethanolamine
N-Nitrosodiethylyamine
N-Nitrosodimethylamine
N-Nitrosodi-n-propylamine
N-Nitro-N-ethylurea
4-(N-Nitrosomethylamino)-1-(3-pyridyl)-1-butane (NNK)
N-Nitro-N-methylurea
N-Nitrosomorpholine
N-Nitrosomorpholine
N-Nitrosonornicotine
N-Nitrosopyrrolidine
N-Nitrosodimethylamine
Norethisterone
Ochratoxin A A
4,4'-Oxydianiline
Oxymetholone
Phenacetin
Phenazopyridine Hydrochloride
Phenolphthalein
Phenoxybenzamine Hydrochloride
Phenytoin
Polybrominated Biphenyls
Polychlorinated Biphenyls
Polycyclic Aromatic Hydrocarbons, 15 Listings:
- Benz[a]anthracene
- Benzoblfuoranthene
- Benzol[j]fluoranthene
- Benzol[k]fluoranthene
- Benzol[a]pyrene
- Dibenzo[a,h]acridine
- Dibenzo[a,j]acridine
- Dibenzo[a,h]anthracene
- 7H-Dibeno[c,g]carbazole
- Dibenzo[a,e]pyrene
- Dibenzo[a,h]pyrene
- Dibenzo[a,i]pyrene
- Dibenzo[a,l]pyrene
- Indeno[1,2,3-cd]pyrene
- 5-Methylchrysene

Procarrazine Hydrochloride
Progesterone
1,3-Propane Sultone
ß-Propiolactone
Propylene Oxide
Propylthiouracil

Reserpine
Safrole
Selenium Sulfide
Streptozotocin
Sulfate
Tetrachloroethylene
Tetrafluoroethylene
Tetranitromethane
Thioacetamide
Thiourea
Toluene Diisocyanate
n-Toluidine and n-Toluidine Hydrochloride
Toxaphene
Trichloroethylene
2,4,6-Trichlorophenol
1,2,3-Trichloropropane
Tris(2,3-dibromopropyl) Phosphate
Urethane
4-Vinyl-1-cyclohexene Diepox

From “Ninth Annual Report on Carcinogens”, 2001, U.S. Department of Health and Human Services, National Toxicology Program. For the purpose of this Report “known carcinogens” are defined as those substances for which the evidence from human studies indicates that there is a causal relationship between exposure to the substance and human cancer.

**For the purpose of the Report, substances “which may reasonably be anticipated to be carcinogens” are defined as those for which there is limited evidence of carcinogenicity in humans or sufficient evidence of carcinogenicity in experimental animals.