An Evaluation of the Chemtronics Superfund Site

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Warren Wilson College

What's there?

- During the operation of Chemtronics Inc. a large number of chemicals passed through the site.
- For the most part these chemicals have been capped or neutralized.
- Contaminants that remain on site are currently undergoing treatment to prevent spread, and ultimately, to be removed.
- Currently, contaminants remain contained within the site.

Topics

- Risk Assessment Practices
- BZ
- CS and RDX
- Chlorinated Solvents
  - Chemistry
  - Air Stripping
- Perchlorates
- Remediation with Vegetable Oil

Reference

- Parts Per Billion (ppb) – One part in a billion or approximately 1 tablespoon of sugar in Lake Tomahawk
- Half Life – The time it takes for half of a substance to break down
- Precipitation – Formation of a solid within a solution or other solid
- Volatile – The tendency of a substance to vaporize
- Migration – Movement of a substance from the point of origin

Risk Assessment

Megan Brooks-Planck

Risk Assessment

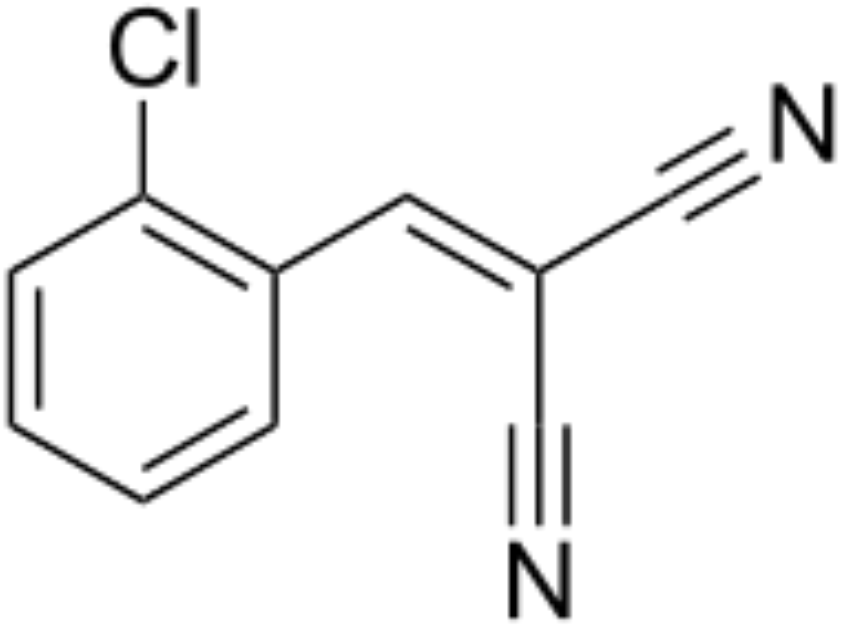
- The EPA determines risk using a four step process.
  - Hazard Identification
  - Dose-Response Assessment
  - Exposure Assessment
  - Risk Characterization

CS and RDX

Eden May

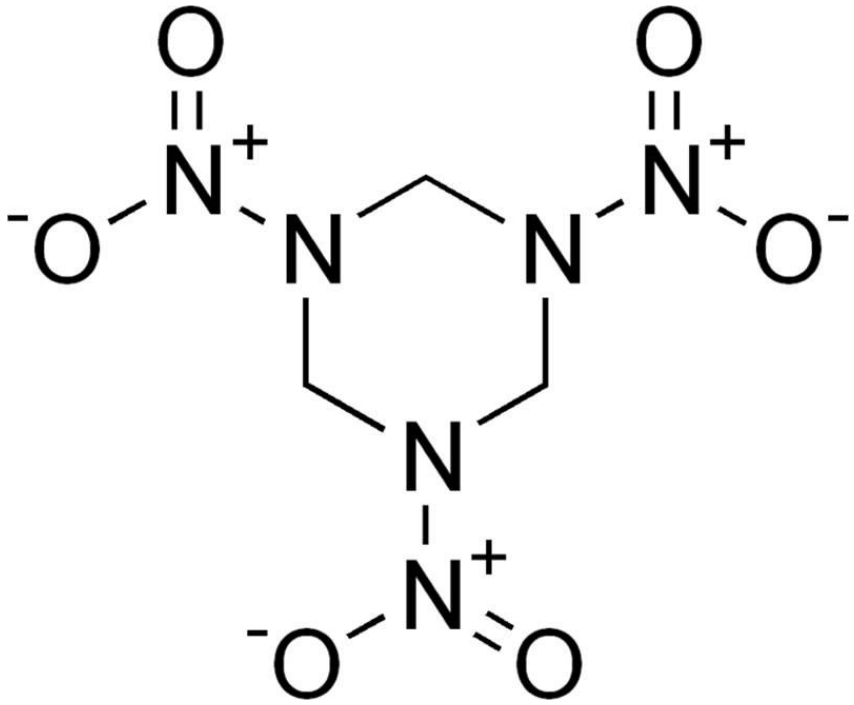
What is CS?

- "Tear gas"
- Non-lethal, used as an aerosol
- Can damage lungs, heart and liver
- Present in soil at some sites
- Decomposes quickly in water
- Half life is 41 minutes



What is RDX?

- Produced as an explosive
- Can cause nausea, vomiting, confusion and amnesia
- EPA human health standard 103 micrograms/ liter
- 220 micrograms/liter in one well



RDX Degradation and Remediation:

- In situ – anaerobic conditions - **reduction**
- Cannot be attributed to single biological or chemical process
- Similar explosives may also be removed by reductive processes

- Conclusions
  - Microbial and chemical processes play important roles in reducing RDX in the aquifer
  - Reduction time took ~10 days for abiotic transformation
  - Electron donors enhance rate
  - *Rhodoferx spp.* bacteri critical to in situ reduction in anoxic conditions

BZ

Michael Buttrick

What is BZ?

- 3-Quinuclidinyl benzilate
- Potent hallucinogen
- Tested and produced during 1960's and 70's
- Designed to be distributed as aerosol
- Never saw official use
- Exposure Limit
  - ID_{50} (incapacitating dosage):
    0.00616 mg (direct i.v.)

Degradation of BZ

- No BZ detected in recent years
- Small amounts of Benzilic Acid decomposition product are present
  (less than 2 parts per million)
- Any BZ not removed during initial clean-up has turned to Benzilic acid
- Storage barrels of BZ were removed 25 years ago
- If any BZ was missed, its decomposition rate would indicate that
  less than .0000000005% remains

Current Levels of BZ

Preliminary Soil Concentration (1988):

Benzilic Acid: 56.9mg/kg of soil

BZ: 17.1mg/kg of soil

Chemtronics Site Data (2007):

Benzilic Acid:

Soil Concentration: 9.3mg/kg of soil

Groundwater Concentration: 1.4mg/L water

BZ:

Soil: Not Detected

Groundwater: Not Detected

Chlorinated Solvents

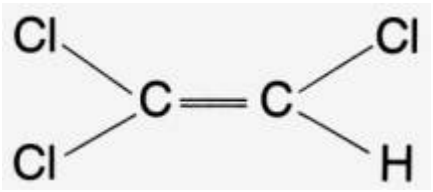
Meng Yuan Li

What are Chlorinated Solvents?

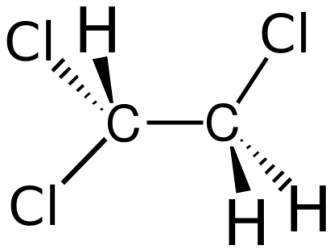
- Metal degreasing agents
- Are present at highest concentrations on site
- Found at high levels in some wells, not in other wells
- Common industrial pollutant
- Carcinogenic to humans exposed at work
  - Kidney, liver cancer
  - Non-Hodgkin lymphoma
- Neurobehavioral deficits
  - Long-term exposure to low concentration of TCE
- Evidence only from long term high level exposure

What are Chlorinated Solvents?

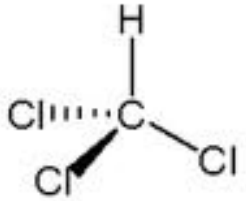
TCE Trichlorethylene



TCA Trichloroethane



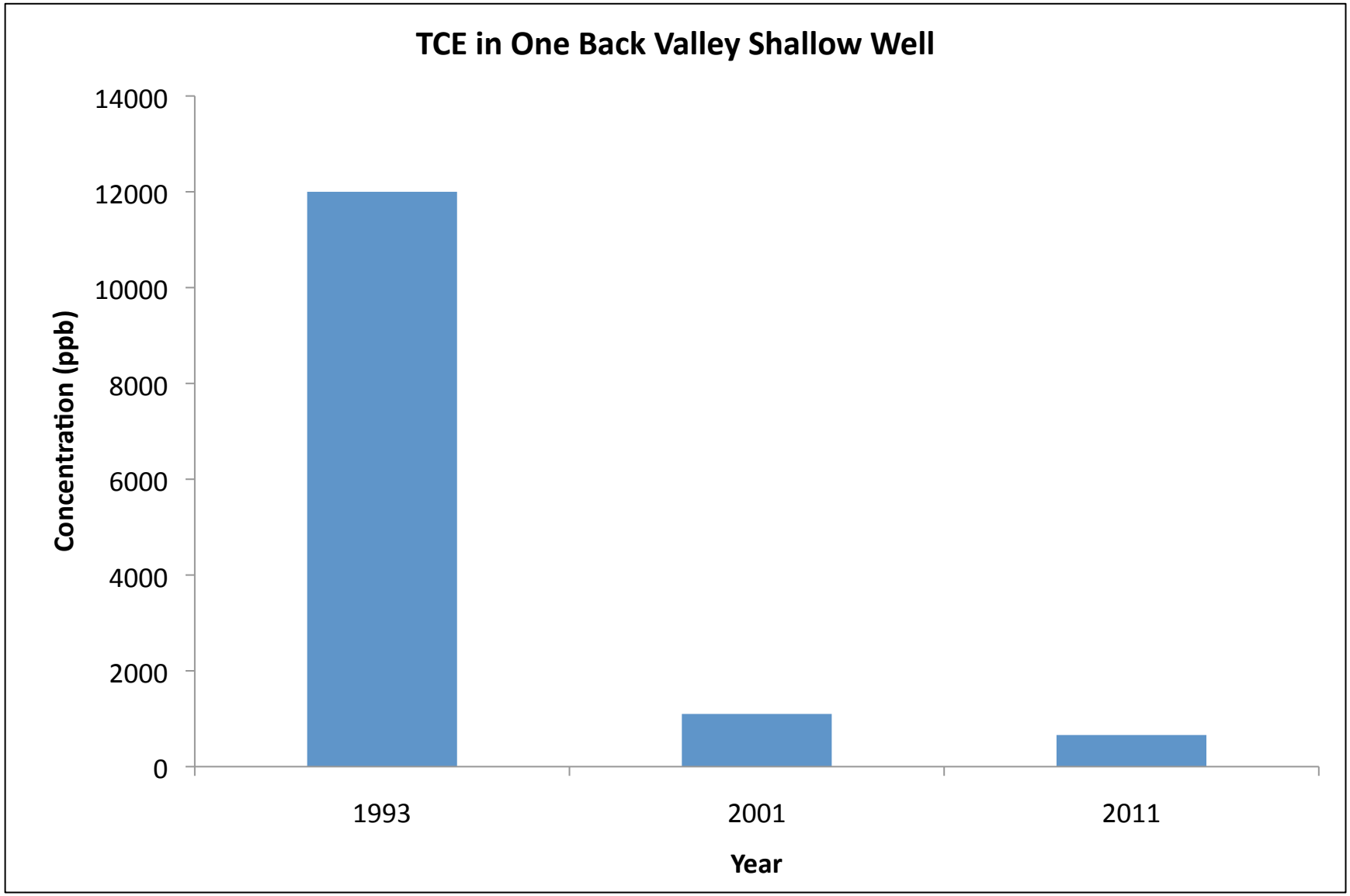
Chloroform



EPA drinking water limits

5 micrograms/liter	200 micrograms/liter	70 micrograms/liter

All found in groundwater at levels exceeding EPA limits in some wells



EPA standard for TCE = 5ppb

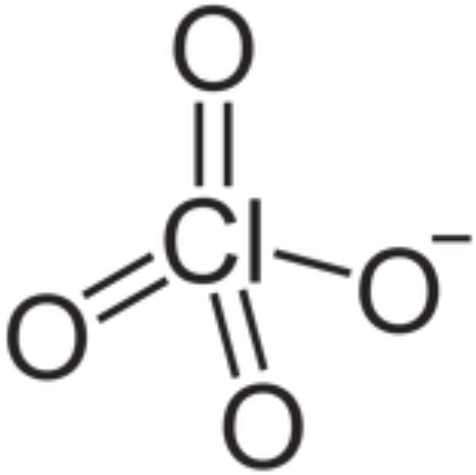
Perchlorates

Elizabeth Bonnell

What is perchlorate?

Source:

- Fireworks
- Warfare
- Some chemical processes
- Can form naturally



Chemtronics Site Sources

- Explosives

Health effects of perchlorate

- Competes with iodide in the thyroid gland
  - Only at high perchlorate levels
  - Some concern for pregnant women
- Not likely to cause cancer

Current Levels

- 2500 micrograms/liter in one Chemtronics well
- 6 micrograms/liter maximum permissible level in California
- Not travelling to off-site wells

What are they doing to clean it up?

- No previous methods at Chemtronics
- Possible Methods:
  - Anaerobic Degradation now being tested
    - Seems promising
  - Treatment through physical processes not likely now

Bioremediation:
Emulsified Vegetable Oil

Davis Jones

What does reduction mean?

- Reduction is the gain of electrons
- If something gains electrons (is reduced) something else has to lose the electrons (is oxidized)
- Some bacteria can speed up the reaction
- Vegetable oil is a possible source of electrons leading to reduction of pollutants

General Remediation

- July 2012 – Enhanced In situ Bioremediation (EISB)using food grade vegetable oil (EVO) approved by the EPA
  - Contractor
- Four sites tested in Front Valley
- Current activity: FSCT – Feasibility Screening/ Candidate Testing
  - Microcosm testing – Bacterial strains
  - Shallow well test

General Remediation

- EVO provides underground emulsion to stimulate BOZ – biologically active zone
- BOZ stimulates bacterial growth
- Acts as electron donor to reduce chlorinated solvents

  reduce = gaining an electron

Contaminants Treated

Chemicals of Potential Concern

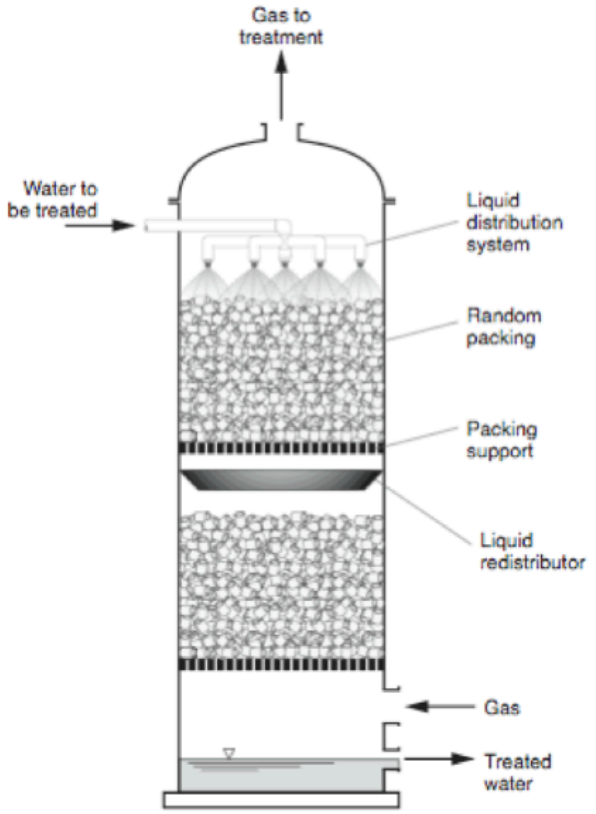
- VOC –volatile organic compounds (TCE, PCE, 1-2-DCA, CF)
- Nitroaromatics (RDX, HMX, 2,4,6- TNT)
- Perchlorate

Bioremediation can be effective for all three categories

Other Types of Remediation

Rebecca Johnson & Stephanie Williams

Remediation: Air Stripping



Schematic of a Packed Tower Air Stripper (Crittenden et al., 2005)

- Contaminated water enters at the top of the column as air enters at the bottom
- Packing provides increased surface area
- chlorinated solvents enter the gas phase
- Treated water exits through the bottom of the column, solvents are off gassed

Reaction in air

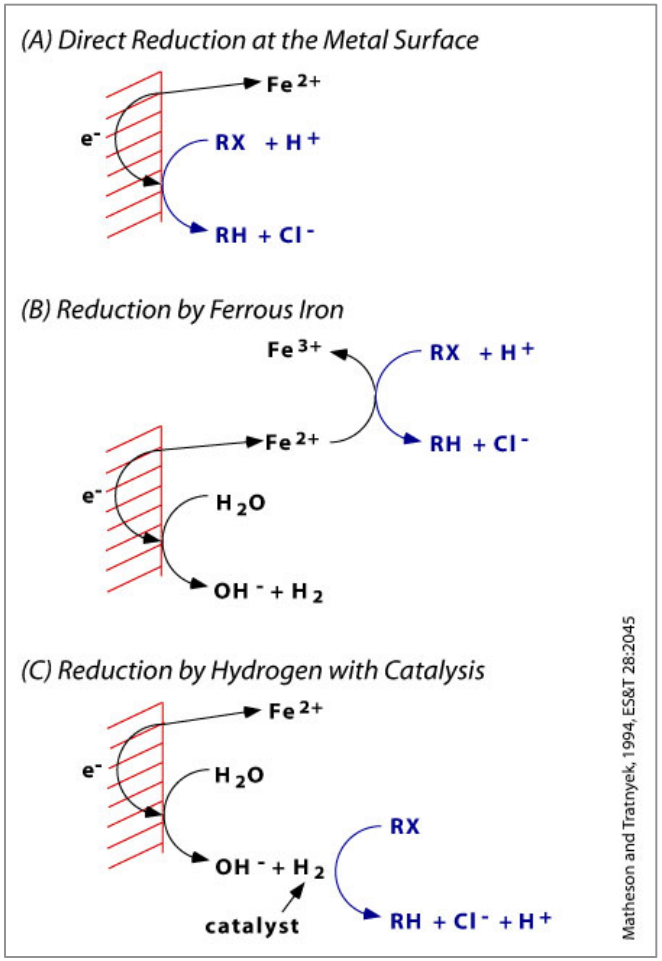
- Light can cause removal of chlorinated solvents in air
- TCE breaks down into CO_2 and HCl
- The half life of TCE is 3.5 days
- After two weeks, TCE is essentially gone from air

Other Methods for removal of solvents

- Natural attenuation

"Let nature take care of it" (bioremediation, dilution, etc)

- Zero-Valence Iron
  - Metal-water interface
  - Corrosion of iron
- Bioremediation
  - Bacteria remove Cl and replace with H
  - Final product is harmless
  - Currently being tested on-site



Superfund and the Swannanoa Community

Megan Brooks-Planck
Warren Wilson College

With the discovery of toxic waste dumps in the 1970s, a need developed for cleanup and removal of hazardous materials. Waste left behind stays behind, and can pollute soil, water, and air, ultimately leading to human contamination. The Superfund was established in 1980 as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as a means to mandate the cleanup of hazardous waste sites by responsible parties (U.S. Environmental Protection Agency 2012b). Once a hazardous site is placed on the National Priorities List (NPL) due to the threat of hazardous substances, pollutants, or contaminants it is slated for cleanup led by the Environmental Protection Agency (U.S. Environmental Protection Agency 2012a). The Chemtronics site in Swannanoa, North Carolina, was placed on the NPL in 1982.

Swannanoa, North Carolina is home to the Chemtronics Superfund Site. In the spring of 2013, the EPA helped concerned citizens in Swannanoa form a Community Advisory Group (CAG) as a liaison to the Superfund site owners, the EPA, and the general public. Our Advanced Environmental Chemistry class had the opportunity to serve this CAG by researching and presenting the highly technical information regarding the site and the potential dangers it presents to the community. Working with the Chemtronics CAG was so much more than a service project.

Warren Wilson College is one of the few colleges that require service in order to graduate. At the time of my attendance, each student had to complete 100 hours of service as well as a comprehensive reflection of his or her service. By my senior year in 2013, I had completed many hours of service for a wide range of causes and organizations, but this project was something different. Service-learning courses have the unique ability to bring textbook information into a real context with a meaningful purpose. I had participated in other service-learning projects in other classes, but never before in the chemistry department. The study of chemistry is often restricted to the lab or classroom, so having the opportunity to apply serious chemistry in a meaningful way was fantastic.

The Chemtronics Superfund site is located just miles from Warren Wilson College, but is also close to homes within the Swannanoa community. Curiosity and even animosity associated with the site is only natural. While the contamination present on the site is the result of industry, the Superfund in itself has a mixed reputation in many communities. The EPA remediation process is a slow one. Even the initial steps of establishing Potentially Responsible Parties (PRP) to be held accountable can take years, and until that is determined the clean-up process cannot begin. Additionally, there is often suspicion of government agencies working within the community. Superfund in general is an unwelcome presence, indicating contamination and hazardous materials, but the Chemtronics site is one of particular notoriety.

Operating as a manufacturer for the United States Department of Defense, the site saw production of many hazardous chemicals during its years of operation. Chlorinated solvents, a common pollutant at superfund sites, are present in the highest concentrations here, but several unique pollutants are also found onsite. Perhaps the most unusual is 3-Quinuclidinyl benzilate, commonly referred to as BZ. This compound was manufactured in the 1960s and 1970s as a weaponized hallucinogen, but never saw official use. Following government orders, all

stockpiles of this compound were destroyed, and due to its natural instability any remaining traces have long since decomposed into its harmless constituent parts (U.S. Environmental Protection Agency 2008).

A well-known output of the Chemtronics site is the compound 2-chlorobenzalmalononitrile, also known as CS gas, or tear gas. This non-lethal aerosol has a short half-life in both air and water. The half-life of a compound is the amount of time it takes for half of the substance to break down. For example, the half-life of CS in water is just 15 minutes, indicating that after 15 minutes only half of the original material remains, after 30 minutes only a quarter of the original material remains, and so on. This short half-life means that CS is not persistent in air or water. Since the closure of the site, CS in air and water has long since broken down. The half-life in soil is longer however, and so some traces do remain present on the site (U.S. Environmental Protection Agency 2009).

The compound cyclotrimethylenetrinitramine, or RDX, was also produced at the Chemtronics site. RDX is a potent explosive, many times more powerful than TNT, and has negative effects if consumed. In anaerobic, or oxygen-free, conditions RDX biodegrades naturally. This compound is capable of leaching from soil to groundwater, and potentially on to plant or aquatic life (Agency for Toxic Substances and Disease Registry 2012). RDX is present at the Chemtronics site. Since the Chemtronics site was placed on the NPL in 1982 efforts have been focused on preventing the spread of these contaminants found onsite, rather than removing them completely. This prevents spread of unwanted contaminants, without the cost associated with complete remediation.

The priorities of a site on the NPL are primarily to determine what hazards and risks are present, to prevent these hazards from spreading to offsite locations, and to finally remove contaminants altogether through the process of remediation. Environmental remediation is essentially the removal of pollution or contaminants from soil, water, and air. Many methods of remediation exist, on a scale of availability to the area, cost, and effectiveness against a given contaminant. Bioremediation is a method of remediation applied at the Chemtronics site that uses natural processes to remove targeted contamination. This can be accomplished through certain types of plants or bacteria. One method uses emulsified vegetable oil to increase the natural rate of remediation by providing resources for bacterial growth, which in turn reduce the amount of certain types of contaminants. Air stripping is another type of remediation used to treat water contaminated by chlorinated solvents. Water is run through a column where target materials are transferred to air. There they quickly break down, releasing comparatively clean water.

During its years of remediation, the Chemtronics site has undergone intensive testing of soil, water, and air, the results of which are available to the public in the nearby Warren Wilson College Library. This data includes years of reports consisting of thousands of pages of text and numbers. In spring 2013, the Advanced Environmental Chemistry class worked in conjunction with the Chemtronics CAG to process this data, introducing it in a form that the public more easily understands. Students, including myself, chose topics of concern and focused on key questions related to the site. These topics included specific chemical compounds, types of remediation and removal, and EPA processes. Students produced a comprehensive report on their individual topic for the class, as well as a group PowerPoint and individual poster presentations for the CAG.

My topic was on risk assessment practices as carried out by the EPA. This method of risk assessment is a four-step process, beginning with identification of any possible contaminants onsite. The next step is dose-response assessment, analyzing the way in which any given amount

of a contaminant will affect human health. Following this step, exposure assessment determines current risk of exposure, testing air, water, and soil near the contaminated site. The final step is risk characterization, taking all the previously collected information into account. This end product is a detailed assessment of the current and potential risk posed by a contaminated environment, such as the Chemtronics site (Office of Emergency and Remedial Response 1989).

The research process began with students gathering information on the site as a whole. The sheer volume of data available in the library archives was almost overwhelming, and the class worked together a great deal during this process, comparing notes, suggesting resources, and helping each other find and understand data. This exploration into the history of the site provided a framework for students to begin their own research on individual topics, while placing information into a local context. A group PowerPoint was created in order to bring together each of the individual topics for presentation to the Swannanoa community. Each student presented a PowerPoint to the rest of the class on his or her specific topic for initial feedback and to determine the best possible order of topics. The presentations were then combined into one document. One of the most helpful parts of the process was a practice presentation to the Environmental Policy class, a group of students interested in the site, who were able to offer advice on presenting to the general public. It was important to keep the final audience in mind when carrying out research, and especially when preparing the PowerPoint presentation. After this practice session, final feedback was collected and used to create posters for the Chemtronics CAG.

As a student I put more time into this project than any other service project I participated in during my four years at Warren Wilson College. The first part of the task, finding the information, may have taken the longest, especially considering the sheer volume of data that each student had to search through, but for me at least, this step was not the most difficult. As a student of both environmental chemistry and environmental policy, I was not new to the language of the EPA. Avoiding technical language that might be unclear or confusing to those who are less familiar with the subject matter was a challenge for me. In the process of drafting, proof-reading, and discussing the project with others in and out of the chemistry department, it became easier to discuss the topic from a variety of viewpoints, rather than focusing on the technical or political aspects of the issue that come more naturally to me. During this process I learned to closely analyze my own work, asking myself if I was being clear, or if I could answer questions on this topic as needed. Unlike typical class presentations I could not expect my audience to have a background in environmental sciences or chemistry. It was very important that I make no assumptions.

The cumulative moment of this project was the night of our presentation for the Chemtronics CAG. It was at this point in the project that we actually interacted with community members, an experience that brought our studies outside the classroom in a real, beneficial way. We were able to hear their concerns, questions, and thoughts on the Chemtronics site, and the Superfund presence there. As a policy student I have studied the importance of community involvement, but actually taking part in it was something else entirely. It was taking this final step that brought everything else together, all of our research, time, and work had brought us to this final point of interaction, and it was there that we were able to make a difference. We arrived early to the meeting so that we could set up our posters and prepare for our presentations. We were scheduled to speak toward the end of the meeting, and were able to sit and observe before our turn came. Those participating in the CAG were community members from all walks of life.

While a few of those present had a true understanding of the site, many more knew only the rumors that have flooded the community for years.

I observed the difficulty of keeping participants focused on the task at hand, allowing questions without getting off topic, and making sure every voice was heard. I was impressed by the group leaders, and took away valuable tips on coordinating such a diverse group of concerned citizens. When it came time to present our data, the meeting was reaching its close. The first student gave an oral overview of the project, outlining the history of the site, and providing some definitions on the "Reference" slide of the PowerPoint. This slide was projected during the poster presentations to help the audience understand some of the more technical terminology used on the posters. Most importantly, she explained the current status of the Superfund site. While contaminants are still present on the site, extensive testing has shown that none of the contaminants present are traveling offsite (U.S. Environmental Protection Agency 2007). While there is still a great deal to be done before the site itself is fully remediated, the EPA has succeeded in containing contamination.

She then introduced the topic of each succeeding student, and we took questions as a group, before inviting participants to come forward and ask questions of us individually. Each student had a poster prepared and was ready to answer questions and explain his or her topic. The community was interested, positive, and very kind to us. All of us were able to have conversations with members of the community and provide the positive news that those chemicals researched by this group are not leaving the superfund site and currently presented no threat to those living in the area. I know that my own experience was a very positive one. I was able to connect to a part of my own community and those living near me, and I felt that we were able to ease some of their concerns with the research we had carried out.

The Chemtronics site will be a part of the Swannanoa community for many years to come, and I would love to see the CAG and the Warren Wilson College Chemistry Department continue this relationship. Not only would this relationship provide a service to the community, but would also greatly benefit participating students and provide them with a true sense of accomplishment. As remediation continues on the site, more and more data will become available, hopefully showing a downward trend in contamination.

On a personal level, conducting research and finding answers for this project helped to sharpen my skills in thorough record keeping and careful note taking, and my experience working with the community allowed me to continue developing my interpersonal skills. Presenting a difficult subject to the community helped me make challenging concepts clearer and understandable. I was lucky to be a part of this service-learning project, which also received very positive feedback from the class as a whole. Comments from my classmates spoke very highly of the program, explaining that they saw their research and communication skills grow, all while learning to apply course materials in a real-world setting. While service learning has been a part of my college experience from the beginning, I couldn't have planned a better note to finish my final semester on, and I hope that those who come after me in the environmental studies department can share this empowering experience.

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I would like to thank Dr. Vicki Collins for all of her efforts creating this project and guiding each of us through the process. We couldn't have done it without her insight and support through the entire semester. I would also like to thank Dr. Jessa Madosky who serves as the moderator of the Chemtronics CAG and guided us through the CAG during our presentation and communication.

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