# ADDENDUM INDEX

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organ, respiratory, gastrointestinal and liver, brain and nervous system, immune, kidney, cardiovascular and blood, cancer, mutagenic, endocrine disruption, other, and ecological effects.



### Data Analysis

Using the data sources described earlier, we entered the names of all the products and chemicals into a spreadsheet. Initially, chemicals were separated according to the state in which the data source originated. Analysis of the profiles of health effects revealed minimal differences across states, thus for this report we combined all the data into one multi-state analysis. Using only the chemicals on the multi-state list for which CAS numbers were available, we produced a profile based on how often each of the 12 possible health effects were associated with the chemicals. We created separate profiles for the water soluble chemicals alone, and the volatile chemicals alone. We also did an analysis of the drilling chemicals from the Wyoming well-blowout and an analysis of the chemicals found in the New Mexico evaporation pits. Finally, we tested the utility of the spreadsheet for providing guidance for water quality monitoring, focusing on the most potentially harmful and frequently used chemicals. The spreadsheet is available at http://www.endocrinedistruption.org/chemicals.multistate.php.

## RESULTS

### Product Information

As of May, 2010, TEDX identified 944 products used in natural gas operations in the United States. Of these, between 95 and 100% of the ingredients were available for 131 (14%) of the products (Figure 1). For 407 (43%) of the products, less than 1% of the total product composition was available. For many of those 407 products, only the name of the product with no identifiable chemical name or percent composition was reported. A total of 632 chemicals were reported in the products and we were able to locate CAS numbers for 353 (56%) of them.

### Health Effects Profile

Using the health effect information for the 353 chemicals with CAS numbers, we created a profile of possible health effects that depicts the percentage of chemicals associated with each of the 12 health effect categories (Figure 2). Viewing the profile from left to right, more than 75% of the chemicals on the list can affect the skin, eyes, and other sensory organs, the respiratory system, the gastrointestinal system, and the liver. More than half the chemicals show effects on the brain and nervous system. These first four categories represent effects that would likely be expressed upon immediate exposure, such as eye and skin irritation, nausea and/or vomiting, asthma, coughing, sore throat, flu-like symptoms, tingling, dizziness, headaches, weakness, fainting, numbness in extremities, and convulsions. Products containing chemicals in powder form, irritants, or highly corrosive and volatile chemicals would all come with MSDS warnings in one or more of these categories. In all probability, none of the chemicals in these categories would normally be ingested during natural

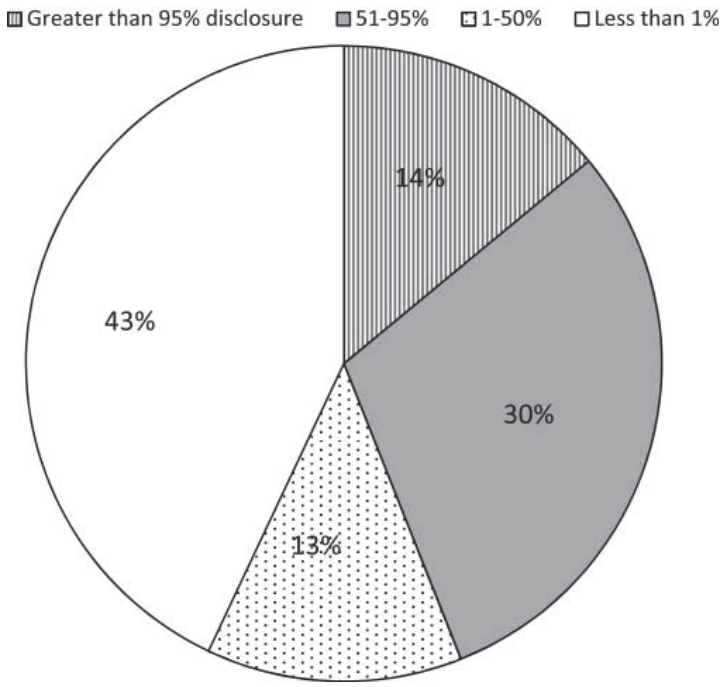


**Figure 1.** Percent of composition disclosed for 944 products used in natural gas operations.

gas operations, but immediate eye, nasal, dermal contact, and inhalation could lead to rapid absorption and cause direct exposure to the brain and other vital organ systems.

Health categories that reflect chronic and long-term organ and system damage comprise the middle portion of Figure 2. These include the nervous system (52%), immune system (40%), kidney (40%), and the cardiovascular system and blood (46%). More than 25% of the chemicals can cause cancer and mutations. Notably, 37% of the chemicals can affect the endocrine system that encompasses multiple organ systems including those critical for normal reproduction and development. The category of "other" is more common, and includes effects on weight, teeth, and bone and the ability of a chemical to cause death. More than 40% of the chemicals have been found to have ecological effects, indicating that they can harm aquatic and other wildlife.

### Volatile and Soluble Chemicals

Separate health category profiles are shown in Figure 3 for the volatile and water soluble chemicals. Approximately 37% of the chemicals are volatile and can become airborne. More than 89% of these chemicals can harm the eyes, skin, sensory organs, respiratory tract, gastrointestinal tract, or liver. Compared with the soluble chemicals, far more of the volatile chemicals (81%) can cause harm to the brain and nervous system. Seventy one percent of the volatile chemicals can harm the cardiovascular system and blood, and 66% can harm the kidneys. Overall, the volatile chemicals produce a profile that displays a higher frequency of health effects than the water soluble chemicals. In addition, because they vaporize, not only can

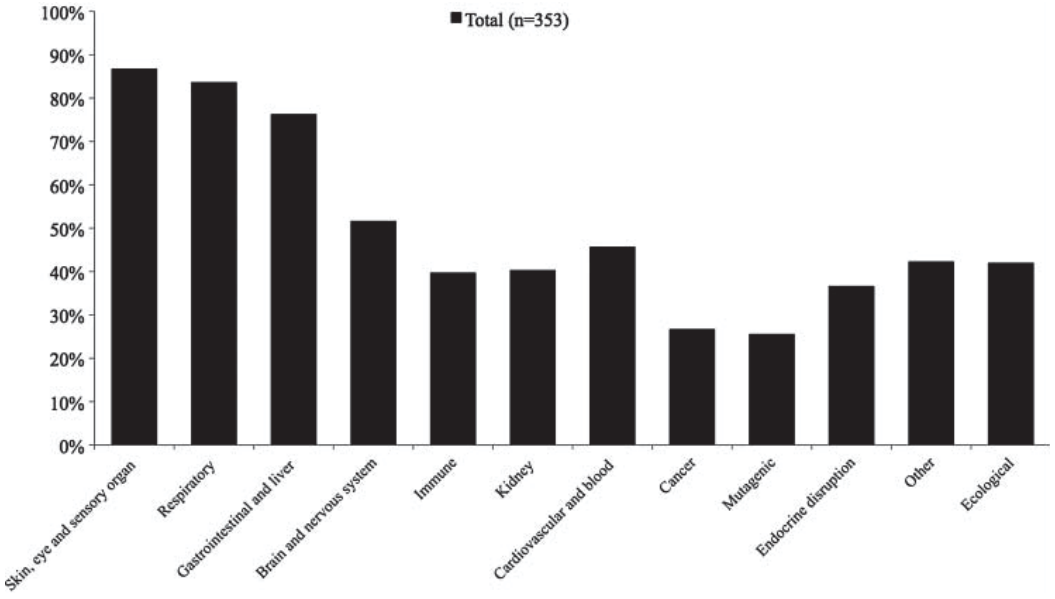


**Figure 2.** Profile of possible health effects of chemicals with CAS numbers used in natural gas operations.

they be inhaled, but also ingested and absorbed through the skin, increasing the chance of exposures.

### Drilling Chemicals

The profile for the 22 drilling chemicals identified from the well blow-out in Wyoming are shown in Figure 4. The profile was unique in the following ways. All

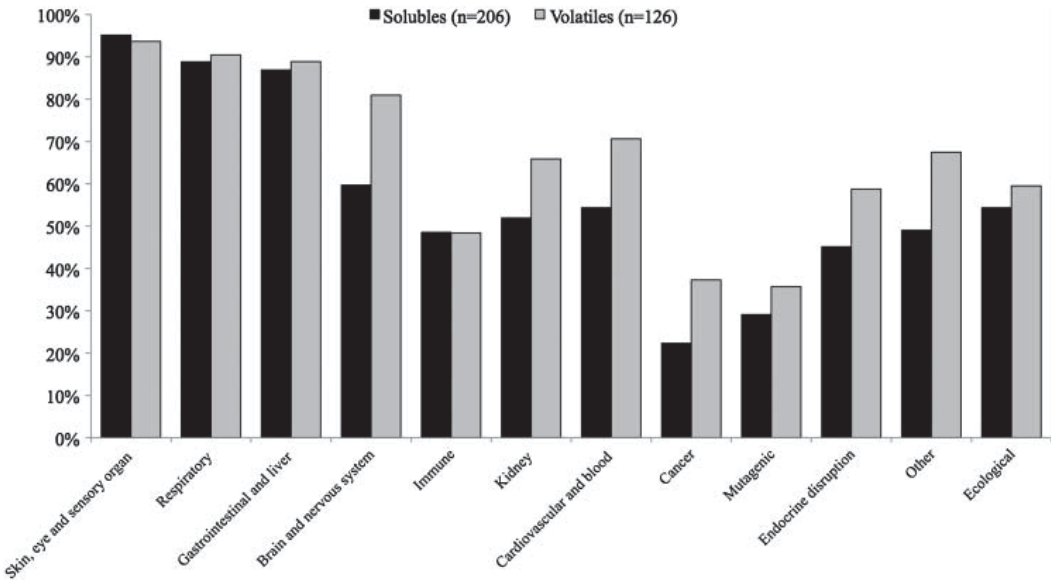


**Figure 3.** Profile of possible health effects of soluble and volatile chemicals with CAS numbers used in natural gas operations.

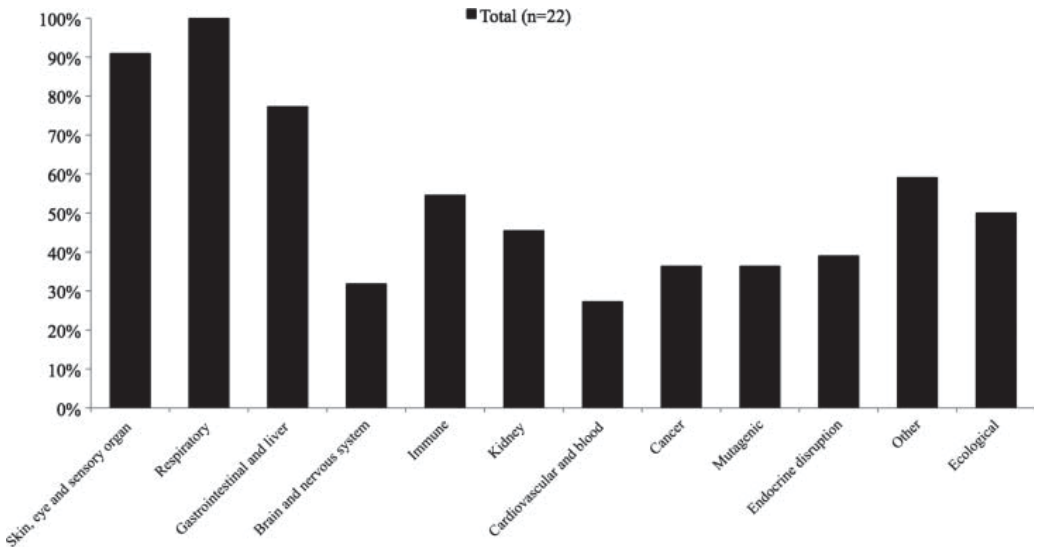


**Figure 4.** Profile of possible health effects of chemicals with CAS numbers used to drill the Crosby 25-3 well, Wyoming.

the chemicals used in the drilling fluids were associated with respiratory effects. Nearly 60% were associated with "other" effects, a category that includes outright mortality as an end point. A relatively high percentage of chemicals that affect the immune system were used.

### Evaporation Pit Chemicals

Shown in Figure 5 are the health effects of the 40 chemicals and metals reported in the New Mexico evaporation pits. These chemicals produced a health profile even

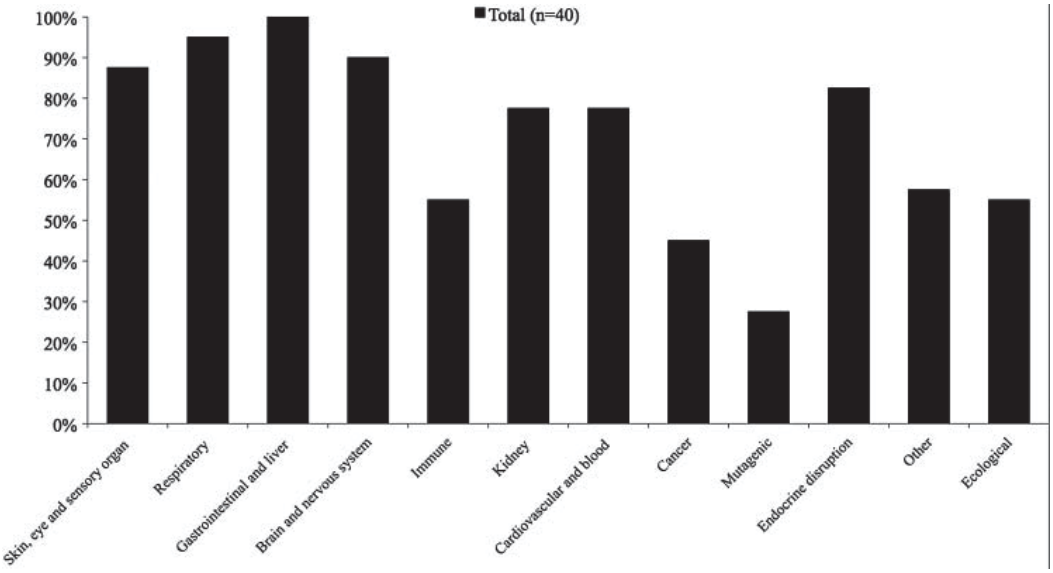


**Figure 5.** Profile of possible health effects of chemicals with CAS numbers found in six New Mexico drilling evaporation pits.

more hazardous than the pattern produced by the drilling and fracking chemicals. Upon further investigation, we discovered that 98% of the 40 chemicals found in the pits are listed on USEPA's 2005 CERCLA (Superfund) list and 73% are on the 2006 EPCRA List of Lists of reportable toxic chemicals. Of the nine chemicals found to exceed the New Mexico state limits, all are on the CERCLA list and all but one are on the EPCRA List of Lists.

### Analyses for Water Quality Monitoring

For the purpose of water quality monitoring guidance, we analyzed the data according to the most potentially harmful chemicals and the most frequently used chemicals. In Table 2 is provided a list of the most egregious chemicals, those with 10 or more health effects. Roughly half of these chemicals are used in only one product on our list, making it impractical and a waste of time and money to try to test water for the most harmful chemicals. A more practical approach would be to test for the most frequently used chemicals. Although we do not know how often each product is used, we assume that the more products that contain a given chemical, the more likely it is to be detected in a water sample. Shown in Table 3 are all the chemicals on our list that were found in at least seven different products. Many of these chemicals are relatively harmless. The most frequently cited chemical was crystalline silica (quartz), which was reported in 125 different products. Note that petroleum distillates and a variety of alcohols are found in numerous products, as are several forms of potassium, which is a relatively easy and inexpensive chemical to detect in water. This list may prove useful in devising a water monitoring program. Regardless of how many health effects a chemical has, elevated levels of frequently used chemicals found in a water source could provide evidence of communication between natural gas operations and water resources.

## DISCUSSION

Industry representatives have said there is little cause for concern because of the low concentrations of chemicals used in their operations. Nonetheless, pathways that could deliver chemicals in toxic concentrations at less than one part-per-million are not well studied and many of the chemicals on the list should not be ingested at any concentration. Numerous systems, most notably the endocrine system, are extremely sensitive to very low levels of chemicals, in parts-per-billion or less. The damage may not be evident at the time of exposure but can have unpredictable delayed, life-long effects on individuals and/or their offspring. Effects of this nature would be much harder to identify than obvious impacts such as skin and eye irritation that occur immediately upon contact. Health impairments could remain hidden for decades and span generations. Specific outcomes could include reduced sperm production, infertility, hormone imbalances, and other sex-related disorders. Further compounding this concern is the potential for the shared toxic action of these contaminants, especially those affecting the same and/or multiple organ systems.

It was difficult to arrive at a "short list" of chemicals that would be informative for water quality monitoring because of the vast array of products constantly being developed, and the wide selection of chemicals used in those products. We can,

**Table 2.** Chemicals with CAS numbers that have 10 or more adverse health effects.

| Chemical | CAS # | Number of products |
|---|---|---|
| (2-BE) Ethylene glycol monobutyl ether | 111-76-2 | 22 |
| 2,2′,2″-Nitrilotriethanol | 102-71-6 | 3 |
| 2-Ethylhexanol | 104-76-7 | 7 |
| 5-Chloro-2-methyl-4-isothiazolin-3-one | 26172-55-4 | 2 |
| Acetic acid | 1186-52-3 | 1 |
| Acrolein | 107-02-8 | 1 |
| Acrylamide (2-propenamide) | 79-06-1 | 6 |
| Acrylic acid | 79-10-7 | 2 |
| Ammonia | 7664-41-7 | 3 |
| Ammonium chloride | 12125-02-9 | 2 |
| Ammonium nitrate | 6484-52-2 | 2 |
| Aniline | 62-53-3 | 1 |
| Benzyl chloride | 100-44-7 | 2 |
| Boric acid | 10043-35-3 | 4 |
| Cadmium | 7440-43-9 | 1 |
| Calcium hypochlorite | 7778-54-3 | 1 |
| Chlorine | 7782-50-5 | 1 |
| Chlorine dioxide | 10049-04-4 | 2 |
| Dibromoacetonitrile | 3252-43-5 | 1 |
| Diesel 2 | 68476-34-6 | 19 |
| Diethanolamine | 111-42-2 | 4 |
| Diethylenetriamine | 111-40-0 | 1 |
| Dimethyl formamide | 68-12-2 | 1 |
| Epidian | 25068-38-6 | 1 |
| Ethanol | 64-17-5 | 8 |
| Ethyl mercaptan | 75-08-1 | 1 |
| Ethylbenzene | 100-41-4 | 7 |
| Ethylene glycol | 107-21-1 | 17 |
| Ethylene oxide | 75-21-8 | 2 |
| Ferrous sulfate | 7720-78-7 | 1 |
| Formaldehyde | 50-00-0 | 4 |
| Formic acid | 64-18-6 | 8 |
| Fuel oil #2 | 68476-30-2 | 9 |
| Glutaraldehyde | 111-30-8 | 11 |
| Glyoxal | 107-22-2 | 2 |
| Hydrodesulfurized kerosene | 64742-81-0 | 1 |
| Hydrogen sulfide | 7783-06-4 | 1 |
| Iron | 7439-89-6 | 3 |
| Isobutyl alcohol (2-methyl-1-propanol) | 78-83-1 | 3 |
| Isopropanol (propan-2-ol) | 67-63-0 | 47 |
| Kerosene | 8008-20-6 | 3 |
| Light naphthenic distillates, hydrotreated | 64742-53-6 | 2 |

**Table 2.** Chemicals with CAS numbers that have 10 or more adverse health effects. *(Continued)*

| Chemical | CAS # | Number of products |
|---|---|---|
| Mercaptoacetic acid | 68-11-1 | 2 |
| Methanol | 67-56-1 | 74 |
| Methylene bis(thiocyanate) | 6317-18-6 | 2 |
| Monoethanolamine | 141-43-5 | 5 |
| NaHCO3 | 144-55-8 | 5 |
| Naphtha, petroleum medium aliphatic | 64742-88-7 | 2 |
| Naphthalene | 91-20-3 | 18 |
| Natural gas condensates | 68919-39-1 | 1 |
| Nickel sulfate | 7786-81-4 | 1 |
| Paraformaldehyde | 30525-89-4 | 2 |
| Petroleum distillate/naptha | 8002-05-9 | 7 |
| Petroleum distillate/naphtha | 8030-30-6 | 1 |
| Phosphonium, tetrakis(hydroxymethyl)-sulfate | 55566-30-8 | 2 |
| Propane-1,2-diol | 57-55-6 | 6 |
| Sodium bromate | 7789-38-0 | 1 |
| Sodium chlorite (chlorous acid, sodium salt) | 7758-19-2 | 1 |
| Sodium hypochlorite | 7681-52-9 | 1 |
| Sodium nitrate | 7631-99-4 | 3 |
| Sodium nitrite | 7632-00-0 | 3 |
| Sodium sulfite | 7757-83-7 | 1 |
| Styrene | 100-42-5 | 1 |
| Sulfur dioxide | 7446-09-5 | 1 |
| Sulfuric acid | 7664-93-9 | 1 |
| Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione (Dazomet) | 533-74-4 | 3 |
| Titanium dioxide | 13463-67-7 | 2 |
| Tributyl phosphate | 126-73-8 | 1 |
| Triethylene glycol | 112-27-6 | 1 |
| Urea | 57-13-6 | 3 |
| Xylene | 1330-20-7 | 11 |



however, provide some guidance by pointing out four types of chemicals that are used in a relatively high number of products. These include (1) the silicas, which appear frequently as product components; (2) potassium based chemicals, which are also found in numerous products, although with relatively low toxicity; (3) petroleum derived products, which take on many different forms (including some without CAS numbers), and some of which are toxic at low concentrations and might be detected with diesel or gasoline range organics tests; and (4) the alcohols for which new detection technology is being developed, and because they are among the chemicals with the most health effects.

**Table 3.** Chemicals with CAS numbers found in the highest number of products.

| Chemical | CAS # | Number of products | Number of health effects |
|---|---|---|---|
| Crystalline silica, quartz | 14808-60-7 | 125 | 7 |
| Methanol | 67-56-1 | 74 | 11 |
| Isopropanol (propan-2-ol) | 67-63-0 | 47 | 10 |
| Petroleum distillate hydrotreated light | 64742-47-8 | 26 | 6 |
| (2-BE) Ethylene glycol monobutyl ether | 111-76-2 | 22 | 11 |
| Bentonite | 1302-78-9 | 20 | 6 |
| Diesel 2 | 68476-34-6 | 19 | 10 |
| Naphthalene | 91-20-3 | 18 | 12 |
| Aluminum oxide | 1344-28-1 | 17 | 3 |
| Ethylene glycol | 107-21-1 | 17 | 10 |
| Sodium hydroxide | 1310-73-2 | 17 | 5 |
| Barite (BaSO4) | 7727-43-7 | 15 | 5 |
| Heavy aromatic petroleum naphtha | 64742-94-5 | 15 | 5 |
| Crystalline silica, cristobalite | 14464-46-1 | 14 | 5 |
| Mica | 12001-26-2 | 14 | 3 |
| Sodium chloride | 7647-14-5 | 14 | 9 |
| Crystalline silica, tridymite | 15468-32-3 | 13 | 3 |
| Hydrochloric acid (HCl) | 7647-01-0 | 13 | 7 |
| Glutaraldehyde | 111-30-8 | 11 | 11 |
| Xylene | 1330-20-7 | 11 | 10 |
| Guar gum | 9000-30-0 | 10 | 3 |
| Iron oxide (ferric oxide) | 1309-37-1 | 10 | 5 |
| Potassium chloride | 7447-40-7 | 10 | 8 |
| Potassium hydroxide | 1310-58-3 | 10 | 7 |
| Xanthan gum | 11138-66-2 | 10 | 4 |
| Fuel oil #2 | 68476-30-2 | 9 | 11 |
| Hydrotreated heavy petroleum naphtha | 64742-48-9 | 9 | 8 |
| Limestone (calcium carbonate) | 1317-65-3 | 9 | 2 |
| Polyacrylamide/polyacrylate copolymer | 25085-02-3 | 9 | 3 |
| Sodium carboxymethylcellulose (polyanionic cellulose) | 9004-32-4 | 9 | 5 |
| Calcium hydroxide | 1305-62-0 | 8 | 8 |
| Crystalline silica (silicon dioxide) | 7631-86-9 | 8 | 4 |
| Ethanol | 64-17-5 | 8 | 12 |

**Table 3.** Chemicals with CAS numbers found in the highest number of products. *(Continued)*

| Chemical | CAS # | Number of products | Number of health effects |
|---|---|---|---|
| Formic acid | 64-18-6 | 8 | 11 |
| Graphite | 7782-42-5 | 8 | 4 |
| 2-Ethylhexanol | 104-76-7 | 7 | 11 |
| Acetic acid | 64-19-7 | 7 | 9 |
| Asphaltite (gilsonite, hydrocarbon black solid) | 12002-43-6 | 7 | 4 |
| Butanol (n-butyl alcohol, butan-1-ol, 1-butanol) | 71-36-3 | 7 | 8 |
| Calcium carbonate (sized) | 471-34-1 | 7 | 6 |
| Calcium chloride | 10043-52-4 | 7 | 8 |
| Ethoxylated nonylphenol | 9016-45-9 | 7 | 6 |
| Ethylbenzene | 100-41-4 | 7 | 11 |
| Petroleum distillate naphtha | 8002-05-9 | 7 | 12 |
| Propargyl alcohol (prop-2-yn-1-ol) | 107-19-7 | 7 | 9 |
| Tetramethylammonium chloride | 75-57-0 | 7 | 8 |



Detection of increasing or elevated concentrations of these chemicals near gas operations could indicate that communication between natural gas activities and a water resource such as a domestic well, creek, pond, wetland, and so on is occurring. If a longitudinal monitoring program were to reveal any increase in concentration in one of these target groups, even if the concentrations were well below any water quality standards, it should trigger more testing immediately.

For many years, drillers have insisted that they do not use toxic chemicals to drill for gas, only guar gum, mud, and sand. While much attention is being given to chemicals used during fracking, our findings indicate that drilling chemicals can be equally, if not more dangerous. What we have learned about the chemicals used in the Crosby well blowout provides insight into why citizens living nearby suffered severe respiratory distress, nausea, and vomiting and had to be evacuated from their homes for several days. It might also shed light on why other individuals living near gas operations have experienced similar symptoms during the gas drilling phase (prior to fracking).

From the first day the drill bit is inserted into the ground until the well is completed, toxic materials are introduced into the borehole and returned to the surface along with produced water and other extraction liquids. In the western United States it has been common practice to hold these liquids in open evaporation pits until the wells are shut down, which could be up to 25 years. These pits have rarely been examined to ascertain their chemical contents outside of some limited parameters (primarily metals, chlorides, and radioactive materials). Our data reveal