

Part A: The Effect of the Dimensions of Learning Model on the Epistemological Beliefs
of Students Enrolled in General Chemistry Laboratory for Post-Baccalaureate
Pre-Medical Students and Part B: Environmental Quality Survey Utilizing
TRI Explorer and USGS Water Data and the Analysis and Characterization
of Particulate Matter using Scanning Electron Microscopy

Darcie Wallace

A Dissertation Presented to the Graduate Faculty of Middle Tennessee State University in
Partial Fulfillment of the Requirements for the
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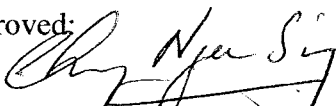
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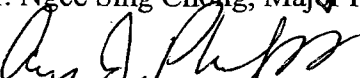
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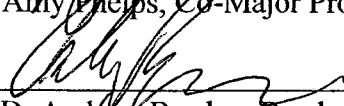
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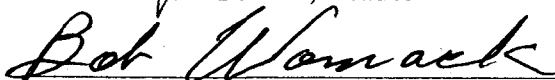
Dr. Ngee Sing Chong, Major Professor



Dr. Amy Phelps, Co-Major Professor




Dr. D. Andrew Burden, Reader



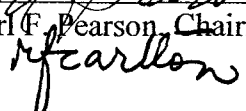
Dr. Bob Womack, Reader



Dr. Preston J. MacDougall, Assistant Chair Department of Chemistry



Dr. Earl F. Pearson, Chairman, Department of Chemistry



Dr. Robert Carlton, Interim Dean, College of Graduate Studies

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“If he is indeed wise he does not bid you enter the house of his wisdom, but rather leads you to the threshold of your own mind”

Kahlil Gibran, The Prophet, 1883-1931

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ABSTRACT

The first part of this dissertation deals with the dimensions of learning model that was developed by Robert Marzano in response to a comprehensive research and theory-based framework on cognition and learning. The strategy forms a background that can be used in instruction, curriculum, and assessment. The experimental group was exposed to the model and the control group was exposed to normal instruction for three lab activities in a summer general chemistry laboratory. The students were assessed for content knowledge via review of pre-laboratory and post-laboratory questions and for attitudinal changes via the Epistemological Beliefs Assessment for Physical Science Students. The study indicates that there were no attitudinal changes between the two groups. On the other hand, the instructional model is a variable technique, and the experimental group performed better on the post-laboratory questions.

The second part of this dissertation presents the results of an environmental quality survey utilizing the Environmental Protection Agency's TRI Explorer database as well as the United States Geological Survey water quality database. These databases could provide a valuable tool for the assessment of land, air, and water contamination. The top three air, water, and land releases were obtained from 1988 to 2002 for counties surrounding major cities in Tennessee. There was a poor correlation of data between the TRI Explorer and USGS databases for the counties in this study. This poor correlation may be due to the degradation of the chemicals released. It should be noted that there has been a decrease trend in many of the compounds studied, such as chlorofluorocarbons that have been targeted for elimination via legislation.

Air samples were collected on mixed cellulose ester and silver membrane filters using a GS Cyclone particulate sampler and analyzed using scanning electron microscopy with energy-dispersive X-ray analysis. Unlike particulate samples collected on quartz filters, sample loss and morphological changes of particles were minimal with the use of the mixed cellulose ester filters and silver membranes. Residential air samples collected on mixed cellulose ester filters were shown to contain aluminum, silicon, carbon, and oxygen. All particles are cylindrical in shape and are less than 10 μm in aerodynamic diameter. Samples collected in areas with congested automobile traffic are spherical and carbonaceous with a high carbon-to-oxygen ratio.

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**Part A: The Effect of the Dimensions of Learning Model on the Epistemological
Beliefs of Students Enrolled in General Chemistry Laboratory for Post-
Baccalaureate Pre-Medical Students**

CHAPTER 1

1. INTRODUCTION

1.1 Background and Significance of the Study

In the chemistry classroom, there has been a widening gap between the mental maturity of the students and the demands of chemistry.¹ With this disparity, chemistry has received a reputation of being difficult, unappealing and boring amongst students. Not only is there a gap between ability and demand, but also there has been a tremendous growth in various interests and disciplines among students enrolled in chemistry courses.² With the growth of interests and abilities brought about by increase in diversity, the chemistry laboratory may provide an opportunity for teachers to bridge the gap between mental maturity and the demands of chemistry via instructional methods.

Traditional teaching methodology has been connected with “the ends to achieve rather than on improving the means of reaching them”.³ Gallet implies that teaching methods have generally been focused on the outcome of the students final grade rather than on the ways of properly teaching concepts in order to have complete understanding by the students. These instructional methods may have lead to the demise of inquiry in the science laboratory through a focus on the ends rather than the means. Methodology should move from a passive teaching style to engaging the student in active learning. Students have the chance to experience the discipline of chemistry as active learners.^{4,5} Germann and Aram have suggested that the instructor should assist in concept development and understanding, skill development, and modeling.⁶ In this manner, students may become more skillful and independent in the laboratory and classroom. The

laboratory environment is an essential component of science curriculum which may enable teachers to aid students with integration of concepts from lecture to physical observations in the lab. In conjunction with concept development and understanding, the task introduced in lab could provide an increase in meaningful learning, an increase in active involvement of students in knowledge construction, and empower the students to be responsible for their learning.⁷ With the incorporation of various instructional tools into the laboratory curriculum, students may have the opportunity to develop and understand key chemical concepts, whereas teachers may gain new insights regarding the various learning styles and interests of the diverse students enrolled in their courses. The new laboratory could be an active experience for students in which they demonstrate and communicate effectively scientific concepts. In this study, normal laboratory instruction consists of introduction to concepts and procedures used in the experiment.

1.2 Purpose of the Study

The purpose of this study is to assess the impact of using the five dimensions of learning module in activities in the general chemistry laboratory setting. The impact of the module on student involvement as well as learning in the laboratory setting will be evaluated. Content knowledge prior to lab instruction and after instruction will be assessed via pre laboratory and post laboratory questioning.

1.3 Hypothesis

There will be a significant difference in the epistemological beliefs and content knowledge of general chemistry students exposed to laboratory activities using the five dimensions of learning as an instructional tool rather than students exposed to normal laboratory instruction.

1.4 Definition of Terms

Dimensions of Learning: Instructional model translating research and thinking from dimensions of thinking into a practical model that teachers of any content area can utilize to improve the quality of teaching and learning in the classroom.⁸

Dimensions of Learning 1: Positive attitudes and perceptions should promote an encouraging environment for learning and task clarity.

Dimensions of Learning 2: Acquiring and integrating knowledge

Declarative knowledge: The knowledge and understanding of facts and concepts in which meaning is constructed, organized and stored by the learner.

Procedural knowledge: The knowledge of processes and skills in which models are constructed, shaped, and internalized.

Dimensions of Learning 3: Extending and Refining Knowledge

Comparison: Basic technique in which specified items are determined for similarities and differences. The items are specified as well as attributes comparisons are based upon.

Classification: Natural technique where items to be classified are identified, sorted into groups, and rules are formed for categories and items may be reclassified based on these rules.

Induction: The process of making general conclusions from specific observations is induction.

Deduction: Often confused with induction, deduction is the process of utilizing principles to understand unstated conclusions.

Analyzing Errors: The process of identifying and communicating errors in thinking is error analysis in the dimensions of learning model.

Analyzing Perspectives: Perspective analysis is the process of identifying one's position on an issues and reasons behind that issue.

Constructing Support: The process of constructing supportive statements is a means for providing support for statements.

Abstracting: The process of finding and describing general patterns in specific information is abstraction in the module.

Dimensions of Learning 4: Using Knowledge Meaningfully

Decision Making: The process of answering questions such as what is the best method for completing a task or which is more suitable for the task is a valuable construct of dimension four.

Investigation: The types of investigation are definitional, historical, or projective. Known facts or acceptance about a concept are identified.

Experimental Inquiry: Observations, analyses, predictions, tests, and reevaluations are used to answer explanatory questions.

Problem Solving: The process of achieving a goal that is blocked by an obstacle.

Invention: The process of creating or improving something that fulfills a need.

Dimensions of Learning 5: The Habits of the Mind

Self Regulation: Traits of self regulation include being aware of one's own thinking, efficient planning, knowing additional resources to use for learning, being sensitive to feedback, and evaluation of actions.

Critical Thinking: Traits of critical thinking include being and seeking accuracy, being clear, open-minded, restrain impulses, taking a position when situation warrants, and being sensitive to others feelings and knowledge level.

Creative Thinking: Characteristics include intense engagement in tasks, pushing the limits of knowledge and abilities, generating and maintaining standards, and developing new ways of seeing situations outside of conventional boundaries.

Laboratory: Learning experiences in which students interact with materials to observe phenomenon.⁹

1.5 Setting of the Study

The study performed at Goucher College was conducted with two laboratory sections of post baccalaureate premedical students in an eight week summer general chemistry laboratory. Goucher College is a liberal arts private college in Maryland with approximately 1300 undergraduate and 1000 graduate students. The general chemistry course has an average enrollment of thirty students. Hence, the sample is not intended to be representative of students nationwide enrolled in chemistry at the undergraduate level.

CHAPTER 2

2. LITERATURE REVIEW

The laboratory is an environment in which students react to experiences to observe a phenomenon. Throughout the history of laboratory experiences, many educators have had similar views. The differences among educators are not in this definition, but rather in how students are exposed to the experiences, which lead to the observations.

With the progressive education movement in the early 1900s, John Dewey established a philosophical view regarding laboratory experiences. His learning by doing philosophy directly supports the need to devise a better method for laboratory instruction. Dewey stated “direct experience is even more [than] a matter of quality; it must be of a sort to connect readily and fruitfully with the symbolic material of instruction”.¹⁰ There is a relationship between direct experiences such as the laboratory and the instruction in a lecture classroom. Students should be given the opportunity to participate in situations that illustrate the importance of material and the problems that may arise with the concepts and ideas. Dewey suggests that manipulative skills may be a by-product of the learning, but the main purpose of the experiences with the skills and concepts is to enlarge and enrich the scope of the student’s experiences regarding content knowledge in school. In addition to development of experiences, the laboratory should provide students with an opportunity to reproduce life situations in an effort to simulate the science profession. According to Dewey, the lab should provide a means for students to

gather and use information and ideas, which are not segregated, and to enrich the course of life through progressive experiences.¹⁰

Instructional methods in the science laboratory changed after World War I. No longer was the climate one for advancing students' ability to solve problems through experiences, but rather to confirm and illustrate concepts in the textbook, and obvious means of tell and show.⁹ In many aspects, the chemistry laboratory can still be seen as this type of instruction in high enrollment courses, where labs are often disjointed from lecture. In the 1960s, lab instruction shifted to become a central aspect of science education. It became an area where instruction stressed the processes of science and how these processes can be utilized to solve real world problems. Instruction also revolved around the development of higher order cognitive skills rather than memory recall of concepts and facts.⁹ By the 1980s, the curriculum reforms of the 1960s were almost abandoned and replaced with approaches favorable to teachers.

Not only should historical methods of laboratory instruction be examined, but also the roles and objectives of both the teachers and the students in the classroom. According to research by Hilosky, the teacher should be the team leader.¹¹ In relation to historical lab practices, the teacher should guide the students through the learning process. In addition to being a team leader, the instructor should amplify the cognitive abilities of the students by providing knowledgeable and meaningful instructional methods.¹²

In addition to teacher roles in the laboratory, students have expectations also. Students should be active members in the classroom by becoming involved in higher order cognitive skills and abilities such as planning and designing experiments. In 1982, nearly fifteen years prior to Hilosky's work, Hofstein and Lunetta reported that students

should gain abilities such as communication, observation, and investigative skills, to name a few.⁹ Hilosky also stated that students should be active and responsible members of the team.¹¹ Furthermore, one study suggested that students should already possess some knowledge prior to gaining experiences in the laboratory. This knowledge may be extracted from prior experience, lecture material, or pre-laboratory reading and questions.

Science education research conducted across the globe has indicated similar findings. In 1970, a study conducted by George Charen found that high school laboratories lacked experiments, which aided in critical thinking abilities.¹³ Also, there was a lackadaisical approach to teaching effective problem solving skills.

An Australian study in the 1990s found several criticisms of laboratory objectives. There was a significant over-emphasis of content learning rather than understanding the learned content. With this over-emphasis, the instructional style was recipe style, which is in a sense robotic; where the students are not encouraged to question why they are performing tasks. With this recipe style and over emphasis of content, there were considerable educational setbacks in the development of critical thinking, problem solving and investigative skills. Garrett and Garrett later proposed that the objectives be revised to include concept learning and understanding through manipulative skills and investigation skills.¹⁴

Other research findings were in agreement with the high school and Australian university studies.^{9, 12, 15, 16} The laboratory should provide a comfortable climate to drive concept learning and understanding from the classroom. Laboratory has an elemental ingredient for the enrichment of experiences that foster inquiry, problem solving and manipulative skills while further enhancing the knowledge of students.

As described by Domin in 1999, there are four styles of laboratory instruction.¹⁷ There have been various studies regarding the effectiveness of each style. Prior to this discussion, it is necessary to briefly define the styles.

The basic style often used in the science laboratory is expository. This method is well suited for large classes due to the low cost and minimal instructor guidance. Often, the experiments are cookbook or recipe style, which provides the students with detailed procedural information for the experiment. Basically, students spend time in the lab determining if the correct result was obtained, rather than using higher cognition abilities such as planning or investigating.

The expository approach has been well investigated at the university level.^{17, 18, 19, 20} Berg, Garrett and Garrett have provided outlines of the major goals for science education at the university level.^{14, 19} Throughout the educational process, the students should develop and use problem solving skills, independent thinking, critical thinking, and creative thinking. Garrett and Garrett proposed two research questions regarding how laboratory courses could aid in the achievement of the goals. By using questioning and interviewing during laboratory activities, students exhibited poor outcomes and attitudes in expository experiments, which indicates the need to use other instructional styles.¹⁴ However, Berg did find that some students actually need more explaining and attention in the laboratory, and therefore, the expository method may be more suitable for efficient learning.¹⁹

An inquiry experiment, which is the second type of method, has received substantial research interest. The teacher provides less direction for the students, therefore the students are active in the learning process. With this increase in student

involvement, there may be an improvement in attitude and interest in the subject matter. Even though this method would directly benefit the students, it has not been widely adopted by instructors for a few reasons. Even though the students use higher cognitive skills throughout the lab assignment, there is little opportunity for them to practice and further develop the skills outside of the laboratory. Instructors have also stated that with the time spent on teaching students how to plan or analyze results, there is little emphasis placed on the actual content from the activity.¹⁷

Inquiry as a means to promote and support the curiosities of students involves the use of prior knowledge in the content area as a method for promoting scientific thinking. Gagne in 1993 defined scientific thinking as problem solving in which a problem is shown, a search conducted, and the proposed solution evaluated.²¹ Inquiry laboratory experiments promote sound scientific thinking and support the use of higher cognition. Germann and Aram found that the processes of recording and analyzing data, drawing conclusions, and providing evidence were self-taught in expert students. On the other hand, novice students used the scaffolding to support the demands of the inquiry skills utilized.⁶

Discovery and problem-based lab styles are utilized less in the sciences. It may be noted however that these techniques may be used more readily in upper division courses rather than in entry-level courses. Both of these methods provide students with hands on opportunities with the issues that may arise in the work place. Both styles are time-consuming for instructors and the students. In the problem-based approach, the instructor poses a question and provides the materials necessary to answer the question.

Problem solving activities have the potential to develop initiative, creativity and communication skills for students.³

The use of discovery activities may stimulate learning in the classroom. The content of activities can vary, and provide valuable connections to real-world applications. Research indicates that environments which emphasize cooperative learning and discussions via discovery have been more successful.²² Through surveys, students have indicated that they enjoy working in environments that promote discovery and communication. In a freshman level experiment teaching spectrophotometry, students in the computer simulation group performed better on instructor designed post measures than students in the control group and discovery group. Furthermore, there was a significant difference between the control group and both experimental groups, indicating that introductions of various teaching tools could enhance students learning and understanding.²³

Problem solving skills have been taught by example, through rigorous homework problems, tests, and lab experiments. Students may apply a set of limited and rigid rules to aid in solving the problem. Students may begin to use a pattern of data or unit fitting to solve problems. In addition, students may have the inability to extend the problem solving approaches to other areas. Through instructional methods that promote problem solving, difficulties such as lack of concept understanding and failure to use additional resources can be overcome.²⁴

In 1991, Bounce presented research investigating the use of problem categorization in an effort to improve student achievement in chemistry problem solving.²⁵ Problem categorization is the process of assigning a description to the problem

according to the major concept. The study found that students assigned to the treatment group, explicit method of problem solving, who were asked to categorize problems, had higher average scores on the assessment than the control group.²⁵ However, there was no statistical difference between the groups, indicating that similar content was learned, but perhaps the process skills were not assessed.

Browne and Blackburn investigated the development of problem solving skills in organic chemistry. Through course exit surveys, the group found that students were unhappy with the lack of correlation between lecture and laboratory, and the use of collaborative groups to solve problems was stimulating for the students.²⁶

Studies in a West African secondary school system explored poor performance and quantitative problem solving in chemistry.²⁷ The content taught was the gas laws and mole concept in the gas phase. Group 1 students were introduced to a chart and list of objectives, the students practiced by solving the chart, and were given feedback. Group 2 students were introduced to the chart, and given the assignments but were not encouraged to use the chart to solve the problems. Group 3 students were introduced to the learning for mastery of heuristics and taught content through lectures and demonstrations. The control group was introduced to problem solving and taught the content. In this study, Asieba and Egbugara reported a statistically significant difference among the four groups with respect to each treatment. Through post hoc analysis, problem-solving skills were more developed in group one denoting that content mastery is essential for good problem solving skills.

An interesting problem solving method was developed by Mettes *et al* for a physical chemistry course.^{28, 29} The Program of Actions and Methods is a four-phase

module that engages students in active problem solving with concepts, laws, and formulae. Each phase guides the student through analysis, linking data with known relationships, planning, organizing a solution, and evaluating the solution. The study found that the students in the experimental group, who received instruction in the module, showed improvements in mean scores for the course and the quality of problem solving.²⁹ In addition, the study found that there was a statistically significant difference between the students receiving instruction in the module rather than the control group.²⁹

An additional strategy developed for problem-solving specifically for the chemistry laboratory is the 5E method.³⁰ The module incorporates inquiry at early stages in the education of the student. Through the module, students remain focused on the concepts and using those concepts to solve problems. The five levels are engage, explore, explain, elaborate, and evaluate. In engagement, the students use pre-laboratory questions, background and safety information to complete questions and discussions. In level 2, exploration, there are a series of laboratory discussions regarding the procedures. In level 3, explanation, there are smaller group discussions regarding organization, planning, or concepts. In level 4, elaboration, there is further exploration of the problem. In the final phase, evaluation, the students write and present their results. The researchers used checklists to evaluate the progress of students in lab through the 5E model. The researchers found students were still only partially engaged in the tasks of the laboratory experiments.

In addition to research conducted to explore the four styles of laboratory instruction, but there has also been research regarding the examination of different strategies to use in the classroom to enhance preparation and understanding of chemistry.

In one particular study with 400 students, preparation for class was explored. The study found that students in the quiz group did statistically better than students in the scheduled presentation group, unscheduled presentation group, and the control group.³¹ It was determined that students managed their time based on what had the most impact on their final grade. The use of marathon problems, series of problems designed to lead to complete solution to original problem, in chemistry lectures have also shown increases in student participation, interaction, and preparation.^{32, 33}

As well as investigating the impact of student preparation, attention has also been given to the use of visual aids, such as video presentations and computer simulations. In 1975, Pantaleo discovered that students enrolled in laboratories which viewed instructional tapes for instrumentation operation had an average quiz score higher than students who did not view video recordings.³⁴ The general purpose of the video recording was to decrease laboratory instruction time, and give the students the ability to view the recordings multiple times prior to laboratory. One week prior to the laboratory, the experimental group reviewed a videotape demonstrating the procedures used in the experiment. The control group received instruction during the laboratory instruction period. Examinations conducted by Burchfeild found that there was no significant difference between mean gain scores on assessments of content for students who used computer assisted instruction and those students who did not use the computer assisted instruction.³⁵ To the contrary, the graphing and data interpretation skills of the students in the experimental group significantly improved.

In addition, there has been an extensive exploration of the use of concept maps and diagrams to teach content in the chemistry lecture and laboratory.^{7, 36, 37, 38} Nakhleh

suggested that the use of diagrams and concept maps in the classroom increased meaningful learning and students' confidence.⁷ Concept mapping can also be a good tool for the assessment of conceptual understanding.³⁷ Research conducted with a second semester general chemistry course found that there was no statistically significant preferred method of instruction, between cooperative learning, class discussion, concept mapping, and lecture, rather combinations of methods helped with the learning abilities of all students.³⁸

It has been widely discussed that combination of instructional methods such as the Program of Actions and Methods and the 5E Module may enhance the conceptual development and understanding of chemistry students. Combinations of learning approaches may also aid in raising the quality of students' questions in the classroom thereby increasing their overall understanding of concepts.³⁹ Likewise, it has been noted that students may use a variety of approaches to learning based upon their perception of the task.⁴⁰ In George Gilbert's article, "How Do I get the Answer?", he recommends a series of instructional changes that may provide guidelines for instructors.²⁴ His recommendations support the use of teaching models in the sciences. The suggestions range from use of various resources other than the textbook, use of models and diagrams, and the development of problem stating skills.

It should be noted that another model, commonly used in primary and secondary education, is the Dimensions of Learning model developed by Robert Marzano. Student thinking, according to Marzano, does not happen in discrete identifiable categories.⁴¹ On the contrary, student thinking can be visualized as an interrelated dynamic consisting of dimensions.

Research involving the investigation of the perceptions and attitudes of students has recently been well documented.^{1, 5, 16, 42, 43, 44} Students should learn how to work together, to be active in their learning, and to be able to reach their own conclusions.⁵ By providing an environment which promotes cooperative and independent learning, a student may develop these skills. By developing lessons that support good perceptions, attitudes and task clarity, Marzano's method could foster a laboratory experience that develops scientific learning. Science projects using current research issues or environmental issues has been documented to increase student motivation and learning in the classroom.^{16, 42, 43} These methods use realistic problems to engage students in creating a community of trust, safety, and cooperation that supports positive attitudes and perceptions.

A study by Wong and Barry investigated this strong correlation between perceptions of classroom environment and student outcomes such as inquiry. The group found a positive relationship between participation in the laboratory and attitude toward science.⁴⁴

In Marzano's model, knowledge is constructed, organized, shaped, and internalized by the learner. Chemistry courses can contribute to science literacy and critical thinking. To have significant conceptual changes in chemistry, students must be stimulated to go beyond memorization of mere facts and definitions. Research conducted with under-prepared science students utilized strategies to help with constructing meaning, storage, and internalizing declarative knowledge. The research also examined strategies from dimension 3, error analysis, classification, and comparison. While the research indicated that there was no significant difference between the control and

experimental groups, it should be noted that scores on post test with the experimental group did show improvement as compared to the control group.⁴⁵ This clearly indicates that although there was no difference in instructional methods, students gained content knowledge when taught the strategy. The study had limitations from small sample size and limited experimentation time.

Ultimately, by combining instructional techniques in the dimension of learning model, students may gain positive attitudes and perceptions about chemistry, while also gaining, integrating, and using knowledge meaningfully in a way that leads to strong habits of the mind.

CHAPTER 3

3. METHODOLOGY

3.1 Background

The Dimension of Learning (DOL) instructional strategy is a practical model which can be used in the chemistry laboratory to improve the quality of teaching and learning. Not only does the model address content knowledge, but it also can be used to improve the attitudes and perceptions of students toward chemistry. By encouraging an environment conducive to learning, the strategy could improve the content knowledge and skills of students in the laboratory. The evaluation instrument which may measure the effectiveness of the DOL model is the Epistemological Beliefs Assessment for Physical Science Students.

The Epistemological Beliefs Assessment for Physical Science Students (EBAPS) instrument is based upon five areas - knowledge structure, nature of learning, real-life applicability, evolving knowledge, and source of ability to learn. The category, nature of learning, addresses dimension one, attitudes and perceptions about learning. For example, question twelve of the instrument states that “when learning science, people can understand the material better if they relate it to their own ideas”. The question probes students to find value in tasks and a way to do this is to relate it to everyday situations.

Dimension two of the DOL model, acquiring and integrating knowledge, is related to the EBAPS category, structure of knowledge. The instrument examines how students may understand the sciences. For example, question two from the instrument states “when it comes to understanding physics or chemistry, remembering facts isn’t

very important". This question is used to glean information regarding how students develop and understand procedural and declarative knowledge regarding concepts and principles.

Category three, real-life applicability, asks questions that relate to the extension and refinement of knowledge, which is dimension of three in the intervention model. To illustrate the similarity, question three describes how computers can predict behavior of physical objects as well as humans. This illustrates the process of induction.

Category four of the EBAPS instrument portrays dimension four. For example, question six states "when it comes to controversial topics such as which foods cause cancer, there's no way for scientists to evaluate which scientific studies are the best." This requires the student to evaluate the statement and make decisions based upon the knowledge that they have gained in the course. The students must understand the investigation and experimentation are mechanisms for evaluating studies.

Dimension five, the habits of the mind, is related to the source of the ability of the students to learn, which is category five of the instrument tool. For instance, question five states that studying in a different way can make a big difference for a student who is having trouble in class. This directly engages the student in self-regulated thinking.

3.2 Design

The Epistemological Beliefs Assessment for Physical Science Students (EBAPS) instrument was administered to the two groups of students enrolled in the general chemistry laboratory. This was utilized to determine if the experimental and control groups were different prior to the intervention. This will also serve as a pre-test prior to the intervention. The control group received normal laboratory instruction, whereas the

experimental group received instruction using the dimensions of learning model. Normal laboratory instruction consisted of a description of the concepts and procedures used in the activity. Each section completed three laboratory activities, which were “Examination of pH of Various Food and Environmental Samples”, “Determination of Partition Coefficients of Organic Pollutants using CaChe Molecular Modeling”, and “Air Pollution-The Effects of Ozone”. After the completion of the activities, both groups were given the EBAPS as the post measure. Examining the scores gained between pre- and post- laboratory questions assessed content knowledge.

For activity 1, “The Examination of pH of Various Food and Environmental Samples”, the students in both the control and experimental groups worked in groups of two to three students depending upon the class distribution. The control group received normal procedural instruction, in addition to instruction using standard pH meters for the activity.

On the other hand, the experimental group received a twenty minute lecture on the concept of pH. The subjects in the experimental group were asked questions prior to and during the activity, such as to discuss as a class what they already know about pH. By engaging the students in the warm-up, positive attitudes and task clarity can be developed. In the introductory activities, the students observed demonstrations on how to use a standard pH meter and pH paper to find the pH of oven cleaner. Symbolism, for example acids turn blue litmus paper red and heartburn is associated with high acid levels, was used to help the students. The experimental group was also introduced to the three definitions of acids and bases - Arrhenius, Bronsted Lowry, and Lewis definitions - whereas the control group was not introduced to all of these in the pre-laboratory

instruction. This included a comparison of the definitions, which is a DOL 3 strategy. In addition to symbolism as a DOL 2 strategy, the students were introduced to the steps for investigation, which is a DOL 4 strategy, for the study of environmental water samples. In difference with the control group, the experimental subjects had the opportunity to use the Logger Pro 3.3 computer program equipped with Vernier pH Probes to find the pH of the samples in the activity. The students were guided through the use of the program and probes for this activity. The students were then allowed to continue the activity. It should be noted here that the experimental groups assigned roles within their own group for completion of the lab. There was a student assigned to record pH values, as well as a student to collect the samples. At the close of the session, the class discussed how the sample makeup could interfere with measurements, such as sediment in the natural water samples. The class also discussed the precision of the pH meters as opposed to the litmus paper. It should be noted that dimension 5 is ultimately observed in the post-laboratory questions, which require the students to answer questions such as why some people may find that alkaline materials are useful for cleaning laundry. These types of questions were not introduced in the reading or lecture and therefore require the students to use critical thinking skills and outside resources to complete the questions.

The instruction for activity two, Determination of Partition Coefficients of Organic Pollutants using CaChe Molecular Modeling, was significantly different than the previous activity. In order for the activity to proceed as planned, the subjects received two one-hour lectures covering detection and separation methods, such as radiant detectors and chromatography. After the two lectures, the control and experimental groups received different instructions. The control group was given only instruction on

how to use the modeling program to draw and calculate the partition coefficients for the activity. The subjects were also given minor oral instruction in *ortho*, *para*, and *meta* substituent nomenclature. It should be noted that the students have no prior knowledge of the nomenclature, and, in fact, one student commented after turning in the pre-laboratory questions that “she figured out the structures [of the molecules] by going to other sources”.

The experimental group received a twenty-minute laboratory briefing prior to starting the second activity. Instruction connecting the previous two one-hour lectures was given in the briefing. In order to bring task clarity and relate the material that the students have learned, the topics, mobile and stationary phases, were reintroduced to the students. The subjects were guided through using online tools to find structures and general information about compounds, specific to the lab assignment. After class discussions, the students were directed through the modeling program using a simple molecule, such as methane. As well as learning the basics of the modeling program, the subjects were directed on the use of the program to calculate partition coefficients. Unlike the control group, the experimental group remained in the lab to complete the assignment. Groups discussed independent and dependent variables regarding the graphs of log partition coefficients and log retention time. Throughout the activity, the subjects were exposed to declarative and procedural knowledge. The post-laboratory questions involved skills such as comparing a series of pesticides for structure and partition coefficients. Like activity 1, the-post laboratory questions involved critical thinking, self-regulation, and creative thinking.

Activity 3, “Air Pollution-Ozone, Carbon Dioxide, and UV”, extended over a two-day period due to subject error resulting in minimal crystal formation and weather conditions. The control group received normal instruction, which consisted of how to make the carbon dioxide and ozone detectors. The control group was exposed only to the pre-laboratory readings. The experimental group had a thirty minute briefing consisting of ultraviolet rays and their effects and ground level ozone. Dimensions 1 and 2 of the module were included in the instruction. The students were introduced to the types of UV rays and the damaging effects. In addition, the students were engaged in a discussion regarding ozone in the upper atmosphere as well as ground level. After these discussions, the subjects were guided through the carbon dioxide detector procedure. As a class, the procedure was developed and carried out. With this guidance, the subjects were able to engage in dimension 4, experimentation, when designing a procedure for developing an ozone detector. After implementation of the procedure, the subjects used additional resources to find data such as UV index, weather conditions, and ozone levels for the sample date. After day two of the experiment, the students obtained results for the conversion of benzophenone to benzopinacol by photochemical reduction. For those students who did not receive adequate yields, they were instructed to explain in post-laboratory question 1 why the results were inadequate. Although they may not have gotten adequate results, the subjects were still able to engage in critical thinking. It should be noted that three of the six experimental groups and all five of the control groups received adequate products in amount and appearance.

3.3 Sample

The subjects (N=29, experimental group=16, control group=13) were enrolled in General Chemistry for the post-baccalaureate premedical program at a small liberal arts college in the mid Atlantic region of the United States. The average age of the subjects was 24.7 years of age. Traditionally, students enrolled in the course have not had chemistry at the college level, but may have been exposed in secondary school.

3.4 Evaluation Instrument

As previously examined the EBAPS instrument is based upon five categories, which are related to the dimensions of learning model. The instrument has thirty multiple-choice questions, which include these five areas. Nine questions incorporate the structure of knowledge. Eight of the thirty questions deal with the nature of learning. Three questions have real life applications and two questions deal with evolving knowledge. Eight of the remaining questions examine the sources of a student's ability to learn. The instrument is divided into three sections. Section one contains seventeen questions where the student is asked to read the statement and indicate using a Likert scale how strongly he/she agrees or disagrees with the statement. Part two, questions 18-23, are multiple-choice scenarios presented for the students to read and respond. The final section requires the students to read a scenario where two subjects disagree about an issue, and then the student will indicate which statement he/she agrees.

3.5 Procedure

A quasi-experimental design was used to conduct this research.⁴⁶

O X₁ O

O X₂ O

O = pre-test and post-test measure

X₁ = experimental group treatment

X₂ = control group treatment

The EBAPS assessment was given at the beginning of the summer session, after the researcher obtained proper consent. College-issued identification numbers were used to ensure confidentiality. Answer sheets were also provided to the students. Scores from the pre- and post-laboratory questions for each activity was used to evaluate the content knowledge of the subjects. After the completion of the three laboratory activities, the students in the experimental and control groups were given the EBAPS tool. The Excel template that accompanied the instrument, which was designed by the inventory developers, was used to properly score the responses.

The control group received normal laboratory instruction which consisted of background information to complete the activities. The experimental group received twenty to thirty minute interactive instruction for each laboratory activity. This instruction for the experimental group was designed to include the five dimensions of learning.

CHAPTER 4

4. RESULTS AND DISCUSSION

This study examined laboratories designed in accordance with the Dimension of Learning instructional strategy developed by Marzano and normal laboratory instruction, employed in a post-baccalaureate general chemistry laboratory course. Pre- and post-measures utilizing the EBAPS attitudinal survey as well as scores on pre- and post-laboratory questions were obtained from the control and experimental groups. Independent t test scores were computed for the pre- and post- EBAPS survey in addition to pre- and post-laboratory questions. Laboratory questions prior to and after instruction were analyzed for the control and experimental groups.

This study investigated the use of three laboratory activities in order to enhance the five dimensions of learning in general chemistry laboratory courses. The study hypothesized that there would be a significant difference in the epistemological beliefs and content knowledge of general chemistry students exposed to the activities utilizing dimensions of learning rather than students exposed to normal laboratory instruction.

In order to determine if the students in each group were gaining content knowledge and understanding, the pre- and post-laboratory questions were examined. Independent two-tailed t-tests were performed using GraphPads Quickcalcs (<http://www.graphpad.com/quickcalcs/index.cfm>) for total score on pre- and post-questions. For lab activity one, the control and experimental groups began the activity at the same knowledge level. The t-test indicates no significant difference in pre-laboratory scores for the groups. On the other hand, after instruction, there was a significant

difference between the two groups indicating that dimensions of learning design may enhance content learning and understanding in the laboratory, which can be seen in Table

1. The experimental group had a higher average, 89.75%, compared to the control group's average, 86.46%, on the post activity.

Table 1: Comparison of experimental and control groups for laboratory 1

	Number of Subjects	Pre- Lab Mean	Standard Deviation	t*	Post- Lab Mean	Standard Deviation	t*
Experimental	16	86.13	5.68	0.8983	89.75	3.96	2.3468
Control	13	88.00	5.48		86.46	3.48	
				p<0.3770			p<0.0265

* $\alpha=0.05$

After examining the subjects' pre-lab questions, eight students in the control group and thirteen students in the experimental group were unable to write a generic neutralization reaction. After examining the post-lab questions, all the students in the sample were able to effectively write a neutralization reaction. Notably different in the post-lab questions was the experimental group's organization and supportive statements for answers as compared to the control group.

For lab activity 2, the control and experimental groups began the activity at the same knowledge level. It should be explained that each group received the same two one hour lectures prior to the pre- and post-lab questions, which may have raised questions regarding the validity of the research. The t-test indicates no significant difference in the scores for the groups, which can be observed in Table 2. Unlike the first activity after instruction, there was no significant difference between the control and experimental groups, possibly indicating that the two hour lecture may have played a role in this finding.

Table 2: Comparison of experimental and control groups for laboratory 2

	Number of Subjects	Pre- Lab Mean	Standard Deviation	t*	Post- Lab Mean	Standard Deviation	t*
Experimental	16	79.3	11.4	0.5928	91.63	3.3	1.5907
Control	13	74.9	25.5		87.31	10.3	
				p<0.5582			p<0.1233

* $\alpha=0.05$

Examination of the pre-lab questions for activity two revealed that the subjects did not fully have a grasp on the concept of partition coefficients. It should also be noted that the subjects answered questions adequately but did not define the abbreviations used. This would have required the students to use outside sources other than the textbook and lab manual to properly respond to the questions. Notably different with the post-lab questions, the tables were better organized as compared with Lab 1 for both groups. In the post-laboratory questions, the students were asked to find the log partition coefficient for a compound by using the graph and extrapolating to discover the result or using linear regression to obtain the result. The control group did not effectively complete this task. Ten of the thirteen subjects estimated the value. On the other hand, the experimental group effectively used extrapolation techniques to obtain the result. In addition to these findings, students in the control group were describing partitioning as a method for determining the rate at which a chemical disperses in a system rather than the concentration of the chemical in a system. This was not an issue with the answers given by the experimental group.

Similarly to Lab 1, activity three reveals promising findings. As with the previous activities, the experimental and control groups began the activity at the same knowledge level, as revealed in Table 3. On the contrary, there is a significant difference in total activity scores for the two groups, indicating that the module may be enhancing the learning and understanding of the experimental group as compared to the control.

Table 3: Comparison of experimental and control groups for laboratory 3

	Number of Subjects	Pre- Lab Mean	Standard Deviation	t*	Post- Lab Mean	Standard Deviation	t*
Experimental	16	95.9	5.23	1.6906	98.19	1.83	2.1433
Control	13	80.0	26.4		84.08	26.4	
				p<0.1024			p<0.0413

* $\alpha=0.05$

Pre-laboratory question analysis did not reveal any misconceptions for each group. It should be explained that two subjects in the control group did not complete the pre-lab questions, which would attribute to the low mean on the activity, and one student in the control group did not complete the post-laboratory questions. There were significant differences in the responses for the groups on the post-question activity. The students were instructed to provide a detailed description of the procedure that was used to construct the carbon dioxide detector and the ozone detector. Five of the students in the control group did not indicate volumes or masses of the chemicals used in the ozone detection portion of the activity. On the other hand, the experimental group effectively described and outlined the procedure. The control subjects also did not indicate in the post-laboratory questions the levels of ozone detected using their prepared apparatus. Finally, the control group did not effectively describe the role of nitrogen oxides in ozone formation. The students basically restated the question and neglected the role of volatile organic compounds. In contrast, the experimental group described the role of nitrogen oxides and volatile organic compounds for the formation of ground level ozone.

The EBAPS attitudinal survey was given to the students prior to instruction to determine if the groups were equivalent. According to Table 4, the scores on the survey were not significantly different for the experimental and control group. According to Table 5, comparing the experimental and control groups after instruction, the scores were also not significantly different. Hence, the hypothesis, which states that the experimental group will have changes in attitudes towards science and an increase in content learning when exposed to the DOL strategy rather than students not exposed to the strategy, is rejected.

Table 4: Comparison of experimental and control groups on EBAPS attitudinal survey
prior to instruction

	Number of Subjects	Mean on Pre- Assessment	Standard Deviation	t*
Experimental	16	3.0495	0.2991	1.0062
Control	13	2.9448	0.2508	
				p<0.323

* $\alpha=0.05$

Table 5: Comparison of experimental and control groups on the EBAPS attitudinal survey after instruction

	Number of Subjects	Mean on Post-Assessment	Standard Deviation	t*
Experimental	16	2.9583	0.3834	0.2528
Control	13	2.9897	0.2558	
				p<0.8023

* $\alpha=0.05$

The survey is divided into five axes, which correspond to the five dimensions of learning. Axis 1, structure of knowledge, is similar to dimension 2. Independent t-tests revealed no significant difference in the survey prior to instruction as well as after instruction, which can be seen in Table 6. Pre-axis mean represents the mean of the students' scores prior to the introduction to DOL and the lab activities. Independent t-tests for axis 2, which is related to dimension 1, revealed no significant difference prior to and after instruction, which can be examined in Table 7. Furthermore, t-tests performed for axis 3, which is associated with dimension 3, indicates no significant difference prior to and after instruction. Results can be observed in Table 8.

Table 6: Comparison of experimental and control groups for axis 1

	Pre-Axis Mean	Standard Deviation	t*	Post- Axis Mean	Standard Deviation	t*
Experimental N=16	2.82	0.299	0.1807	2.68	0.547	0.2272
Control N=13	2.79	0.450		2.64	0.401	
			p<0.858			p<0.822

* $\alpha=0.05$

Table 7: Comparison of experimental and control groups for axis 2

	Pre- Axis Mean	Standard Deviation	t*	Post- Axis Mean	Standard Deviation	t*
Experimental N=16	3.25	0.367	0.1171	3.23	0.583	0.7636
Control N=13	3.27	0.294		3.37	0.347	
			p<0.9076			p<0.4517

* $\alpha=0.05$

Table 8: Comparison of experimental and control groups for axis 3

	Pre- Axis Mean	Standard Deviation	t*	Post- Axis Mean	Standard Deviation	t*
Experimental N=16	2.76	0.519	0.1122	2.61	0.681	0.3703
Control N=13	2.79	0.479		2.53	0.427	
			p<0.9115			p<0.7141

* $\alpha=0.05$

T-tests for axis 4, dimension 4 in the module, indicate a significant difference in the pre assessment, and no significant difference after instruction. This is a compelling finding, but had no ultimate change in the overall scores. This difference was not corrected. However, after instruction there was no statistical difference between the groups indicating issues, such as sampling method or behavioral changes, may have altered the observations. Perhaps there were selection or behavioral differences between the pre- and post-measures which may have biased the results. Lastly, axis 5 scores, which is related to dimension five of the module, are not significantly different prior to and after instruction.

Table 9: Comparison of experimental and control groups for axis 4

	Pre- Axis Mean	Standard Deviation	t*	Post- Axis Mean	Standard Deviation	t*
Experimental N=16	3.44	0.526	2.7833	3.35	0.537	0.6629
Control N=13	2.85	0.617		3.48	0.537	
			p<0.0097			p<0.5130

* $\alpha=0.05$

Table 10: Comparison of experimental and control groups for axis 5

	Pre- Axis Mean	Standard Deviation	t*	Post- Axis Mean	Standard Deviation	t*
Experimental N=16	3.21	0.573	0.7508	3.16	0.709	0.2028
Control N=13	3.062	0.493		3.21	0.985	
			p<0.4592			p<0.8408

* $\alpha=0.05$

Within this study, there are external and internal threats to validity.

Fundamentally, the sample was non-random, and therefore may not be a representation of students in general chemistry laboratory courses. Furthermore, the sample consists of students enrolled in a post-baccalaureate pre-medical program. The students in the sample may have already perfected study techniques and may easily adapt to the sciences. Also, the instrument may not be measuring the effect of the dimensions of learning module with the experimental group as compared to normal instruction given to the control group.

Considering the breadth and speed at which material is covered in a summer chemistry course, the research may be threatened by attrition as well as behavioral adjustments in the subjects. For example, one student in particular in the control group consistently failed to complete assignments. Although the pre-test found no significant difference in the two groups studied, the subjects may still bring in characteristics that threaten the validity of the study. For example, students in the experimental group may have better procedural skills than the control group, which may allow them to perform better on critical thinking problems. With the speed of the course, the subjects may be exhausted, and therefore unable to perform as well on assessments. Overall, the confounding threats to the validity of the study are the non-random sampling technique, attrition, and behavioral attributes.

A variety of studies conclude that a combination of instructional strategies promote learning and understanding in the science classroom.^{24, 39, 40, 41} This study found that the beliefs of the students regarding science remain relatively unchanged after exposure to the module. However, the DOL instructional strategy is a varied model, and

the students performed better on post-assessments for the laboratories. On the other hand, this study indicates that learning and understanding concepts may be enhanced when combining techniques. This study parallels the findings of Dujari.⁴⁵ In each study, no significant difference was observed between the experimental and control groups, but improvement in scores was observed within the experimental group. It should be noted that the Dujari study only examined dimensions two and three of Marzano's module.

Results indicate that there is not a significant difference between the two groups in the epistemological beliefs at the culmination of the study. Therefore, the hypothesis is rejected. On the other hand, the results in the pre- and post-laboratory questioning indicate mixed results. After lab 1, there was a significant difference in content knowledge and understanding. Results indicate no significant difference in activity 2 between the groups. However, there was found to be a significant difference after the completion of activity 3.

CHAPTER 5

5. CONCLUSIONS

This study employed the use of novel teaching strategies in the general chemistry laboratory. The research concludes that the implementation of the dimensions of learning (DOL) module developed by Robert Marzano does not increase the overall epistemological beliefs of chemistry students to a statistically significant amount. However, it should be noted that the data indicate the scores on the teacher-developed assessments were higher for the experimental group receiving supplemental instruction in the model than for the control group receiving normal laboratory instruction. Score comparison among the experimental group indicates that some students profited more from utilizing a combination of instructional strategies. Although the administered survey results indicate no significant difference between the experimental and control group, assessments for lab concept 1 and 3 indicate a significant difference. Therefore, substantiating the findings signifying the use of a combination of teaching methodologies in the laboratory may enhance a student's overall concept learning and understanding.

Further studies involving the concept development, learning and understanding of the post-baccalaureate class may include subsequent attitudinal surveys with the combination of the dimensions of learning model technique throughout the academic year in which the students are enrolled in organic chemistry. The material presented in organic chemistry laboratory is significantly different than the general chemistry course, and therefore this could provide a means for demonstrating the academic growth of the students. The students entering the pre-medical program have minimal to no experience

**Part B: Environmental Quality Survey Utilizing TRI Explorer and USGS Water
Data and the Analysis and Characterization of Particulate Matter using Scanning
Electron Microscopy**

in the science laboratory, and they may grow in skill and concept level throughout the academic year.

Further studies may also be conducted to examine possible differences between post-baccalaureate and entry-level college students using the dimensions of learning module. There is an age difference between the groups, as well as academic differences. The post-baccalaureate students have already been exposed to the rigors of college, whereas many entry level students may not have any college courses. Research may include examining the use of the module and its influence on performance in the laboratory between the two groups in an effort to determine if one may profit more than the other. In summary, the findings suggest that the dimension of learning module may enhance learning in the laboratory for some concepts, and hence it may be beneficial to see if the module is applicable to other concepts and courses.

CHAPTER 1

1.1 BACKGROUND

The environment is a finite and consists of valuable resources. Many anthropogenic demands are placed upon the environment, and the capability of the environment to fulfill these are weakening. This phenomenon is particularly true in urban areas where population, industrial, and commercial activities are increasing.

After industrial accidents in India and the United States, environmental organizations and the public expressed demands for information on toxic chemicals that were being released outside of industrial facilities.^{47, 48} With this accelerated interest, the Emergency Planning and Community Right-to-Know Act, herein referred to as EPCRA, was ratified in 1986. The main objective for EPCRA is to inform communities about chemical hazards in their areas. The Toxics Release Inventory, referred to as TRI, is a program whereby the Environmental Protection Agency (EPA) and the states to collect data annually on the releases and transfers of toxic chemicals from industries and to make the data available to the public. In 1990, additional data regarding waste management and reduction activities were required to be reported on the TRI forms. The data are available through the Environmental Protection Agency website via the TRI Explorer program as well as the Scorecard website of Environmental Defense Funds (EDF).

The United States Geological Survey (USGS) was established on March 3, 1879 by President Rutherford B. Hayes.⁴⁹ The survey has collected water resource data since 1896 and is available through the National Water Information System (NWIS) Web database. Both the current and historical data of water quality from over one and half

million sites in the United States including Puerto Rico and Guam are available in the database. The NWIS web is an easy to use database with access to an extremely large volume of data for internal and external users, such as the public. An environmental quality survey utilizing various reputable online resources may provide a valuable tool for the assessment of land, air, and water contamination in urban and surrounding communities.

Along with an increased interest in industrial accountability for toxic chemical releases, there has been within the last fifteen years a surge of research activities concerning the characterization of particulate matter. Single particle analysis consists of the collection of particles on an inert filter followed by analysis via microbeam methods or real-time sampling and analysis with instrumentation in the field.

1.2 LITERATURE REVIEW

1.2.1 Environmental Quality Survey Utilizing TRI Explorer and USGS Water Data

The National Environmental Policy Act of 1969, referred to as NEPA, was designed to establish a policy regarding the care of the environment. The policy was developed to promote harmony between humans and the environment. In this policy efforts were taken to ensure the prevention of damage to the environment and the enrichment of environmental education.⁵² Furthermore, NEPA was developed to establish a policy and to provide for the means for the development of a Council on Environmental Quality. The policy recognizes the impact of humankind's activities on the interrelations of all components of the environment, such as population growth,

industrial growth, and resource exploitation. NEPA further stated that the use of all practical means to improve and coordinate plans, functions, programs, and resources for the well being of all citizens.

The Federal Water Pollution Control Act in 1972 set the foundation for the regulation of pollution discharge into water. In 1977, the Federal Water Pollution Control Act became known as the Clean Water Act. The Clean Water Act, CWA, enables the EPA to set wastewater standards for industries and general water quality standards for all contaminants.⁵² The Safe Drinking Water Act of 1974 was enacted to protect waters which will be used, or may potentially be used, as a supply source for consumption. These 1977 provisions focused on toxic pollutants. Furthermore, in 1987, revisions of CWA authorized citizen suit provisions, funded sewage treatment facilities, and enhanced relations between the EPA and states. Citizen suit provisions allow citizens to bring lawsuits against not only the violators of the acts, like CAA and CWA, but also the EPA. The suit allows also for citizens to initiate an enforcement action in federal court to ensure the protection of the environment. The number of violations may often exceed the federal and state resources available to prosecute; therefore, citizen suit provisions have not been critical in overcoming these shortages of resources. An example of one recent suit, Sierra Club versus Simkins Industries Inc., finds a group suing a Maryland paper mill for violations of CWA. For discharging pollutants into the Patapsco River and hence violating the environmental permit, the company was fined \$977,000 and ordered to fully comply with CWA.⁵⁰ The group was successful in remediating the pollution, and with the monetary penalty the deterrence of other polluters was established.

The leading cause of water quality problems is nonpoint source pollution, which comes from many separate sources. One source may consist of pollutants that are picked up from surface run-offs or percolated through the ground. The pollutants are then deposited in the surface water or introduced to groundwater. Pollutants containing organic matter can originate from sources such as sewage, leaves, and run-off from pastures or livestock areas. Nonpoint source pollution of water has detrimental outcomes on drinking water supplies, recreation, fisheries, and wildlife. Runoff from agricultural fields and urban areas contribute significantly to the pollutants endangering water quality. When there is excessive runoff from an agricultural area to surface waters, there is an enrichment of dissolved nutrients such as phosphates and nitrates that stimulate the growth of aquatic plant life. This phenomenon, eutrophication, often causes an algal bloom and disrupts the ecosystem, resulting in detrimental effects to the surroundings. The consumption of oxygen via the respiration of aquatic plants such as algae leads to a decrease in dissolved oxygen and consequently the death or impairment of aquatic life forms in the water.

The deterioration of water quality is not a new problem. In 1956, Middleton and Rosen studied five Midwestern cities and discovered that alkylbenzenes, insecticides, polycyclic aromatic hydrocarbons, kerosene, and synthetic detergents in drinking water supplies.⁵³ Kraybill later noted that of 2221 organic compounds in water systems worldwide, 765 were present in drinking water.⁵⁴ Most of the chemicals reported are volatile organics, which indeed pose a problem not only in drinking water but also in the atmosphere.

The Federal Insecticide, Fungicide, and Rodenticide Act of 1972, FIFRA, provides the regulatory framework for the distribution, sale, and use of pesticides. Reports on the toxicological and ecological effects of pesticide usage conducted by EPA, academic, or industrial researchers are used to evaluate the safety of a pesticide prior to the approval of pesticide registration. The registration process helps guarantee that the pesticides are properly labeled and will not cause unreasonable harm to the environment. Supercritical fluid chromatography combined with atmospheric pressure ionization mass spectrometry has been used to detect pesticides in soil samples.⁵⁵ The residues of pesticides may be found in the soil, as well as groundwater, drinking water, food and sediment. Pesticides may be applied to crops to control unwanted organisms, but by leaching into the ground the pesticides and their metabolites can create a health hazard.^{55, 56}

In 1980, Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) which allowed a tax to be levied on the chemical and petroleum industries and granted federal authority to respond to releases of hazardous substances that may endanger public health or the environment. In addition, CERCLA has established a trust fund for cleaning up abandoned or uncontrolled hazardous waste sites. Requirements were established for closed or abandoned sites and the liability of persons responsible for the releases at these sites was specified in this act. The trust fund provided money for clean-up when no responsible party could be identified.

An example demonstrating the effectiveness of CERCLA and FIFRA occurred when employees at a wastewater treatment facility in Hardeman County, Tennessee, had

complaints of eye irritation and respiratory distress. After analysis of both the air and water at the plant, data revealed the presence of hexachlorocyclopentadiene and hexachlorobicycloheptadiene.⁵⁷ After complaints from the residents of the county concerning foul odors and unpleasant tasting well-water, EPA discovered a 200-acre land dump once operated by a pesticide manufacturer. The effluent from the pesticide manufacturer also leaked into the wastewater treatment facility. With more than twelve chlorinated organic compounds contaminating the wells, the individuals exposed began to develop symptoms of liver degeneration. After discontinuing the intake of the well-water, the health of the residents gradually improved. Due to poor record keeping, the amount and types of pesticides dumped were unidentified. This is a primary example in which CERCLA and FIFRA addressed the problems of facilities no longer operating.

Even with increased policy development in the United States and United Nations regarding environmental pollution, there were still significant accidents, which altered policy and raised public interest in pollution control and prevention.⁴⁷ In December 1984, methyl isocyanate was released from a plant in Bhopal, India, killing approximately three thousand people and injuring many more. By 1986, the Emergency Planning and Community Right to Know Act, EPCRA, was passed in the United States to avoid or reduce the likelihood of a large death toll resulting from incidents such as the one in India.⁵⁸

The Toxics Release Inventory, TRI, that was first implemented in 1996 covered 650 toxic substances and 23,000 facilities that were reporting releases of the toxic substances.⁴⁷ TRI requires facilities with more than ten full time employees that process more than 25,000 pounds in aggregate or use more than 10,000 pounds of any of the

chemicals on the TRI list to report releases and waste strategies annually.⁵⁹ There is a fine imposed upon the industries by the Environmental Protection Agency for failure to report.

In 1990, the Pollution Prevention Act was passed to broaden the TRI to include source reductions, recycling and treatment reports.⁴⁷ This became an alternative approach to pollution control. With drawbacks seen in the TRI reports, pollution prevention has become a strategy to help industries and the government focus on the elimination of hazards via changes in production processes.⁶⁰

Overall, TRI has proven positive for businesses, by providing information to managers regarding generation amounts and financial costs.⁴⁷ Corporations have also included environmental goals and achievements based on TRI data in the annual reports to investors, communities, environmental groups, and government agencies.

Groups, such as Office of Management and Budget, have found that TRI data have been utilized in three ways. Individual facilities can be studied, general trends related to pollution can be studied, and pollution prevention drives can be encouraged through the use of TRI information.⁶¹ Dolinoy and Miranda employed TRI data and atmospheric modeling for the Durham, North Carolina, region to determine how non-reporting facilities could alter the data when included with reporting facilities. The study determined that the mapping of pollution transport was enhanced when data from non-reporting facilities are taken into consideration.⁵⁹

With urban activities at their highest, there is a greater effect exerted by the human inhabitants upon the environment. The environmental stressors of air and water pollution directly affect people. In combination with other stressors, there is a probability

of an increase of the occurrence of pulmonary diseases, including lung cancer, emphysema, asthma and colds. Other forms of stress like smoking and malnutrition must also be considered when correlating pollution and health hazards. Although crops and livestock may be some distance away from cities, animal and plant growth may be stunted or suffer from damaging effects due to the pollution of the water and soil.

Due to the large magnitude of activities such as heat generation from industries and particulate matter formation, the temperature and humidity in cities will be higher. Precipitation, cloud coverage and fog are also more common in cities. Hence, pollution affects the ecology of an urban area. Pollution causes damage to metal surfaces, soot damage to exterior and interior surfaces, and discoloration and hardening of rubbers, plastics, and papers.

As discussed above, urban growth, business development, and industrial development accompany economic growth within an area. Along with these advances, there is significant impact on the environment. By using facility-reported data to sites such as TRI, there may be indicators for further investigation to determine if there is a pollution problem within a given area. The purpose of programs such as TRI and USGS water quality surveys is to provide citizens with valuable and accurate information on chemical releases and waste management activities in their communities. Data provided by USGS in the past three decades has also contributed to research and policy development in the agricultural sector. The studies revealed a dimming boundary between urban and rural areas with respect to pollutants.⁶¹ For instance, higher concentrations of insecticides were found in urban areas rather than rural.

1.2.2 Composition and Morphological Analysis of Particulate Matter

Epidemiological studies in the 1980s and 1990s have indicated a correlation between adverse health effects and particulate matter (PM) in ambient air. According to one theory, the effect of toxicity is related to the gathering of solid material in the epithelial lining of the lungs. Cilia on the upper portion of the lining vibrate to remove foreign substances. With particulate matter lodged in the lining, the cilia are unable to appropriately remove the substances, therefore suggesting lung damage by the particulate matter.⁶³ There has also been indication that transition metals present in the PM may participate in reactions causing injury to the lungs. With these potential health effects, there has been a great deal of efforts in developing techniques for characterization of PM.

Particulate matter may be composed of solid or liquid aerosol particles, which are suspended in the air. In general, particulate matter includes dust, soot, dirt, smoke, and droplets of liquid emitted into the atmosphere. Fine particulate matter is present in two size fractions that are significant with regard to human health. $PM_{2.5}$ refers to particles that have an aerodynamic diameter less than 2.5 μm (micrometer), and PM_{10} the particles with an aerodynamic diameter less than 10 μm . The current NAAQS criteria includes an annual and daily average standards of 50 $\mu\text{g}/\text{m}^3$ (microgram/cubic meter) and 150 $\mu\text{g}/\text{m}^3$ for PM_{10} and 15 $\mu\text{g}/\text{m}^3$ and 65 $\mu\text{g}/\text{m}^3$ for $PM_{2.5}$, respectively.⁶⁴ $PM_{2.5}$ are fine particles that originate from combustion sources such as automobiles and power plants. PM_{10} are also known as coarse particles. These coarse particles occur due to mechanical crushing, grinding, or abrasion of surfaces. PM_{10} may be suspended and dispersed by wind and anthropogenic sources. Along with the other criteria air pollutants, particulate matter causes a decrease in visibility, deterioration of plant life and reduced crop yields.

Particulate matter is derived from a variety of sources. Current research concerning the formation, composition, and morphology of airborne particulate is centered on gasoline powered vehicles.⁶⁵ Diesel engines emit significantly greater concentrations of particles on a per mile basis, but miles traveled by gasoline powered vehicles in urban areas exceeds that of diesel vehicles. Combinations of mechanisms contribute to the formation of particulate matter. Nucleation of particles can be influenced by the operating temperature and precursors, which may arise from liquid fuel droplets in the fuel-rich regions of the combustion chamber in the engine and products from incomplete fuel oxidation. Oxidation can be affected by the operating temperature and oxygen availability. The amount of hydrocarbons accessible for adsorption and the amount of surface area for adherence can influence the growth characteristics of PM. The number of particles that coagulate on one particle can further influence the growth of the particulate matter.

Atomic emission mass spectrometry with a glow discharge ionization source has been used to analyze urban particulate matter to provide elemental and chemical composition information.⁶³ The glow discharge mass spectrometer enables continuous monitoring and discrete sampling due to the small size, low power consumption, ease of operation, and multi sampling capabilities. For sample sizes of approximately 50 μg , the detection limits are on the order of tens of nanograms (10^{-9} grams).

Electron optical methods, such as scanning electron microscopy, allow for the determination of morphology, elemental composition, and crystal structure of particles.^{51,64} Problems ranging from the cost of analysis to analytical reproducibility may arise from some techniques used for the characterization of particulate matter. Sample

collection methods should be designed to reduce the variability of results obtained via electron optical methods by reducing or eliminating sample loss. To minimize variability, loss of particles should be eliminated during sample preparation. In addition, the preparation techniques should be standardized. Not only should the above be monitored, but careful data interpretation is also desired to decrease the variability of the results. X-ray fluorescence spectroscopy (XRF) has been used to provide multi-elemental analysis of PM. XRF analysis of medium and heavy elements has been demonstrated from samples obtained from sections of filter paper tape.⁶⁷

There are a variety of commercially available size-selective particle samplers. Each is dependent on flow rate and particle size during collection. The GS cyclone and SKC aluminum cyclone are used to collect respirable particles. The aluminum cyclone construction eliminates electrostatic problems, and the sampling is more efficient due to this as well as the sharp cut-off in the particle size selection for the respirable fraction. Scanning electron microscopy in conjunction with energy dispersive x-ray spectroscopy has been utilized to characterize the morphology, microstructure, and composition of particles resulting from the combustion of coal, residual oil, and diesel fuel.^{68, 69, 70, 71} In this study, Chen and others were able to identify and characterize ultrafine soot aggregates and spherical solid char particles. The study concluded that diesel soot contains more sulfur than combustion-derived coal and residual oil particles. Other research has also provided a means for differentiating between combustion products based upon the oxygen to carbon ratio as determined by energy dispersive x-ray spectroscopy. Stoffyn-Egli and others found that oil and coal black carbon particles have a oxygen to carbon ratio of less than 0.15.⁶⁹ Through scanning electron microscopy

analysis, oil and coal black carbon particles were spherical with the latter having pitted surfaces.⁶⁹

Solid phase micro-extraction, SPME, has been utilized successfully for the collection of hydrocarbons and formaldehyde contaminated air samples.⁷² SPME is used as a diffusive sampler that is reusable and flexible. Active samplers draw air at a constant flow rate through solid sorbents, solvent-containing impingers, or into whole air sampling devices.

Sampling of inorganic gases and vapors may be carried out using a variety of samplers. Samplers used by the Occupational Safety and Health Administration (OSHA) range from sampling bags, reagent-impregnated filter, and solid sorbents. Combination sampling devices such as those used in OSHA method ID-110 and ID-200 are three-piece cassette holders with a filter, back-up pad, and space between the filter and pad.⁷³ In method ID-200, PM is collected on a Teflon filter, and the sulfur dioxide travels through the filter and is subsequently converted to sulfate by a base-impregnated carbon bead.

There is a variety of commercially available size-selective particle samplers. Each is dependent on flow rate and particle size desired during collection. The GS cyclone and SKC aluminum cyclone are used to collect respirable particles below the 4 μm cut-off point. These particles may cause adverse health effects when deposited in the gas exchange regions of the lungs. The aluminum cyclone construction eliminates electrostatic problems, which are associated with non-conductive cyclones. The sampling of the aluminum cyclone is more efficient due to the elimination of these problems and the sharp size selection of the respirable fraction.⁷⁴

The GS respirable dust cyclone has been developed to overcome problems associated with the Dorr-Oliver cyclone. Cyclone samplers allows the collection of size-fractionated particulate matter by simulating the flow process of particles via aspiration and penetration through the respiratory airway.⁷⁵ The orientation of the cyclone was investigated, and found to have a maximum sample collection angles at 0°, 90°, and 180°. The GS cyclone is also equipped with multiple inlets that allow for adjustment of sampling flow rate to optimize velocity and maximize the separation process.⁷⁵

1.2.3 Purpose

The purpose of this study is to utilize the Toxics Release Inventory Explorer and the National Water Information System Web to investigate a possible correlation between the two databases for land, air, and water releases in urban and suburban areas across Tennessee as well as the United States.

A second objective of the research entails the development of particulate matter sampling methods with subsequent analysis via scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDX). One existing method for particulate matter collection is based upon collection on quartz filters. The imaging of the particles is adversely affected due to the build up of charge on surface of the nonconductive filters. Elaborate sample preparation is used to remove the particles from the filter to the SEM stub in order to gain pertinent morphological and elemental information. This research is based on the premise that using mixed cellulose ester fibers and silver membrane filters for collection will provide an adequate method for analysis that will prevent loss of sample and structural changes of the particles.

1.2.4 Definition of Terms

Stationary Sources: Stationary source pollution arises from discharge of power plants, industrial boilers, refineries, and chemical manufacturing facilities. This type of discharge may also be known as point source emissions.

Area Sources: Area sources generate emissions that are either minimum or do not have a well-defined source.

Mobile Sources: Mobile sources of emissions occur from highway vehicles, such as diesel or gas powered automobiles, and off highway vehicles such as agricultural and construction equipment.

Criteria Air Pollutants: Six pollutants, namely carbon monoxide, particulate matter, sulfur dioxide, ozone, nitrogen oxides, and lead are regulated by the Environmental Protection Agency; they are known or suspected to be harmful to public health and the environment.⁷⁶

CHAPTER 2

2.1 METHODOLOGY

2.1.1 Background

In this study, counties surrounding major cities in Tennessee as well as counties with large industrial releases were examined. The cities to be included were Nashville, Memphis, Chattanooga, and Knoxville. The counties with large industrial releases or mobile source emissions to be included were Humphreys, TN, Sullivan, TN, Montgomery, TN, Hamblen, TN, Washington D.C., Harris, TX, Bartow, GA, New York City, and Los Angeles, CA. TRI Explorer provides information regarding the land, air, and water releases as reported to the EPA from 1988 to present. The data are provided in tabular format that may be downloaded as an Excel document. The USGS water quality tool provides information dating as far back as 1963, even though the data may not be available in consecutive years. Contrary to TRI Explorer, USGS provides data for multiple testing sites throughout the county of interest. The data for air, water, and land releases will be obtained using TRI Explorer and compared to the USGS water monitoring data from 1988 to 2002. The top three releases in each category (if available) for both database-searching tools will be determined. The relationships between the two databases will be examined and any correlation between the chemical releases and monitoring data will be investigated. The knowledge obtained from these studies will be presented in tabular format showing the releases from 1988 to 2002 for the top three chemicals released.

Air samples were collected on mixed cellulose ester and silver membrane filters in Sumner County and Rutherford County, Tennessee. In order to determine the

particulate mass collected, the filters were weighed prior to and after sampling. The SEM-EDX technique was used to analyze the two filter types prior to collection and the filters after collection. The mixed cellulose ester filters were coated with gold to prevent space charging effects.

2.1.2 Materials and Methods

2.1.2.1 Environmental Quality Survey Using TRI Explorer and USGS Water Data

Utilizing TRI Explorer (<http://www.epa.gov/triexplorer/>), we determined the top three chemical releases to air, water and land. The USGS water quality surveys (<http://waterdata.usgs.gov/nwis/qw>) were used to find water monitoring data which may show a link to the TRI chemical releases data. The years that the data were obtained were 1988 to 2002. Five counties surrounding each of the four major cities in Tennessee were examined. The counties surrounding Nashville are: Sumner, Rutherford, Williamson, Cheatham, and Davidson. The counties surrounding Memphis investigated in this study are: Shelby, Fayette, Haywood, Madison, and Tipton. The counties surrounding Knoxville studied are: Knox, Sevier, Loudon, Anderson, and Blount. For Chattanooga, the counties studied are: Hamilton, Bradley, Marion, Rhea, and McMinn. Counties with large industrial releases in Tennessee were also examined. These counties are: Humphreys, Sullivan, Montgomery, and Hamblen. Counties for major metropolitan areas including; Washington D.C., county of Harris Texas, county of Bartow Georgia, New York City, and Los Angeles, California, were also investigated due to their large stationary and mobile sources of emissions.

2.1.2.2 Analysis and Characterization of Particulate Matter Using Scanning

Electron Microscopy

A particle size selective GS cyclone sampler from SKC Inc. (Pennsylvania, USA) was used along with 25 mm cassettes and aluminum stand to collect air samples. Air samples were collected on 25 mm mixed cellulose ester filters, 0.8 μm pore size (SKC catalog number 225-1930), and silver membrane filters (SKC catalog number 225-1803). A multi-purpose calibration chamber was used to calibrate the double take air sampling pump.

The pump was calibrated to 2.75 L/min with the desired filter in place. In the field, samples were collected near the breathing zone. Samples were collected using the GS cyclone with the Double Take Air Sampling Pump calibrated to 2.75 L/min. Samples were collected in the breathing zone for 180 minutes for the silver membranes and 300 minutes for the mixed cellulose ester filters. After collection, the cassettes were removed from the cyclone and capped. The filters were weighed prior to and after collection to determine weight of particulate matter collected. The filters were cut into four sections per filter and adhered to aluminum stubs and characterized using a Topcon SEM with EDX detector from Evex Analytical. The voltage was 20 V at a tilt angle of 40°. The mixed cellulose ester filters was coated with gold to minimize space-charging effects. Using the spot mode in EDX analysis, elemental composition of the particles was determined. The electron excitation depth of elements commonly found in airborne particulate matter was modeled using the Monte Carlo simulation of the Lehigh2001 program(<http://web.utk.edu/~srcutk/htm/simulati.htm>).⁸¹

CHAPTER 3

3. RESULTS AND DISCUSSION

3.1 Environmental Quality Survey Utilizing TRI Explorer and USGS Water Data

The information provided from the analysis of the environmental releases as found using TRI Explorer and USGS Water Data is extensive. TRI Explorer, which is a compilation of data reported by industrial facilities to the Environmental Protection Agency, presents air, water, and land releases in pounds per year for the counties of interest in the study. Yearly trends can be observed for organic and inorganic substances with steady decreases observed for the years examined. It should be noted that industrial accidents might cause a drastic increase in releases; hence the data may be skewed. Although industrial accidents may increase the level of releases, the company is still mandated to report the releases in the inventory. Non-production related wastes are releases caused by one time events such as accidents or natural catastrophic events such as Hurricanes Rita and Katrina in the Gulf of Mexico in 2005. USGS water quality data are based upon surface water testing sites within the county of interest. The data are limited due to lack of testing sites in rural areas. Latitude and longitudes are provided for the testing sites. It was determined that minimum correlation exists between the two data sets. The USGS site provides information from testing sites in parts per million, $\mu\text{g/L}$, or mg/L and the TRI sites provides data in pounds released to the environment. Additionally, the TRI data set is a compilation of reported releases by industries, whereas the USGS data set is actual data compiled from water testing sites.

The five counties examined in the metropolitan area of Nashville, Tennessee, were Cheatham, Davidson, Rutherford, Sumner and Williamson counties. In Cheatham

County, the industrial releases in water contained releases of zinc, barium, and manganese compounds, among others. The testing sites in Cheatham County for the years 1989 and 1990 also determined microgram/liter ($\mu\text{g/L}$) levels of these metal compounds. For example, in 1989, 55 $\mu\text{g/L}$ of zinc was detected according to USGS. On the other contrary, no industries reported releases of zinc compounds for 1989 or 1990. But, Montgomery and Davidson Counties, which are adjacent to Cheatham County, reported air and water releases, respectively, for 1989 and 1990. Furthermore, industrial releases for those years consisted of methanol, dichloromethane, and toluene. In Table 11 through 14, the releases of chemicals to air, land, and water for Cheatham County are given from 1988 to 2002. It should be noted that in Cheatham County, land releases were only reported for 1991, 1992 and 1988. Most of the releases in Cheatham County can be attributed to industries in Ashland City, which is in the central portion of the county. These tables will provide the raw data for the discussion of the major chemicals released and the trends of these releases. It is important to keep in mind that only the top three chemical releases are listed, and therefore, the absence of a chemical entry in a given year does not imply that there is no release of the chemical. Instead, the absence may simply mean that the ranking of the chemical release may be lower than the top three or that there may have been a change in the reporting requirement of the TRI data.

Table 11: TRI Explorer data for top three chemical releases to air in Cheatham County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	styrene	216740	1,1-dichloro-1-fluoroethane	68006	n-butyl alcohol	43287
2001	styrene	191800	1,1-dichloro-1-fluoroethane	69947	n-butyl alcohol	45735
2000	styrene	266725	n-butyl alcohol	49437	xylenes	43107
1999	styrene	297434	1,1-dichloro-1-fluoroethane	104418	xylenes	82625
1998	styrene	278200	xylenes	118784	1,1-dichloro-1-fluoroethane	114185
1997	xylenes	155518	1,1-dichloro-1-fluoroethane	146584	styrene	93040
1996	1,1-dichloro-1-fluoroethane	170479	xylenes	146785	toluene	65028
1995	1,1-dichloro-1-fluoroethane	184117	xylenes	145379	toluene	96775
1994	1,1-dichloro-1-fluoroethane	186691	xylenes	144300	toluene	138150
1993	toluene	227750	xylenes	85840	manganese	64000
1992	toluene	227750	xylenes	85840	manganese	64000
1991	toluene	253250	methylene bis(phenylisocyanate)	90000	xylenes	8250
1990	dichloromethane	5750	methanol	5750	acetone	5250
1989	methanol	6704	dichloromethane	5750	acetone	5250
1988	dichloromethane	5750	acetone	5250	methanol	3750

Table 12: TRI Explorer data for top three chemical releases to land in Cheatham County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
1992	xylenes	9100	toluene	3900	zinc compounds	3
1991	xylenes	10000	toluene	6000	n-butyl alcohol	3200
1988	acetone	250	--- ^a	--- ^a	--- ^a	--- ^a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 13: TRI Explorer data for top three chemical releases to water in Cheatham County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	barium compounds	250	manganese compounds	5	---a	---a
2000	zinc compounds	82	barium compounds	33	manganese compounds	20
1999	zinc compounds	587	barium compounds	42	manganese compounds	21
1998	barium compounds	54	sodium nitrite	51	manganese compounds	22
1997	manganese compounds	77	sodium nitrite	71	barium compounds	64
1996	manganese compounds	104	nickel compounds	84	barium compounds	71
1995	sodium nitrite	60	nickel	5	---a	---a
1994	nickel	5	---a	---a	---a	---a
1991	zinc compounds	28000	---a	---a	---a	---a
1990	methanol	750	dichloromethane	750	toluene	750
1989	methanol	750	dichloromethane	750	toluene	750
1988	dichloromethane	750	methanol	750	toluene	750

^a Blank cells indicate data not available because less than three chemicals were released

Table 14: USGS water data for top three chemicals detected in Cheatham County, Tennessee

Latitude/Longitude	Year	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 09'05"/ 87° 07'02"	1989	zinc	55 µg/L	barium	24 µg/L	copper	2 µg/L
36° 09'05"/87° 07'02"	1990	barium	29 µg/L	zinc	3 µg/L	manganese	3 µg/L
36° 13'22"/87° 10'32"	1989	nitrite and nitrate	7.20 mg/L	manganese	<10 µg/L	---	---

^a Blank cells indicate data not available because less than three chemicals were reported

The data provided by the USGS water quality survey yields information for both organic and inorganic compounds. Sampling frequency varies depending upon the site for sampling. As outlined in the tables, many sites have had multiple samples analyzed. For example, in Los Angeles, California, data were obtained from the test site at 35 49'02'' and 118 12'20'' from 1988 to 1991. The USGS water quality survey provides information from more than three million analyses of samples. Physical data, in the form of temperature and pH, can be retrieved along with the analytical data of organic and inorganic chemicals from the database.

Releases of 1,1-dichloro-1-fluoroethane were reported for Cheatham County, Tennessee, from 1994 to 2002 with a decreasing trend. In 1994, 186,691 pounds of the halogenated compound were released into the air in Cheatham County. Recent data from 2002 suggests that the emission of this compound has decreased to levels below 70,000 pounds. The fluorinated compound is used as a foam-blowing agent and a cleaning solvent. The gaseous compound can be degraded photochemically by hydroxyl radicals and has an atmospheric half life of 7.5 years as given in Table 15.⁷⁶ The compound is soluble in water, and therefore removal from the atmosphere by rain is a crucial environmental process. The compound may also adsorb onto soils and sediment when released in water. Due to its potential for stratospheric ozone depletion, 1,1-dichloro-1-fluoroethane has been scheduled to be phased out of production processes by 2020 according to the Montreal Protocol. In 1987, the Montreal Protocol was enacted to reduce emissions from the use and production of ozone-depleting chemicals. There have been successive revisions to the protocol from 1990 to 1999 in order to phase out hydrochlorofluorocarbons.

Table 15: Half lives and degradation pathways of chemicals in the study⁷⁷

Chemical	Half Life	Degradation Process	Chemical	Half Life	Degradation Process
1,1-dichloro-1-fluoroethane	7.5 years	hydroxyl radicals	t-butyl alcohol	14 days, 29 days	hydroxyl radicals, volatilization
chloroprene	18 hours to 10 days	hydroxyl radicals	n-butyl alcohol	46 hours, 29 days	hydroxyl radicals, volatilization
1-chloro-1,1-difluoroethane	12.7 years	hydroxyl radicals	methanol	17.8 days	hydroxyl radicals
chlorodifluoromethane	9.4 years	hydroxyl radicals	styrene	7, 16 hours	hydroxyl radicals, ozone
1,1,2-trichloro-1,2,2,-trifluoroethane	Not available	photolysis UV-C	acrylonitrile	4, 83 days	hydroxyl radicals, ozone
1,1,1-trichloroethane	6 months-25 years	hydroxyl radicals	naphthalene	18, 60 hours	hydroxyl radicals, nitrates
trichloroethylene	7 hours	hydroxyl radicals	pentachlorophenol	29 days	hydroxyl radicals
chloroform	151 days	hydroxyl radicals	hydrazine	6, 9 hours	hydroxyl radicals, ozone
tetrachloroethylene	96 days	hydroxyl radicals	formaldehyde	41 hours	hydroxyl radicals
biphenyl	2 days	hydroxyl radicals	phenol	14.6 hours, 12 minutes	hydroxyl radicals, nitrates
carbonyl sulfide	200-7300 days	hydroxyl radicals	acetaldehyde	24 hours	hydroxyl radicals
carbon disulfide	5.5 days	hydroxyl radicals	1,2-propylene oxide	30 days	hydroxyl radicals

Table 15: Half lives and degradation pathways of chemicals in the study⁷⁷

Chemical	Half Life	Degradation Process	Chemical	Half Life	Degradation Process
cumene hydroperoxide	45 hours	hydroxyl radicals	methyl tertiary butyl ether	5, 50 days	hydroxyl radicals, nitrates
methyl methacrylate	7.4 hours	hydroxyl radicals	cyclohexane	45 hours	hydroxyl radicals
di-N-octyl phthlate	19 hours	hydroxyl radicals	benzene	13 days	hydroxyl radicals
dicyclopentadiene	48 min, 3.1 hours	hydroxyl radicals, ozone	toluene	3 days	hydroxyl radicals
ethylene glycol	2 days	hydroxyl radicals	phthalic anhydride	1.5 minutes, 32 days	hydrolysis, photolysis
1,2,4-trimethylbenzene	12 hours, 6-30 days	hydroxyl radicals, nitrates	maleic anhydride	few hours	ozone
N-hexane	3 days	hydroxyl radicals	pyrrolidine	5 hours	hydroxyl radicals
xylenes	1-2 days	hydroxyl radicals	ethylene	6.5, 1.9, 190 days	ozone, hydroxyl radicals, nitrates
methyl ethyl ketone	14 days	hydroxyl radicals	propylene	24 hours, 4 days, 14.6 hours	ozone, nitrate, hydroxyl radicals
1,4-dioxane	35 hours	hydroxyl radicals	1,3-butadiene	6, 37, 14 hours	hydroxyl radicals, ozone, nitrates
2-methoxyethanol	31 hours	hydroxyl radicals	acetone	71 days	hydroxyl radicals
2,4-dinitrophenol	32.1 days, 4.6 days	photodegradation	dichloromethane	119 days	hydroxyl radicals

1,1-Dichloro-1-fluoroethane is also known as HCFC-141b. According to the Montreal Protocol, the production of this chemical should have been reduced to 2.8% of the 1989 reported level by January 1st, 1996.⁷⁸ The Pollution Prevention Act of 1990 also called for source reduction of other HCFCs as well as CFCs. State Industries, Inc., which manufactures household appliances in Cheatham County, reported releases of this chemical from 1994 to 2001. This compound was added to the TRI substance list in 1994, according to the TRI Explorer site, which would explain the appearance of the HCFC-141b entry in the TRI data of releases for Cheatham County starting from 1994. The provisions set forth in the Montreal Protocol may have accounted for the decrease of the HCFC-141b release in recent years. However, the exact mode contributing to the decrease, whether through a lesser use of this chemical in the industry or through a better recovery method that allows the recycle of the chemical, is not clear.

Chloroprene, also known as 2-chloro-1,3-butadiene, is used in the production elastomers such as neoprene. In the atmosphere, chloroprene will be degraded via photochemical reactions with hydroxyl radicals and ozone molecules. In urban areas in the evening, chloroprene may be removed via reactions with nitrates. This may be an important process in areas throughout Montgomery County, Tennessee, such as Clarksville. Montgomery County indeed has high levels of nitrates which may aid in the removal of chloroprene. Chloroprene is expected to be highly

mobile in soil, and easily volatilized in water. From 1991 to 1995, land releases in Montgomery County by Vulcan Corporation increased from 2011 pounds to 5104 pounds. This may be of concern due to its mobility in soil. In 1996, five pounds of chloroprene was released into water.

Chloroprene is classified as a probable carcinogen affecting the lungs, liver and kidneys. Although this part of the dissertation is not intended to be an exhaustive study of the relationships between TRI releases and epidemiological diseases of the human population, it is worth noting that the incidence of lung and liver cancers in Tennessee are above the average incidence in the United States for the years 1999 to 2001. In 2001, lung cancer rates per 100,000 in Tennessee were 68.9 as compared to the corresponding value of 55.2 for the United States.⁷⁹ For liver cancer in 2001, rates in Tennessee were 4.9 and in the United States 4.7.⁷⁹ A caveat for interpreting this kind of statistical data is that environmental causes of diseases are often confounded with factors such as income level, nutrition, ethnicity, and especially smoking habit in the study of lung cancers as well as that cancers may not appear until decades after exposure.

1-Chloro-1,1-difluoroethane may be released into the environment from its use as a blowing agent and refrigerant. Through reactions with hydroxyl radicals in the atmosphere, 1-chloro-1,1-difluoroethane is degraded. In Los Angeles County, 391,031 pounds of 1-chloro-1,1-difluorethane was released into the atmosphere in 2000. Dow Chemical Company and Honeywell International reported such air

releases in Los Angeles. This is significant because the compound can undergo photolysis in the atmosphere to yield chlorine atoms that can participate in removal of ozone in the stratosphere. Even via releases to soil and water, 1-chloro-1,1-difluoroethane will undergo volatilization readily due to its low vapor pressure.

Similarly, chlorodifluoromethane, or Freon 22, is used in aerosols, blowing agents, and refrigeration systems. The compound decomposes slowly in the atmosphere, and therefore plays a crucial role in the generation of chlorine atoms which contribute to the destruction of the stratospheric ozone layer. Counties such as Tipton and Montgomery in Tennessee and Suffolk County, New York, have air releases of chlorodifluoromethane. Delfield Company in Tipton County and Trane Company in Montgomery County were the companies responsible for Freon 22 emissions. In Tipton County, there has been a minimal increase in emissions. In 1997, 544 pounds of the compound was released as compared to 606 and 750 pounds in 1999 and 2001, respectively. Delfield Company manufactures refrigerators and freezers. In Montgomery County, there have been significantly more releases from 1994 to 2001, which can be seen in Figure 1 from the Trane Company. In 1994, 150,000 pounds was released compared to 113,808 pounds in 2001. Trane Company, located in Clarksville, Tennessee, produces air conditioning and heating units for residential and commercial use. In Suffolk County, New York, TRW Steering Wheel Systems was responsible for emissions of 71,821 pounds in 1994.

Freon 22, also known as HCFC-142B, is a class II compound such compounds have an ozone depletion value less than 0.02 in the phase out program of the protocol.

Prior to 1994 in Montgomery County, there was no reported releases of chlorodofluoromethane, which may indicate that the substance was not used in the facilities for production. After 1994, evidence appears as to its use indicating a possible change in production practices or TRI reporting requirements.

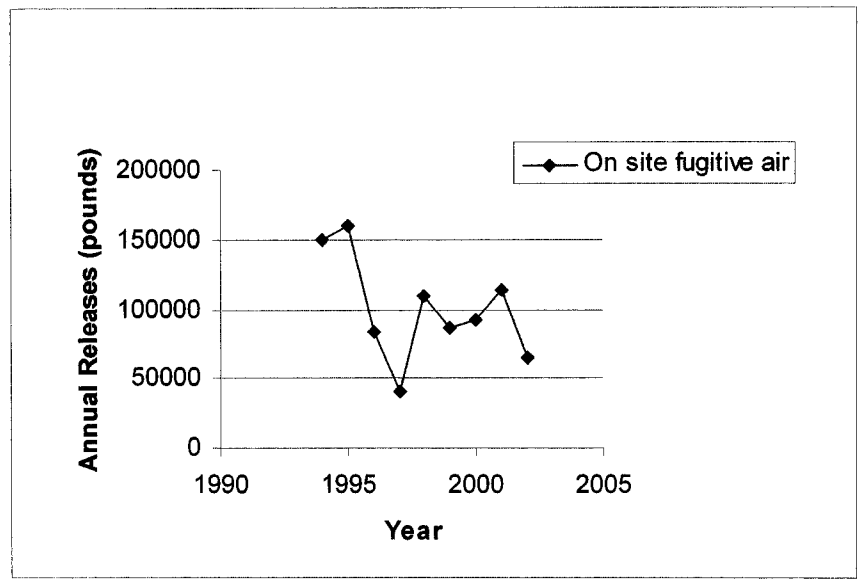


Figure 1: Chlorodifluoromethane releases from Trane Company, Montgomery County, TN

1,1,2-Trichloro-1,2,2-trifluoroethane, also known as Freon 113, was produced and used as a solvent. According to the Montreal Protocol, Freon 113 and other class I CFCs are due to be completely phased out by 2010. On the other hand, HCFCs are due to be phased out by 2030. Freon 113 does not react with hydroxyl radicals, ozone or nitrate radicals in the troposphere, suggesting that it will diffuse into the upper atmosphere or stratosphere.⁷⁷ In the stratosphere, it will yield chlorine atoms that contribute to the removal of the stratospheric ozone layer. Air releases of Freon 113 in Anderson County, Tennessee from 1988 to 1991 show a decrease from 299,220 to 54,023 pounds. The releases in 1991 were from Advanced Measurement Incorporated, Boeing, and Oxford Instruments in Oak Ridge, Tennessee. The data for air releases of Freon 113 in Los Angeles County, California and Suffolk County, New York also show a decreasing trend for this halogenated compound. For Suffolk County, air releases of Freon 113 have decreased from 371,128 pounds to 87,305 pounds in the time span of 1988 and 1993. Air releases of 2.5 million pounds in Los Angeles County were reported in 1989. Years following, there was a decreasing trend in emissions of Freon 113 in Los Angeles County. In 1990, there was 1.7 million pounds released as compared to 31,590 pounds ten years later. In 1990, there were 56 companies responsible for air releases of Freon 113 in Los Angeles County. In 2000, Boeing Company and Honeywell International reported releases of Freon 113. These data clearly indicate the effectiveness of the Montreal Protocol and the proactive role of EPA in slowing down the ozone depletion.

Several counties in Tennessee, such as Davidson and Knox, have reported releases of 1,1,1-trichloroethane or methyl chloroform. This chemical is used in degreasing and metal cleaning processes. If this substance is released into surface water, it will likely evaporate. Land releases will have minimal effect on soil due to its volatilization. On the other hand, releases of 1,1,1-trichloroethane to air will be followed by deposition via rain and degradation in the troposphere. Legislation regarding the phase-out of methyl chloroform since the Montreal Protocol in 1987 has stated that by 1996 the production level should be zero. In 1994, the production level was to not exceed fifty percent of the production level of the substance for 1989.⁷⁸

Industries in Knox County, Tennessee have reported air releases of 1,1,1-trichloroethane. From 1988 to 1991, releases in Knox County were between 124,314 pounds and 130,643 pounds. Air releases in Rhea County, Tennessee have decreased from 1988 to 1992. In 1988, air releases were reported to be 315,000 pounds and in 1992, 136,000 pounds. Minimal releases were reported by industries in Haywood County, Tennessee in the mid-1990s. Facilities in Blount County, Tennessee reported air releases in 1991 of 96,791 pounds. In Anderson County, Tennessee, land and air releases were reported for 1,1,1-trichloroethane at the annual levels of 450 pounds and 265,961 pounds, respectively, in 1988. In 1989, there was a significant decrease in air emissions to 98,060 pounds in Anderson County. In Davidson County, land and air releases were reported by facilities, such as Werthan Packaging and Peterbilt.

In 1989, 1.8 million pounds of the substance was released into the air. The amount released since then has decreased to 259,617 pounds in 1995. In 1990 and 1991, 255 pounds and 360 pounds were deposited by facilities on land. It should be noted that releases of 1,1,1-trichlorethane were not reported after 1995 by any companies in Davidson County due to the phase-out of the compound according to the Montreal Protocol.

Los Angeles County, California reported releases of tetrachloroethylene and 1,2-propylene oxide. Tetrachloroethylene, which was reported to have an annual air release of 905,319 in 1995, is commonly used as a dry cleaning agent. With an estimated half life of 96 days, the chemical will be slowly decomposed by hydroxyl radicals in photochemical reactions. The chemical will also undergo photolysis in natural waters when photosensitizers are present. 1,2-Propylene oxide is a chemical intermediate in polymer synthesis.

Tetrachloroethylene is a possible carcinogen with links to leukemia, esophageal and cervical cancer, and non-Hodgkin's lymphoma. Surprisingly, the rates of leukemia and non-Hodgkin's lymphoma are lower in California than the United States, suggesting exposure instances unrelated to tetrachloroethylene.⁷⁹

Chloroform, CHCl_3 , released in McMinn and Loudon Counties in Tennessee, is used in production of the HCFC-22 hydrochlorofluorocarbon. For the production of HCFC-22, chlorine is first reacted with methane in order to produce chloroform, which is subsequently converted to a chlorodifluoromethane or HCFC-22 upon

treatment with hydrogen fluoride in the presence of a metal catalyst.⁸¹ Chloroform undergoes volatilization in moist soils and surface waters. Chloroform may also be detected in chlorinated drinking water supplies.

Biphenyl was reported to have an annual land release of 13,392 pounds in Hamblen County, Tennessee in 1996. It is produced and used in organic synthesis, as a dyeing agent, and in the control of plant diseases. Although it will exist in the atmosphere as a vapor, it is also found in the particle phase in the atmosphere. Biphenyl may be removed by dry deposition, and according to reported K_{OC} values of 870 to 3300, it will have low mobility in soil. Hence, biphenyl released to land will not be likely to leach into groundwater or surface waters.

Carbonyl sulfide, COS, which is a natural and anthropogenic compound, may have high mobility in soil, and may rapidly volatilize. It is also anticipated to rapidly volatilize when released into water. Carbonyl sulfide is primarily used in the synthesis of thio compounds. It may be released through the manufacturing processes for synthetic fibers. Clean Air Act amendments in 1990 designated hazard air pollutants to be sharply reduced. Blount and Humphreys County, Tennessee, had air releases of carbonyl sulfide. Atmospheric removal of COS is a slow process via its reactions with hydroxyl radicals or oxygen, photolysis, or processes involved with the sulfur cycle in the atmosphere. Therefore, the release of carbonyl sulfide into the atmosphere may be of environmental concern.

Humphreys County has had significant air releases of carbonyl sulfide from 1988 to 2002. In 1988, releases were 8.5 million pounds and in 1992, 4.65 million

pounds. From 1998 to 2002, the releases have increases from 1.4 million to 2.2 million pounds. In Blount County, releases are significantly lower than in Humphreys County. Although the amount released to the atmosphere is different, there is an increase between 1994 and 2001. In 1994, air releases were reported to be 437,000 pounds, whereas in 2001, the reported value was 709,900 pounds. According to the TRI reports, DuPont located in Johnsonville, Humphreys County, which can be seen in Figure 2, Tennessee is responsible for the emissions of carbonyl sulfide. It should be noted that the company has reduced emissions in accordance with the Clean Air Act amendments of 1990. TRI reports for Humphreys County in Tennessee are provided in the Tables 16 to 18.

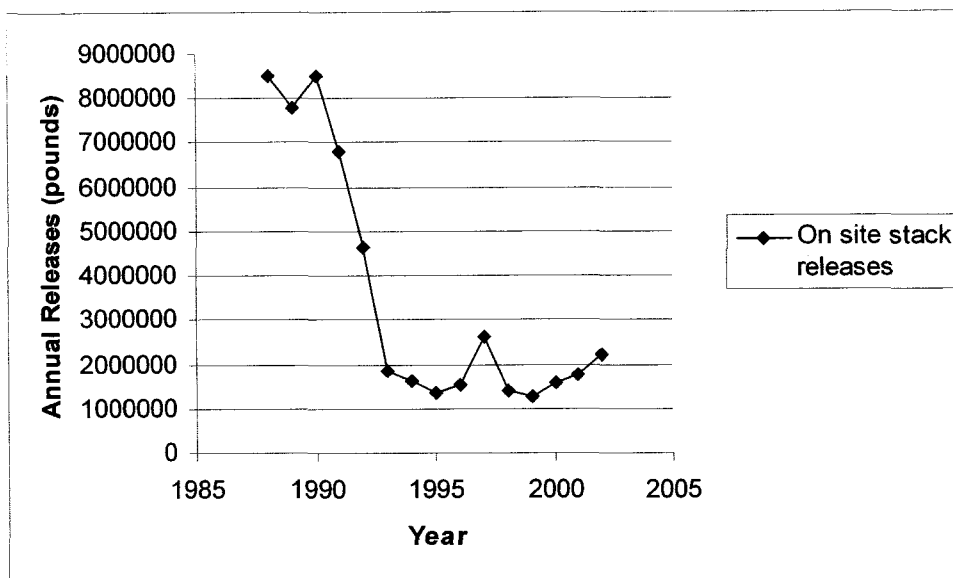


Figure 2: Carbonyl sulfide releases for DuPont in Humphreys County, TN

Table 16: TRI air releases for Humphreys County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	hydrochloric acid	15060376	manganese compounds	10885472	carbonyl sulfide	2196000
2001	hydrochloric acid	8461405	carbonyl sulfide	1771000	styrene	877947
2000	hydrochloric acid	14068505	carbonyl sulfide	1555000	sulfuric acid	980747
1999	hydrochloric acid	13070705	styrene	1872492	carbonyl sulfide	1240000
1998	hydrochloric acid	3971405	carbonyl sulfide	1410000	styrene	1537700
1997	carbonyl sulfide	2630000	methanol	830250	styrene	891686
1996	carbonyl sulfide	1510000	methanol	840250	styrene	594170
1995	carbonyl sulfide	1340400	methanol	810250	hydrochloric acid	342000
1994	carbonyl sulfide	1638900	methanol	840250	hydrochloric acid	380950
1993	carbonyl sulfide	1867000	hydrochloric acid	346700	manganese compounds	190000
1992	carbonyl sulfide	4650000	hydrochloric acid	340300	manganese compounds	178069
1991	carbonyl sulfide	6800000	cyclohexane	206220	hydrochloric acid	357500
1990	carbonyl sulfide	8500000	hydrochloric acid	390000	ammonia	370000
1989	carbonyl sulfide	7800000	hydrochloric acid	380500	ammonia	366488
1988	carbonyl sulfide	8500000	hydrochloric acid	413000	benzene	140484

Table 17: TRI land releases for Humphreys County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	27800	barium compounds	9155	manganese compounds	3000
2001	manganese compounds	10359277	vanadium compounds	2972000	chromium compounds	1287000
2000	manganese compounds	10051615	vanadium compounds	3061000	chromium compounds	1089700
1999	manganese compounds	12685837	chromium compounds	889500	barium compounds	510500
1998	manganese compounds	7269750	chromium compounds	632600	barium compounds	390500
1997	manganese compounds	3360000	ammonia	1800	diethanol amine	125
1996	manganese compounds	3629320	zinc compounds	99000	ammonia	37950
1995	manganese compounds	4360000	barium compounds	116000	cobalt compounds	56000
1994	manganese compounds	4600000	barium compounds	118000	cobalt compounds	58000
1993	manganese compounds	5300000	barium compounds	130000	cobalt compounds	33000
1992	manganese compounds	2735762	barium compounds	90274	cobalt compounds	39778
1991	manganese compounds	1683026	barium compounds	389451	cobalt compounds	33441
1990	manganese compounds	1481112	barium compounds	582335	ammonium sulfate	1800

Table 17: TRI land releases for Humphreys County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
1989	manganese compounds	2310854	barium compounds	450224	ammonium sulfate	46504
1988	manganese compounds	3694589	barium compounds	379610	ammonium sulfate	28063

Table 18: TRI water releases for Humphreys County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	ammonia	430000	vanadium compounds	15000	nitrate compounds	12500
2000	ammonia	440000	nitrate compounds	48000	vanadium compounds	23000
1999	ammonia	480000	nitrate compounds	134000	barium compounds	8700
1998	ammonia	350000	nitrate compounds	145000	manganese compounds	97050
1997	ammonia	380000	nitrate compounds	72000	nickel compounds	1300
1996	ammonia	260000	nitrate compounds	57000	manganese compounds	1673
1995	ammonia	290000	nitrate compounds	17000	manganese compounds	945
1994	ammonia	236253	diethanol amine	875	manganese compounds	791
1993	ammonium sulfate	1500000	ammonia	30000	manganese compounds	891
1992	ammonium sulfate	1600000	ammonia	38000	manganese compounds	348
1991	ammonium sulfate	1900000	ammonia	32000	manganese compounds	468
1990	ammonium sulfate	1400000	chlorine	40400	ammonia	27000
1989	ammonium sulfate	1652033	chlorine	40500	ammonia	39771
1988	ammonium sulfate	2088632	ammonia	42734	chlorine	320

Carbon disulfide, with reported industrial discharges in Loudon and Hamblen counties in Tennessee, is used as a solvent and chemical intermediate. In the atmosphere, carbon disulfide will undergo reactions with hydroxyl radicals. It is expected to be moderately mobile in soil, and have low bioconcentration in aquatic life. In 1988, carbon disulfide releases to air in Hamblen County were greater than 15.3 million pounds with no clear trends in subsequent years that range from 16.8 million pounds in 1997 to 23.7 million pounds in 1989 for data up through 2002, as seen in Figure 3. Liberty Fibers, which was previously owned by BASF, reported releases of carbon disulfide via fugitive and stack air. The same is evident for Loudon County. In 1988, air releases exceeded 2 million pounds with similar releases for 1989 to 2002.

Companies such as BASF have taken the initiative for developing methods for processing fibers via an ionic liquid process that eliminates waste.⁸² Previous methods for commercial viscose process combines 1 part pulp, 2 parts carbon disulfide, and 5 parts water to produce one part cellulose fiber, 7 parts waste and wastewater. Only 70% of the carbon disulfide is recycled. BASF has proposed a procedure that will decrease the use of noxious solvents, such as carbon disulfide, and waste. In Figure 4, a schematic detailing the use of ionic liquids in the production of cellulose fiber is presented. It should be noted that no solvents, such as carbon disulfide, are needed to yield the equivalent amount of fiber in the ionic liquid method. The ionic liquid is also recycled at a rate greater than 99%. Evidently, companies are striving to find pollution prevention methods for production without decreasing the yield of product.

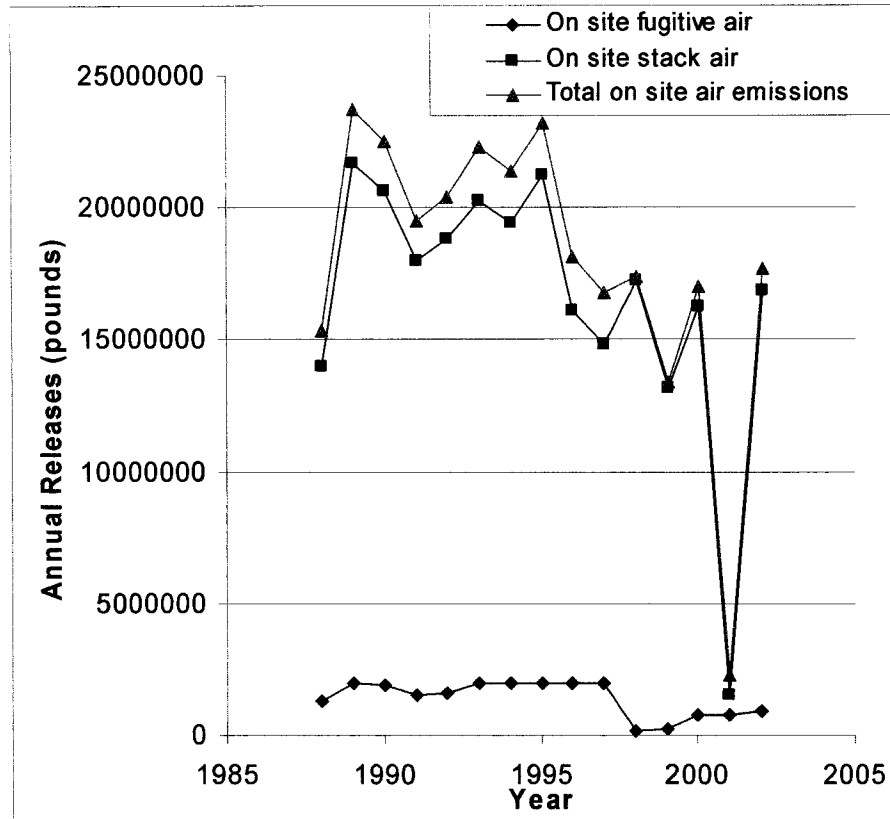


Figure 3: Carbon disulfide releases in Hamblen County, TN

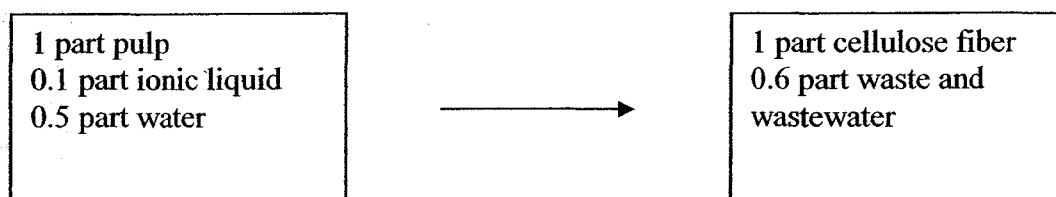


Figure 4: Ionic liquid process to produce cellulose fibers as proposed by BASF ⁸²

In the study of the data sets from 1993 to 2002, Fayette County in Tennessee had air releases of cumene hydroperoxide. It is evident that releases of cumene hydroperoxide declined from 17,500 pounds in 1993 to 5080 pounds in 2002. The compound may be produced naturally from cumene in low levels, but is used extensively in the production of acetone, phenol, and α -methylstyrene. Alkylperoxy radicals and oxygen in natural waters may react with cumene to form cumene hydroperoxide, which then undergoes decomposition rapidly.⁸³ Cumene hydroperoxide reacts in the atmosphere with hydroxyl radicals rapidly and is eventually reduced to an alcohol.

Methyl methacrylate, released to air in counties such as Shelby and Knox in Tennessee, has been used in resins, medical adhesives, dental technology, and cement technology. In 2000, emissions of 53,816 pounds were reported by boat manufacturing companies in Knox County. The total releases of methyl methacrylate to air amount to 45,099 pounds and 70,408 pounds, respectively, in 2001 and 2002. In Fayette County, Tennessee, 1139 pounds were reported as air releases in 2002. In 1989, Shelby County has reported that 398,801 pounds of methyl methacrylate were released to the air and 20,000 pounds released to water. In the atmosphere, methyl methacrylate vapor will be degraded by reactions with hydroxyl radicals. In soil, it is highly mobile, and can readily adsorb to sediment in the water column.

Di-N-octyl phthalate may exist in the vapor and particulate phase in the atmosphere. Deposition allows the removal of the particulates from the atmosphere whereas photochemical reactions with hydroxyl radicals are responsible for the degradation of the vapor phase substance. A minimal release of 250 pounds in 1989 and

1990 of the chemical into water has occurred in Knox County, Tennessee. If released into water, the compound will adsorb to sediment and soil. In addition to these findings, it is not appreciably volatile and therefore will persist at the water-soil interface.

Dicyclopentadiene, released in air in Fayette County, Tennessee, is obtained from petrochemical feedstocks, and is a source of cyclopentadiene. It undergoes rapid degradation by reacting with ozone or hydroxyl radicals. If present in water, dicyclopentadiene undergoes volatilization. Minimal releases of less than 1000 pounds occurred in Fayette County.

Ethylene glycol, which is a common pollutant across the United States, can be directly introduced into the environment. It is often used as a deicer for airport runways, as a coolant and antifreeze, and in brake fluid formulations. Counties such as Davidson and McMinn in Tennessee have released ethylene glycol into water. In 1994, industries in McMinn County reported 6,336 pounds released in water. On the other hand, industries such as DuPont and Peterbilt in the Davidson County reported water releases of 23,000 and 22,000 pounds in 1988 and 1989. DuPont produces plastics, resins, organic fibers, and organic chemicals. Peterbilt produces motor vehicle and truck bodies. In 1996 and 1997, the releases reported from Peterbilt were 750 and 3,850 pounds, respectively. From 1999 to 2002, releases of ethylene glycol have risen in Davidson County from 12,376 to 109,285 pounds. Between 1999 and 2002, two additional companies along with Peterbilt and DuPont began contributing to the releases of ethylene glycol. Quebecor, a commercial printer, and Cone Solvents were mainly responsible for the increase in releases. Sevier County, Tennessee, and Harris County, Texas, have

ethylene glycol releases via the air. Sevier County industries reported releases to air of ethylene glycol in 1992 with a total of 16,798 pounds. Air releases in Harris County by industries in 1994 was greater than 2.5 million pounds. Celanese Ltd., which produces organic chemicals in Harris County, was responsible for most of the releases. Hamblen County, Tennessee, has releases via land of ethylene glycol. There has been extensive reporting of land releases in Hamblen County from 1988 to 2001. In 1988, industries reported 130,000 pounds released compared to 1991 with only 31,000 pounds reported. In subsequent years, industries in this county have reported releases greater than 100,000 pounds. This may suggest errors in the reporting systems or production issues within the industry. Table 19 shows the rank of counties in this study with ethylene glycol releases. Like other organic compounds released to air, ethylene glycol will be degraded via reactions with hydroxyl radicals. Ethylene glycol demonstrates high soil mobility due to its high solubility in water. Based on bioconcentration studies, ethylene glycol does not readily accumulate in aquatic life.

Table 19: Counties ranked by pounds emitted of ethylene glycol by air, water, or land from 1988 to 2002

Rank	County	Mode of Release
1	Harris	Air
2	Hamblen	Land
3	Davidson	Water
4	Sevier	Air
5	McMinn	Water

1,2,4-Trimethylbenzene is used as an intermediate in the production of anhydrides, dyes, and pharmaceuticals. It can be degraded in the atmosphere by reactions with hydroxyl radicals and nitrates. In Tipton County, Tennessee, air releases of 1,2,4-trimethylbenzene were reported by industries from 2000 to 2002. Releases during these years have decreased from 978 to 379 pounds.

n-Hexane has been discharged by industries predominantly in east and west Tennessee. Hexane is used as a solvent or a raw material in chemical production and in the making of glues and varnishes. Not only is hexane found in these uses, but it is also a constituent in natural gas and crude oil. Additionally, it is highly mobile in soil, and can easily undergo volatilization in moist soils. With a high bioconcentration factor, it has the likelihood of accumulating in aquatic life. Human exposure is common in urban areas with high automobile traffic and gas stations. Fayette County, Tennessee, had minimal land releases of 10 pounds, whereas counties such as Shelby, Rhea, Loudon, and Anderson had high air releases. Industries in Rhea County reported 15,300 pounds of hexane released in 2000. In Loudon County, the air release increased from 469,924 pounds in 1996 to 812,336 pounds in 1997. In 1998, releases were similar to 1996. This may indicate increase in production or use by industries, or perhaps even an industrial accident. Industries within Anderson County reported air releases of 93,932 and 98,805 pounds in 1996 and 1997, respectively. Shelby County industries reported approximately 1 million pounds released in 1996 and 1997. It should be noted that Shelby County is also an urban locale.

Xylenes are used as a solvent and as intermediates in petrochemical refineries. Xylenes can also be found naturally in petroleum and forest fires. Although these sources are likely to introduce xylenes into the environment, they can also be readily introduced through fuel exhausts. With an estimated half life of one to two days, xylene can be degraded by reactions with hydroxyl radicals in the atmosphere.⁷⁷ Xylenes exhibit moderate mobility in soil as well as moderate adsorption to soil and sediment in water. Biodegradation in soil and groundwater is an important remediation process.

Nineteen of the counties studied had levels of xylenes released into land, water, and air. This implies that releases of this organic compound are widespread throughout the United States, even in the more rural areas examined in this study. The data set from TRI Explorer indicates only releases from industries, and not from mobile source emissions such as privately owned automobiles. Land releases of xylenes were reported in Davidson, Harris, Shelby, Los Angeles, Blount and Hamilton counties. Isomers of xylene were released by industries in Davidson County in 2000 and 1988. Emissions were 2,360 and 900 pounds. Industries reported releases, 51,114 pounds of xylenes, in 2000 in Harris County, Texas. From 1993 to 1995, industries within Shelby County have reported increases in releases of xylenes from 5,148 to 11,160 pounds. Los Angeles based industries reported releases of m-xylene in 1994, and mixture of isomers in 1990. 59,020 pounds were released in 1990. Releases of m-xylene were also reported in Blount County from 1992 to 1995. From 1992 to 1994, releases were minimal at 1,700 pounds, but in 1995 releases of 12,500 pounds were reported. 9,300 pounds of xylenes were released in 1999 in Hamilton County.

Releases to air in Bartow County, Georgia, have varied in magnitude from 1988 to 1997, which can be seen in Figure 5. In 1988, 24,674 pounds of xylenes were released compared to 70,435 pounds in 1989. In 1990, emissions of xylenes decreased, but again rose in 1997. Air releases in Haywood County, Tennessee, have decreased for the reporting years from 1988 to 1997. In 1988, values indicate 209,079 pounds released and in 1997 the pounds emitted was 15,295 pounds. Air releases in Madison County, Tennessee, have ranged from 42,371 to 23,729 pounds for the years in this study. Likewise, industries in Sumner County, Tennessee, have reported releases to air for xylenes. From 1988 to 1997, industries have reported total emissions of ranging from 248,321 to 92,691 pounds, as seen in Figure 6. Companies responsible for releases in Sumner County are G.F Office Furniture and R & R Donnelly and Sons. For Cheatham County, Tennessee, reported releases from 1991 to 1998 have increased from 85,840 to 146,785 pounds. There has been a decrease in these releases for subsequent years in Cheatham County. In addition to these counties, industries in Montgomery, Rhea, Anderson, and Sevier counties in Tennessee have reported fluctuating releases of xylenes.

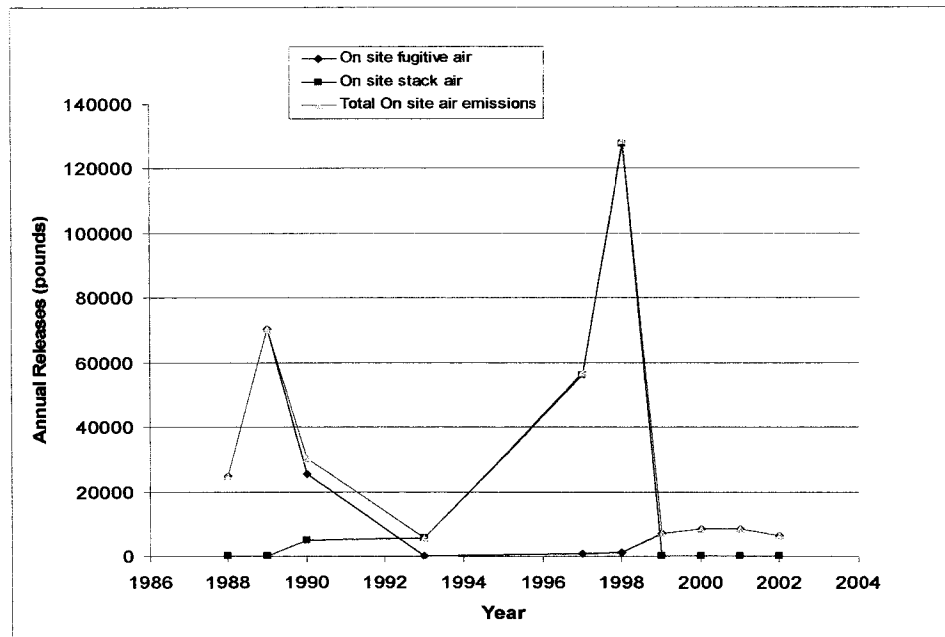


Figure 5: Xylene releases in Bartow County, GA

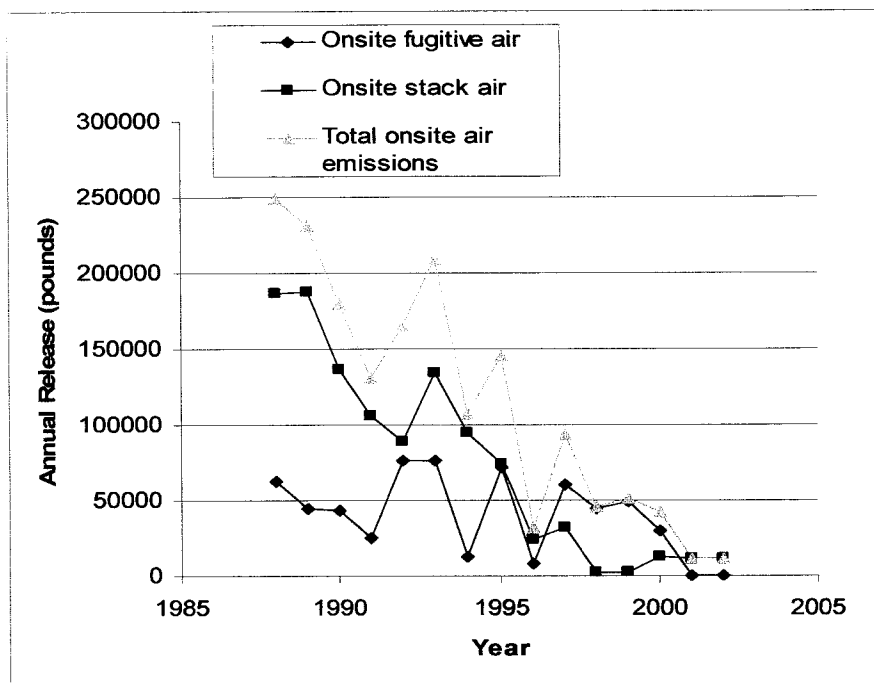


Figure 6: Xylene releases for Sumner County, TN

Industries in Rutherford County, Tennessee, have reported air and land releases of xylenes. Land releases from 1993 to 1994 were 2,569 and 2,261 pounds. Air releases were more significant. For example, in from 1990 to 1992 the levels of emissions rose to 1.2 million pounds. For the remaining years in the study, the levels of xylenes releases have decreased to below 500,000 pounds. These trends can be seen in Figure 7. Suffolk County, New York, industries have reported releases in 1997 and 1996 in air. Between these two years, there was an increase of 50,000 pounds of the chemical released. Although releases in air have increased slightly, there was a decrease in water releases from 250 to 126 pounds in 1989 and 1999.

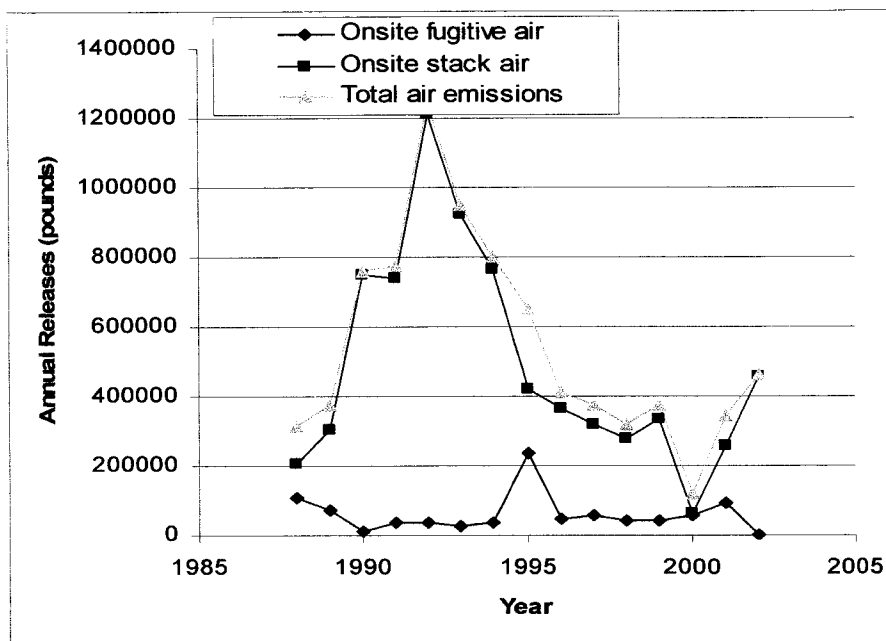


Figure 7: Xylene releases for Rutherford County, TN

Fayette County, Tennessee, industries have reported releases of xylenes to air, land, and water. In 2000, 15 pounds of xylenes was emitted into land and water. In 1990 and 1991, releases were 66,000 and 77,000 pounds correspondingly. Table 20 shows the counties in this studied ranked by pounds of xylenes emitted.

Table 20: Counties ranked by pounds xylenes discharges to land and air from 1988 to 2002

Rank	Air Releases	Land Releases
1	Los Angeles	Rutherford
2	Harris	Fayette
3	Shelby	Sumner
4	Blount	Haywood
5	Hamilton	Bartow
6	Davidson	Suffolk
7	Rutherford	Cheatham
8		Montgomery
9		Anderson
10		Madison
11		Rhea
12		Sevier

Like xylenes, methyl ethyl ketone is widely released by industries. It is used as a solvent for coatings, resins, and plastics, to name a few. As well as xylenes, it occurs as a natural byproduct of metabolic pathways in plants and animals, and may be released by volcanic eruptions and forest fires. Through degradation via hydroxyl radicals, methyl ethyl ketone can be removed from the atmosphere. Sunlight will also cause photolysis of methyl ethyl ketone. Primary release of methyl ethyl ketone occurs via air.

Industries located in Suffolk County, New York, have reported air releases of methyl ethyl ketone from 1994 to 1997. During those years, industrial releases have risen from 69,353 pounds to 131,398 pounds. Releases from 1998 to 2002 have decreased to approximately 1000 pounds. Like Suffolk County, Anderson County in Tennessee has had industrial releases from 1988 to 1994. During this time period, releases to air have declined from 281,303 pounds to 35,888 pounds. Rutherford County, Tennessee, data set also reveals industrial air releases in 2002 of 384,669 pounds of methyl ethyl ketone. Air releases of 17,886 pounds of the chemical in 1994 were reported by facilities in Rhea County, Tennessee. Methyl ethyl ketone has also been the number one chemical among all air releases in Sevier County, Tennessee, from 1988 to 1994. There is a sharp decrease of approximately 40,000 pounds between 1988 and 1989. Facilities in Madison County, Tennessee, have reported air and land releases of methyl ethyl ketone. In 1993, land releases were 4,000 pounds and air releases in 2000 and 2001 were 27,150 and 25,671 pounds, respectively.

1,4-Dioxane has been reported released in Davidson and Sullivan County, Tennessee, seen in Figure No. 8 and 9. This chemical has been utilized as a solvent and

stabilizer for chlorinated solvents. It will degrade in the atmosphere, with a half-life of the reaction estimated to be 35 hours.⁷⁷ Similarly, 1,4-dioxane is highly mobile in soil. Although it is highly mobile, 1,4-dioxane is slow to biodegrade in the environment.

1,4-dioxane has been released into water sources in Davidson and Sullivan Counties. In Sullivan County, there was a decrease in emissions between 1992 and 1995 with a substantial increase in 1996 of 95,000 pounds. This was followed by a decreasing trend in water releases for subsequent years. Eastman Chemical Company was the major source of air and water releases in Sullivan County. Davidson County industries have reported dioxane releases of 3,400 pounds in 1992 and 7,377 pounds in 1998. DuPont and Werthan Packaging in Davidson County reported releases of not only 1,4-dioxane, but also high levels of 1,1,1-trichloroethane releases.

1,4-Dioxane has been shown to cause liver and gall bladder cancers in rats, and therefore is a possible human carcinogen. Similarly, rates of liver cancer in Tennessee are higher than that of the United States but are comparable to rates in Georgia and New York.

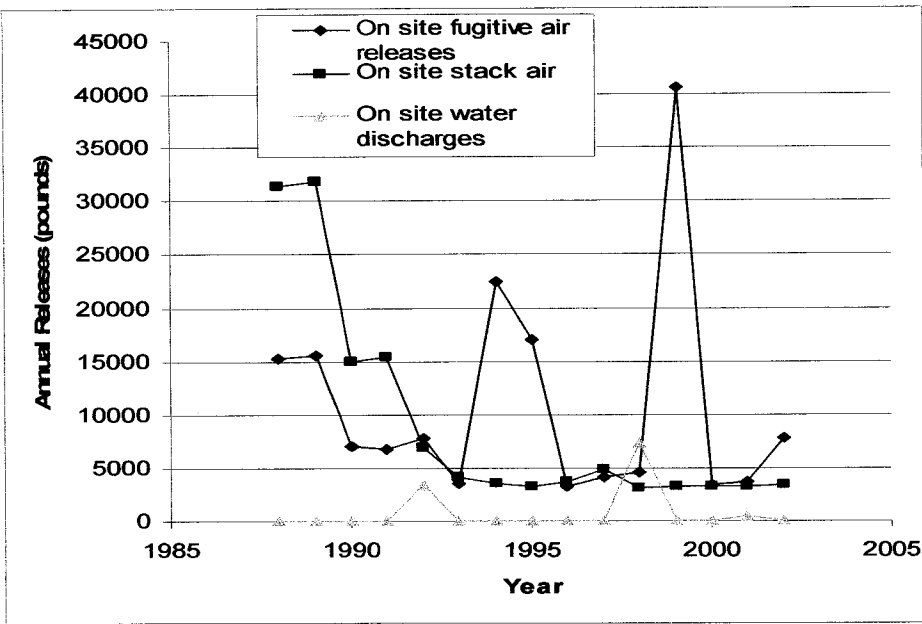


Figure 8: 1,4-Dioxane releases in Davidson County, TN

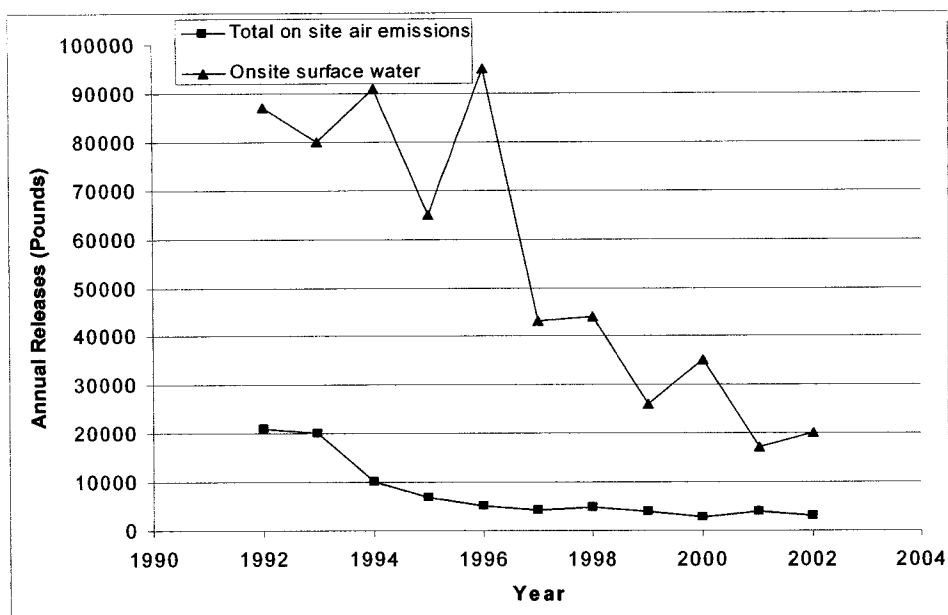


Figure 9: 1,4-Dioxane releases in Sullivan County, TN

122,720 pounds to a high 866,625 pounds. Trichloroethylene has been used in the degreasing procedures, printing industries, and manufacturing process of textiles and papers. In the atmosphere, trichloroethylene will undergo degradation reactions that have an estimated half life of seven hours. With a reported K_{OC} value of 101, trichloroethylene is expected to be highly mobile when released to soil. The chemical is also not expected to adsorb to soil or sediment when released into water sources. It should be noted that trichloroethylene has been extensively detected in water supplies. Trichloroethylene is also a probable human carcinogen, causing liver and kidney tumors in animal studies.

For the release of t-butyl alcohol, there were not any releases in Tennessee, but there were water discharges in Suffolk County, New York, and Harris County, Texas. In 1996, 488,379 pounds of t-butyl alcohol were released in Harris County. In Suffolk County, there has been a gradual decrease from 5,414 pounds to 1,388 pounds from 1998 to 2000. The alcohol has been widely used as a denaturant for ethanol and as an octane booster in gasoline. According to studies, t-butyl alcohol is a degradation product of methyl tertiary-butyl ether. Considering that the two counties that had releases of t-butyl alcohol are also major metropolitan areas, it is likely that the release is even higher in these areas. The alcohol will readily volatilize from soil and water, and may undergo reactions in the atmosphere with hydroxyl radicals.

n-Butyl alcohol was reported released in Williamson, Sumner, Cheatham, Haywood, Anderson, and Sullivan counties in Tennessee. In Anderson County, 31,384 pounds of the alcohol was released into the air in 1995. n-Butyl Alcohol was the second leading air release in Haywood County between 1993 and 1996. During these years, the

levels of emissions declined from 12,067 to 9,991 pounds. In 2002 and 2001 in Cheatham County, releases of n-butyl alcohol were 45,735 and 43,287 pounds. Air discharges in Sumner County in 1996 and 1994 were 34,038 and 46,723 pounds. Contrary to these counties, Sullivan County industries reported water releases. In 1996, there was 26,000 pounds of n-butyl alcohol discharged. It is used as a solvent in the resin industry, as well as paint removers and cleaners. When released to water, n-butyl alcohol is not expected to adsorb to soil or sediment. In fact, mobility of the alcohol in soil is rapid. In the atmosphere, n-butyl alcohol will decompose through reactions with hydroxyl radicals.

Methanol, with several counties in the study reporting industrial releases, is a natural product from plants, and is released by anthropogenic sources from evaporation. Counties, such as Tipton, Humphreys and Sumner, have reported no significant changes in air releases of methanol. Contrary to these results, many counties have reported decreases in methanol releases from 1988 to 2002. For example, industries in Hamilton County, Tennessee, have reported a decrease from 2.6 million pounds to 1.4 million pounds from 1988 to 2001. Sullivan County, Tennessee, industries have also reduced methanol emissions from 3 million to 712,098 pounds for the years in the study. Wet deposition is the primary removal of methanol from the atmosphere. It may also be degraded through reactions with hydroxyl radicals. In water and soil, biodegradation occurs, but with leaching present at the soil interface. Several counties in Tennessee and Los Angeles County, California, reported releases of styrene. Counties such as Cheatham and Rutherford reported similar emissions for styrene for the years included in

this study. However, industries in Humphreys County, Tennessee, reported increases from 594,170 pounds to 1.5 million pounds from 1996 to 1998. Sevier and Knox counties also reported increases, but all emissions were below half a million pounds. Industries within Blount and Tipton Counties reported decreases in styrene air releases. Styrene may occur naturally in the sap of trees. It is also found in the plastic industry, vehicle exhaust, and cigarette smoke. Styrene will break down in the atmosphere by hydroxyl radicals and ozone. Although it has a low mobility in soils, it will readily volatilize in soils and water. Biodegradation in the soil by microorganisms will cause absolute removal of styrene. Styrene is listed as a possible carcinogen. Main exposure to styrene occurs during its production through inhalation.

Acrylonitrile, released to the land in Montgomery County, Tennessee, has been utilized in resins, polymers, and carbon fibers. From 1991 to 1992, there was an increase in land discharges from 4,161 pounds to 7,654 pounds. The estimated half lives of the degradation of acrylonitrile by hydroxyl radicals and ozone are 4 and 83 days, respectively. With high mobility in soil and water, it is expected to easily undergo volatilization. Acrylonitrile has been shown to be a probable carcinogen with production workers being exposed to noxious vapors.

Industries in Shelby County, Tennessee, have reported discharges of naphthalene, pentachlorophenol, and hydrazine. Naphthalene, 250 pounds released in 1989, is used in the making of phthalic anhydride, and is also a component of crude oil. It is subject to degradation by hydroxyl radical and nitrates, as well as photolysis in the atmosphere. In moist soils and water, volatilization is an important process of removal.

Pentachlorophenol, with land releases of 5,047 pounds in 1997, is used as a wood preservative. If released to the atmosphere, it will exist either in the vapor or the particulate phase. Particulate phase pentachlorophenol is removed by deposition, and vapor phase pentachlorophenol is removed through degradation processes. Hydrazine, with a release of five pounds in 1992 in Shelby County, is used predominantly as a chemical intermediate. Each of the three compounds are listed as possible carcinogens. Respiratory effects are common with naphthalene and hydrazine. Pentachlorophenol poses hazards when used in conjunction with polychlorophenols.

In addition, formaldehyde was reported in Shelby County and McMinn County, Tennessee. It is an important chemical that is used in resins, disinfectants and preservatives. In McMinn County, formaldehyde was ranked second among all chemicals released to air by industries. From 1990 to 1997, the quantities emitted have decreased. In 1998, 305,778 pounds of formaldehyde was discharged into the atmosphere. Since 1998, releases have decreased to 209,105 pounds in 2002. Formaldehyde exists in gaseous state in the atmosphere and undergoes similar reactions with hydroxyl radicals.

Phenol is used as a chemical intermediate and disinfectant. It should also be noted that phenol occurs naturally in decaying organic matter; therefore reports through TRI may not be indicative of the concentration of phenol in the environment. Industries in McMinn County, Tipton County, Tennessee, and Harris County, Texas, have reported annual releases of phenol. In 1989 in McMinn County, 5,314 pounds of phenol was discharged into water and 112 pounds was discharged onto land. In 1999 in Tipton

County, 500 pounds of phenol was emitted into the atmosphere. In Harris County, 688,709 pounds of phenol was released into water. During the daylight hours, phenol is decomposed by hydroxyl radicals in the atmosphere, and at night, it is decomposed by nitrates. Phenol is highly mobile in soil and easily adsorbed to sediment through the water soil interface.

Acetaldehyde is commonly found in the environment. It is a natural product of combustion, as well as a product of vehicle exhaust and cigarette smoke. Acetaldehyde is employed in the production of acetic acid and flavor agents. When discharged into the atmosphere, acetaldehyde exists as a gas and will degrade in the atmosphere. The chemical may be transformed into free radicals upon absorption of radiation. In soils, acetaldehyde is highly mobile. Davidson, McMinn and Loudon counties in Tennessee have reported releases of acetaldehyde via air. In Davidson County, industries reported a decrease from 224,385 pounds to 197,318 pounds from 1998 to 2000. Releases of acetaldehyde in Loudon County have also slightly decreased from 1999 to 2001.

The octane booster in gasoline, methyl tertiary-butyl ether, MTBE, has been widely reported especially in the news as an environmental pollutant, specifically in water supplies. Los Angeles County in California and Fayette County in Tennessee have industries which reported releases of the octane booster. Land Releases in Fayette County were 10 pounds and water releases were 5 pounds in 2000. In Los Angeles, water releases have increased from 8,100 pounds in 1991 to 29,201 pounds in 2000. The oil refineries, Chevron, Exxon Mobil and Shell Oil, reported the land and air releases of MTBE. In the atmosphere, MTBE will decompose via reactions with hydroxyl radicals

with a half-life of 5 days, and via nitrates with half-life of 50 days. In soil releases, MTBE is expected to be highly mobile, and therefore will transfer into groundwater. Volatilization in soil and water is an important process for the subsequent transfer to the atmosphere followed by photochemical degradation. It should be noted that the release by industries is not indicative of the concentration of MTBE in the environment, considering it may be released unknowingly by underground leakage from storage tanks of fueling stations.

Cyclohexane is used as a solvent and is present in gasoline. Its TRI air releases in Humphreys County, Tennessee, in 1991 have a total of 206,220 pounds. Similarly to other organics, cyclohexane in the atmosphere will degrade via reactions with hydroxyl radicals. In soil, it is expected to be reasonably mobile and volatile. In the water table, cyclohexane will adsorb readily to soil and sediment. Importantly, biological remediation is highly unlikely to occur for cyclohexane, rather cyclohexane is catabolized.

In addition to cyclohexane, Humphreys County also had releases of benzene, which is usually present in gasoline. In 1988, 140,484 pounds of benzene was released into the atmosphere. Benzene is also used in the production of ethylbenzene and styrene. In the same way as cyclohexane, benzene will degrade in the atmosphere. The aromatic compound is relatively soluble in water and hence is removed via rain. Benzene is highly mobile in soil, and will undergo volatilization in water and soil.

Benzene is a known carcinogen via all routes of exposure. Cancers of the ovary and liver have been reported after chronic exposure to benzene. Liver and lung cancer

rates in Tennessee are above the rates of these cancers in the United States for 1999-2002.⁷⁸ On the other hand, rates of breast and ovary cancer in Tennessee are lower than the United States rates for 1999-2002.⁷⁹

Several counties in this study reported releases of toluene via air emissions, as seen in Table 21. It enters the atmosphere through volatilization of petroleum, solvents, and also via vehicle exhaust. Furthermore, the reported annual releases may not fully portray the concentration of toluene released into the environment. Several counties in the study have industries reporting decreases in toluene emissions to the atmosphere for the period of this study. McMinn, Hamblen, Montgomery, Tipton, Shelby, Bradley, and Cheatham Counties in Tennessee reported a decline in emissions. Industries such as GF Office Furniture and R & R Donnelly and Sons within Sumner County, Tennessee, reported 2.8 million pounds of toluene air releases in 1988 but in 2001, these industries reported total releases of 417,895 pounds or about one-seventh of the 1988 level. Facilities in Harris County, Texas, from 1988 to 1990 reported 3.5 million pounds of toluene released. Reactions with hydroxyl radicals assist in the degradation of toluene vapor in the atmosphere. Volatilization in moist and dry soils is an important fate process for toluene. In water, toluene is expected to undergo biodegradation rapidly, with an estimated half-life of 4 days in aerobic conditions and 56 days in anaerobic conditions.⁷⁷

Table 21: Counties ranked by pounds emitted of toluene to air from
1988 to 2002

Rank	County
1	Harris
2	Sumner
3	Shelby
4	Hamblen
5	McMinn
6	Cheatham
7	Bradley
8	Tipton
9	Montgomery

Haywood County, Tennessee, reported 4,358 pounds of air releases of phthalic anhydride in 1988 relative to 290 pounds in 2002. Phthalic anhydride is used in polyester resins, fibers, and dyes. The anhydride will undergo direct photolysis in the atmosphere and in moist soils. Bradley County, Tennessee, had reported land releases of maleic anhydride, which is also used in the resin industry. In the atmosphere, maleic anhydride will degrade quickly by reactions with ozone. In water, it will rapidly hydrolyze into the acid, and therefore is of minimal direct concern. On the other hand, when discharged onto land, it may biodegrade.

Pyrrolidine, released in Williamson County, Tennessee, and Bartow County, Georgia, is used in drug and antibiotics syntheses. Pyrrolidine will react with hydroxyl radicals in the atmosphere during its decomposition process. In soil, it is highly mobile since it can be protonated thereby increasing its mobility.

Harris County, Texas, has several chemical and oil refineries. Industrial releases of ethylene and propylene were significantly high in Harris County. Ethylene in the atmosphere may be degraded by ozone, hydroxyl radicals, or nitrate radicals with varying half-lives. Volatilization is an important removal process of ethylene from soil and water. It should be noted that its primary release in Harris County was through air sources. From 1988 to 2002, releases of ethylene declined from 6.5 million to 3.1 million pounds. Similarly, propylene was primarily released through air sources in Harris County. Releases of propylene in air have averaged 3.3 million pounds from 1992 to 2001. Propylene is used in the production of resins, plastics, synthetic rubbers, and gasoline. In fact, the main release of propylene into the atmosphere is through

combustion of gasoline, coal, and wood. As with many other compounds discussed such as cyclohexane or benzene, the reported releases by these industries does not give an accurate picture of its environmental concentrations because it can be released via combustion of residential sources or automobiles.

Releases of 1,3-butadiene were also high in Harris County. In 1988, water releases of 1,3-butadiene were 110,250 pounds. Like propylene, 1,3-butadiene is used in the production of rubber, plastics and resins, in addition to tobacco smoke and automobile exhaust. 1,3-Butadiene also is involved in degradation reactions with hydroxyl radicals, ozone radicals, and nitrates in the atmosphere. In soil, the chemical is moderately mobile and will easily volatilize in soil and water.

Acetone is a widely used organic solvent for fats, oils, resins, and plastics. Acetone is photochemically degraded with an estimated half-life of 80 days. Acetone is highly mobile in soil, and readily volatilizes in moist soil and water. Air releases of acetone were reported in several counties of this study including Blount, Cheatham, Davidson, Fayette, Knox, Loudon, McMinn, Rhea, Rutherford, Shelby, Sullivan, and Tipton counties in Tennessee. Many industries in these counties reported decreases in air emissions of acetone for the years in this study. It should be noted that these industries had less than one million pounds of acetone released, except for industries in Sullivan County. In 1988, 34.0 million pounds of acetone was released. Through 1993, the value decreased to 22.4 million pounds, which was released by Eastman Chemical Company in Kingsport, Tennessee. The following years, Eastman reported no releases of acetone. For the remaining years in the study, acetone was not ranked as one of the top three

chemicals released by industries according to the TRI reports. The chemicals which did rank in the top three for the remaining years of the study were hydrochloric acid, methanol, and sulfuric acid. On the other hand, Tipton and Rhea County have reported increases in acetone emissions from 1988 to 1993.

Dichloromethane, a chlorinated solvent, was reported released from industries in Hamblen, Cheatham, Tipton, and Loudon counties in Tennessee, as well as from Los Angeles, Suffolk and Bartow counties. Between 1988 and 1990, industries in Tipton County reported increases in air releases of dichloromethane. Land releases in Loudon County decreased between 1991 and 1992. Facilities in Bartow County, Georgia, and Cheatham County reported little change in air releases between 1995 and 1996. Hamblen County reports indicate a decline in emissions from 1989 to 2000, except in 1997 there was a sharp increase to 864,559 pounds. Suffolk County, New York, and Los Angeles County, California, both report a decline in dichloromethane emissions. In Los Angeles County, air releases decreased from 3.9 million pounds in 1988 to 1.6 million pounds in 1992. In Suffolk County, air releases declined in 1988 from 280,917 pounds to 67,635 pounds in 1995. In addition to solvent uses, dichloromethane is used as a chemical intermediate, fumigant, paint remover, and refrigerant. Studies indicate that dichloromethane will degrade with an estimated half-life of 119 days in the atmosphere. In soil, it will be highly mobile and is resistant to biological remediation. In addition to biodegradation in water, dichloromethane will evaporate, which is an important fate process for the chemical. Dichloromethane is a probable carcinogen with demonstrated tumor development in the lungs and mammary glands.⁷⁷

Industrial releases within the counties in this study did not only include organic chemicals, but also of other compounds like sulfuric acid, barium compounds, and ammonia. There was a significantly better correlation between the TRI and USGS data sets when examining the water and land releases of compounds, such as barium, nitrate, and manganese compounds. Environmental concerns should examine the releases of these branches of compounds. For instance, acids may contribute to increases in acidity levels of rain and other bodies of water. This in turn may cause long-term damage to structures, animal and plant life, and aquatic life. Increased levels of metals in soils may cause damage by altering the profile of nutrients in the soil for proper plant growth and reproduction.

Sulfuric acid may enter the environment through accidental spills, wastewater from mines or steel industries. For the release of sulfuric acid onto land, its mobility will facilitate its travel in the direction of the groundwater flow, and create a contaminated plume. In water, there is an increase in weathering of calcium from rocks and soils upon exposure to concentrations of sulfuric acid. Sulfuric acid will ultimately cause corrosion, discoloration and deterioration of steel, marble, limestone, and slate. Likewise, hydrochloric acid will permeate the soil and may dissolve carbonate soil material. In the atmosphere, ammonia may combine with sulfate aerosols and undergo deposition into soil. It should be noted that industries as well as the USGS have reported findings for nitrate.

3.2 Analysis and Characterization of Particulate Matter using Scanning Electron Microscopy

Scanning Electron Microscopy with Energy Dispersive X-ray analysis (EDX) was used to characterize particles collected on mixed cellulose ester filters and silver membranes. EDX background spectra for the mixed cellulose ester filter coated with gold via a sputtering process and silver membrane filters were examined prior to sampling. After coating the mixed cellulose ester filters with gold, the background shows an even surface with no space-charging effects commonly observed in analysis of quartz filters. In comparison with the mixed cellulose ester filters, the silver membranes likewise have an even surface. The advantage to using silver membranes is the lack of space-charging effects eliminating the need to coat the filters with gold prior to analysis. Sputtering coating of non-conductive specimens may be needed in order to increase the production of secondary electrons. It is important that secondary electrons reach the detector in order to provide a topographical image of the specimen. Areas with shadows indicate that the secondary electrons were unable to reach the detector. Elements that have a higher atomic number easily produce secondary electrons. Furthermore, specimens that may contain elements such as carbon and oxygen would perhaps need to be coated. In this case, the space-charging is minimal because the background is silver, which has a high atomic number and therefore the production of secondary electrons is greater, which can be seen in Figure 11a and 11b. On the other hand, the mixed cellulose ester filters required coating due to the low conductivity, which can be seen in Figure 10.

The elemental analysis for the silver membranes suggests that the filter consists of predominantly silver and traces of chlorine.

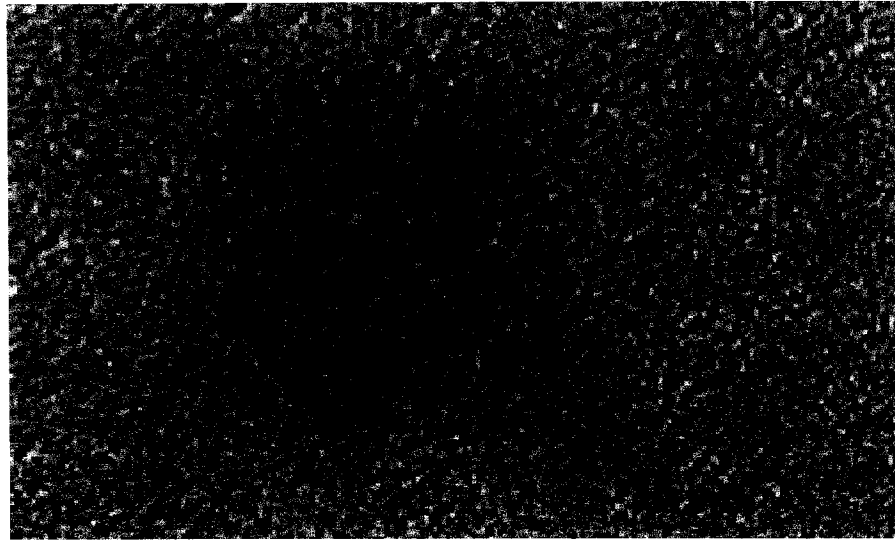


Figure 10: SEM Analysis of gold coated mixed cellulose ester filters showing the lack of space charging effects commonly seen with quartz filters

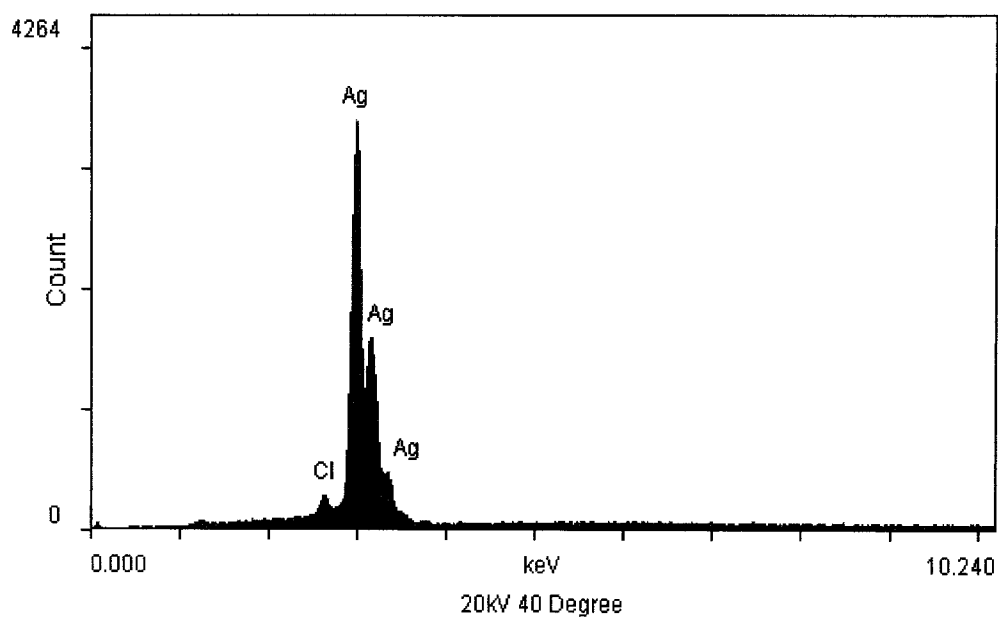
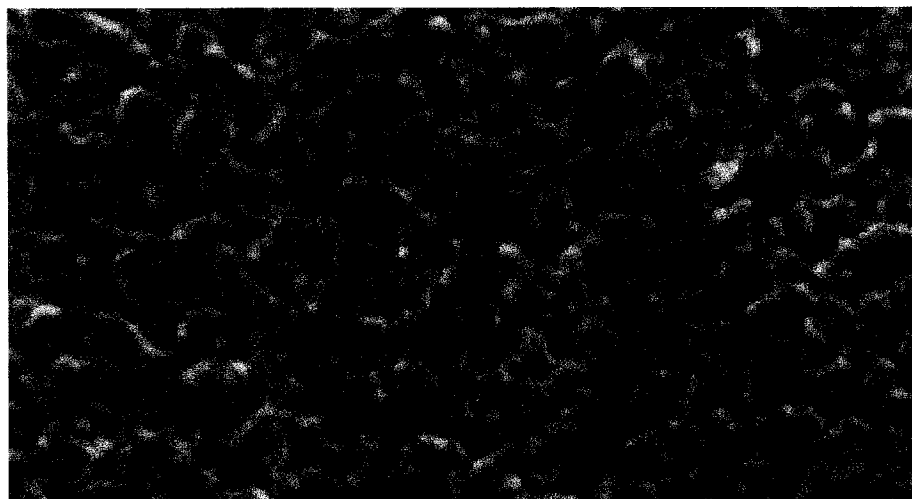


Figure 11a and 11b: SEM/EDX analysis of uncoated silver membranes demonstrating the even surface and the absence of space charging effects

Samples were collected on the two types of filters in residential areas which have heavy vehicle traffic. Samples were also collected during the afternoon and early evening hours when traffic is at its highest. The list of sample locations, type of filter, mass of particulate matter collected, and sampling duration is shown in Table 22.

Table 22: Samples collected on mixed cellulose ester filters and silver membranes for SEM analysis

Sample Number	Filter Type	Mass Collected (μg)	Sample Time (min)	Location
1	Mixed Cellulose Ester	200	300	White House, Tennessee
2	Mixed Cellulose Ester	100	483	White House, Tennessee
3	Silver Membrane	900	185	Murfreesboro, Tennessee
4	Silver Membrane	0	350	Murfreesboro, Tennessee
5	Silver Membrane	300	90	Nashville, Tennessee
6	Silver Membrane	600	180	Murfreesboro, Tennessee
7	Silver Membrane	500	180	Murfreesboro, Tennessee

Samples No. 1 and No. 2, collected on mixed cellulose ester filters, show the composition and morphology of particles collected in White House, Tennessee, which is located approximately thirty miles north of Nashville. In Figure 12a, the SEM micrograph shows an elongated particle approximately 5 microns in diameter. X-ray analysis in spot mode suggests that the particle contains the elements aluminum and silicon. The analysis also identifies carbon and oxygen, but this may be due to the filter composition. Elemental mapping of the particle (Figure 12b) further provides evidence consistent with the composition of aluminum silicates.

In Figure 13, the particle in the lower left corner is greater than 10 μm , and appears to have an irregular shape. In the upper left corner of the micrograph, there is a smaller particle with same elongated shape as the particle in Figure 12. Considering the size and irregular shape, x-ray analysis was not conducted for this particle, as the emphasis of the study is on particulate matter on the scale of 10 microns or less.

This area was further analyzed, and the SEM micrograph can be observed in Figure 14. This particle is cylindrical in shape, with a diameter of less than 10 microns. X-ray analysis of the particles revealed the presence of silicon, calcium, potassium, chlorine, and copper in the elemental composition.

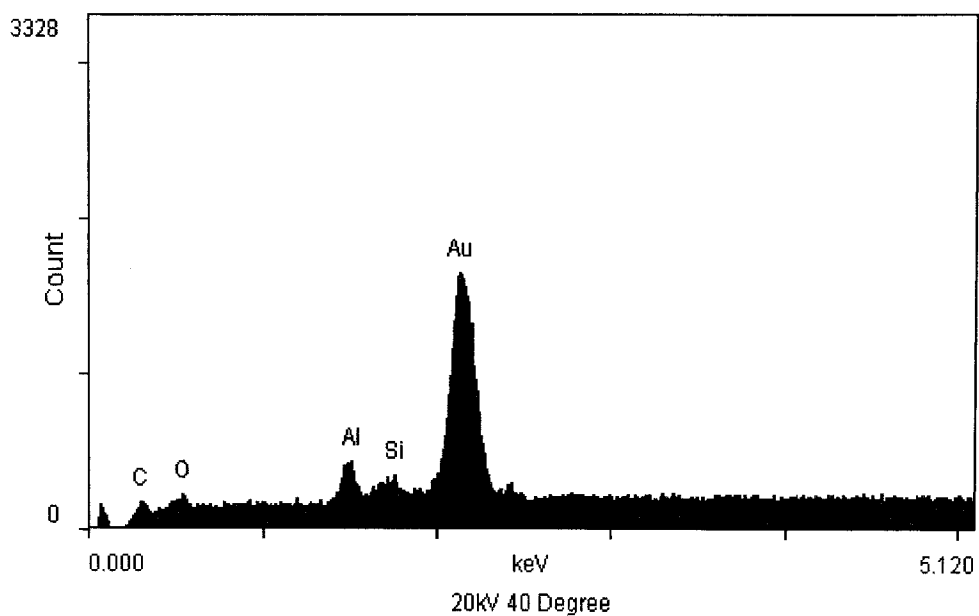
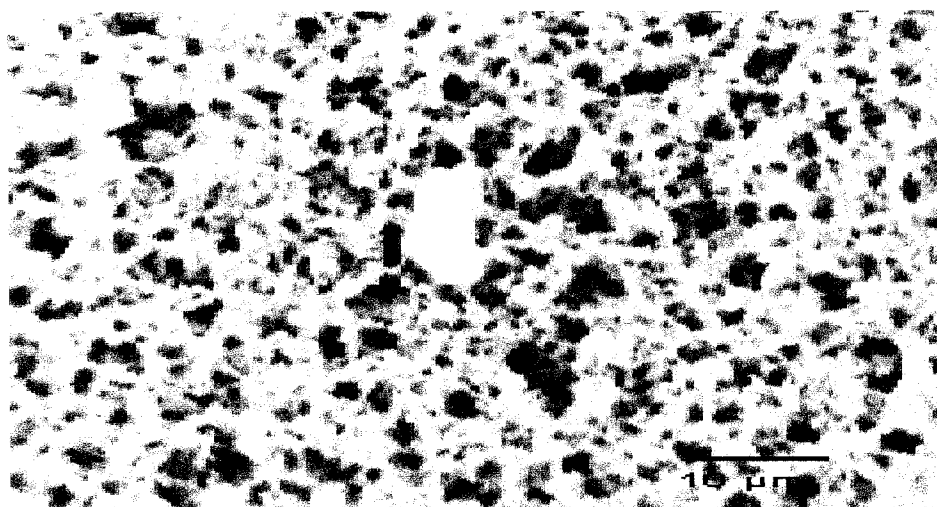
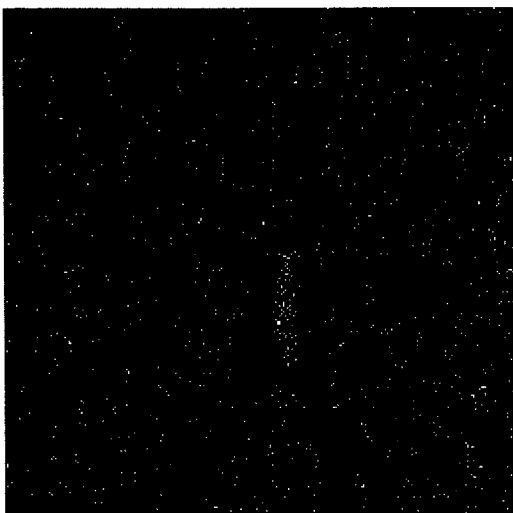


Figure 12a: SEM/EDX analysis of Sample No. 1 collected on mixed cellulose ester filters showing the morphology and elemental composition of the particle with an aerodynamic diameter of approximately 5 μm

Aluminum



Silicon



Figure 12b: SEM/EDX analysis of Sample No. 1 collected on a mixed cellulose ester filter showing the morphology and elemental composition of the particle

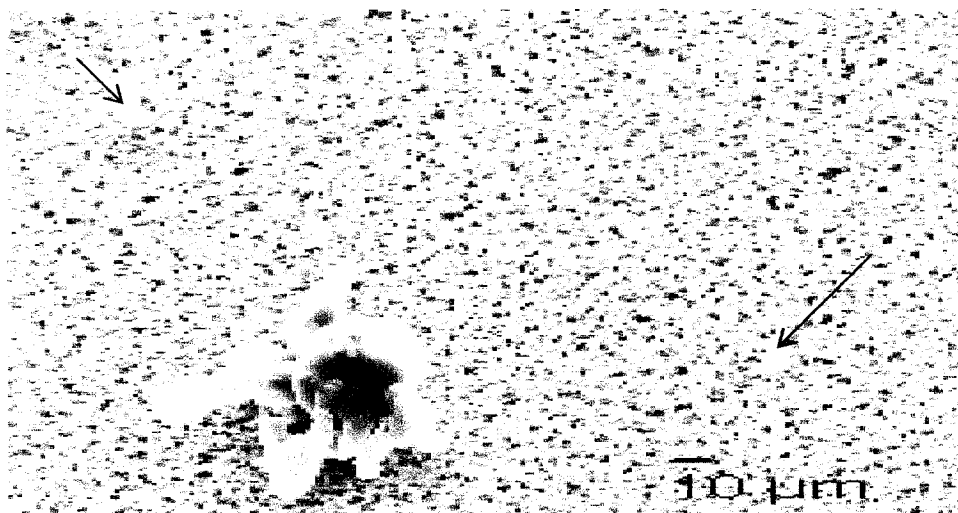


Figure 13: SEM analysis of Sample No. 2 collected on a mixed cellulose ester filter showing the morphology of the particles and additional particles indicated by the arrows

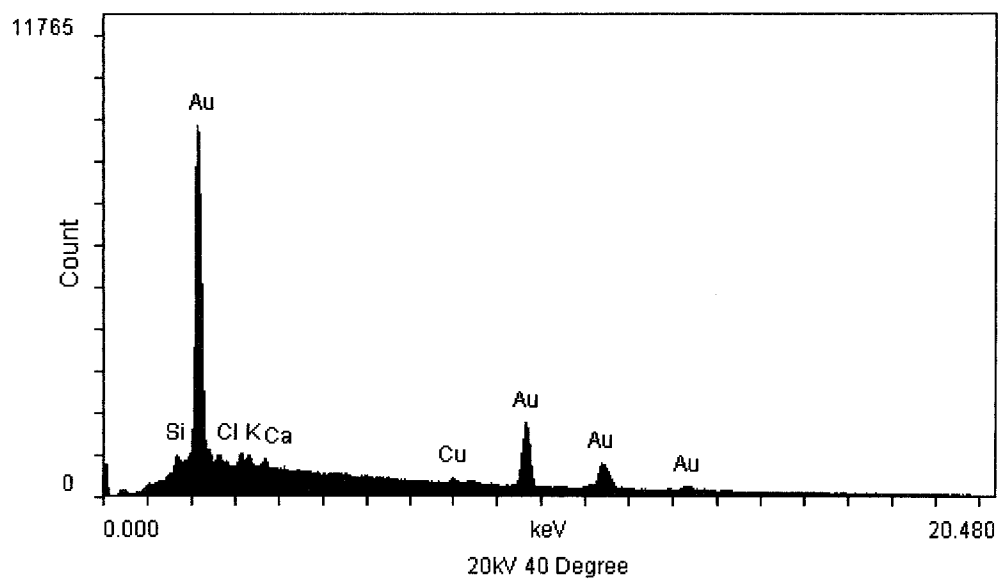
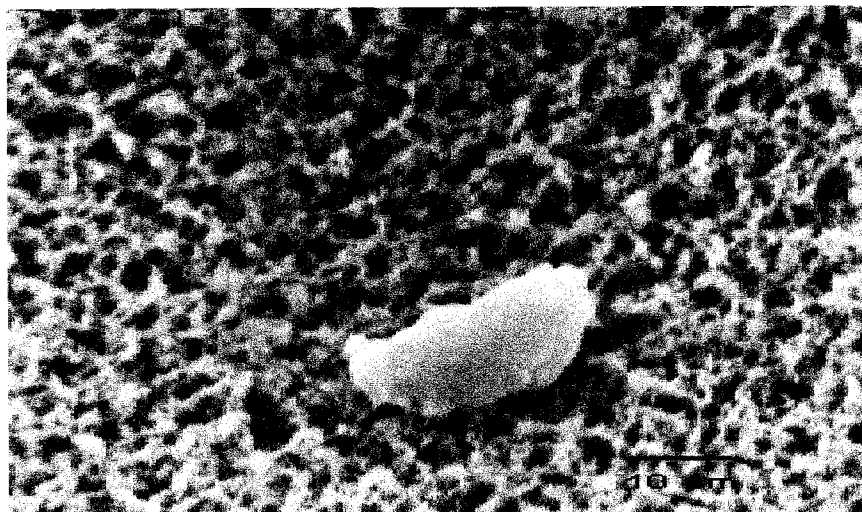


Figure 14: SEM/EDX analysis of Sample No. 2 collected on a mixed cellulose ester filter showing the morphology, diameter of less than 10 μm , and elemental composition of the particle

Samples No. 3-6 provide stunning observations into particulate characterization and morphology. For Sample No. 3, the light element sensitive detector was utilized. In Figure 15, the particle is cylindrical with an axial dimension less than 10 microns. The x-ray analysis indicates the presence of aluminum, silicon, carbon, and oxygen. Silicon and aluminum are distributed throughout the filter background, and carbon and oxygen are the elements that constitute the particle. This feature indicates that the source of the particle may be attributed to weathering processes. The presence of silicon and aluminum may have arisen from weathering processes.

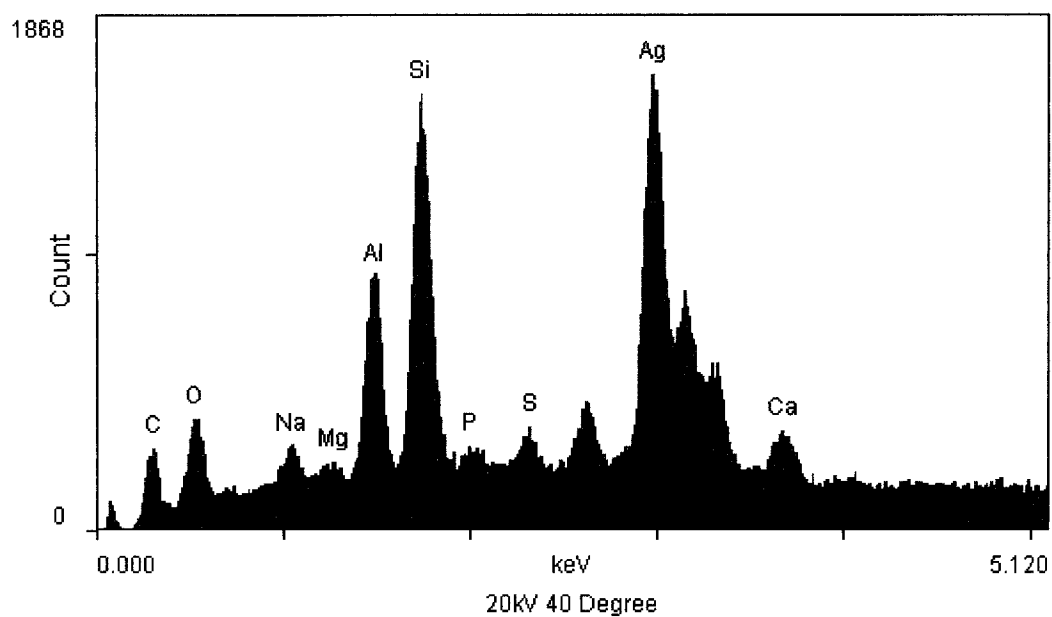


Figure 15: SEM/EDX analysis of Sample No. 3 with a diameter of less than 10 μm collected on silver membranes showing the morphology and elemental composition of the particle

Sample No. 4 collected on the silver membranes was not analyzed because of the lack of mass gain after air sampling. On the other hand, Sample No. 5 collected in Murfreesboro, specifically at the intersection of North Highland Avenue and Highway 231, illustrates several particles of varying size. The sample, seen in Figure 16, was collected during the morning hours at this intersection. By comparison with the 10 micron marker in the lower right corner, the diameters of the three spherical particles range from 8-12 microns. Elemental analysis of the particles indicates the presence of carbon and oxygen. According to literature, spherical particles with high carbon to oxygen ratios develop from automobile combustion. Considering that the sample location and time correspond to a highly traveled intersection during morning travel times, the particles observed in Figure 16 are likely due to the soot emissions from vehicles.

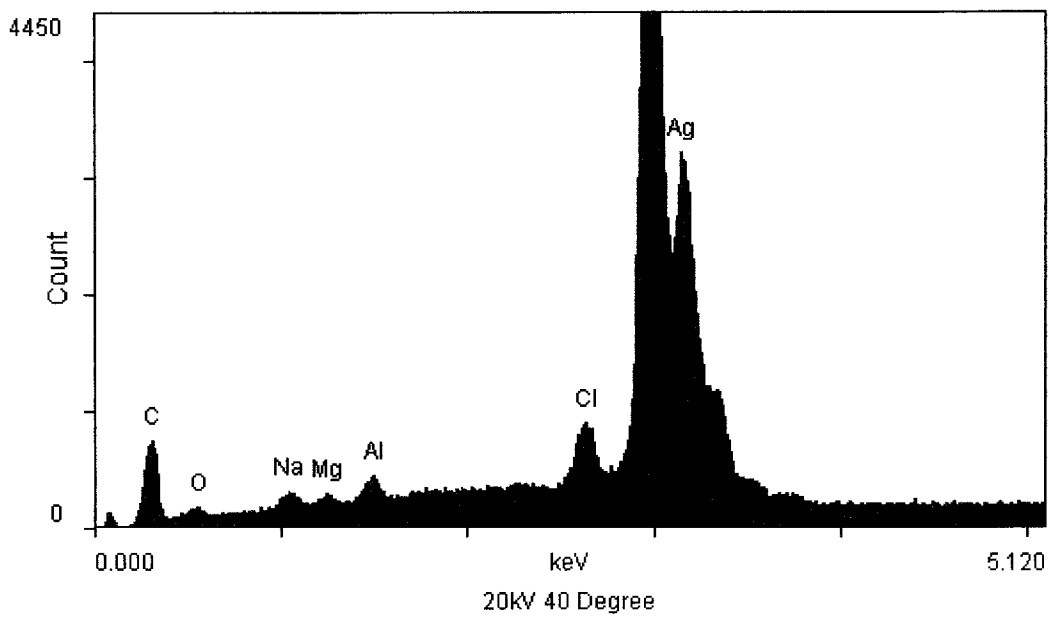
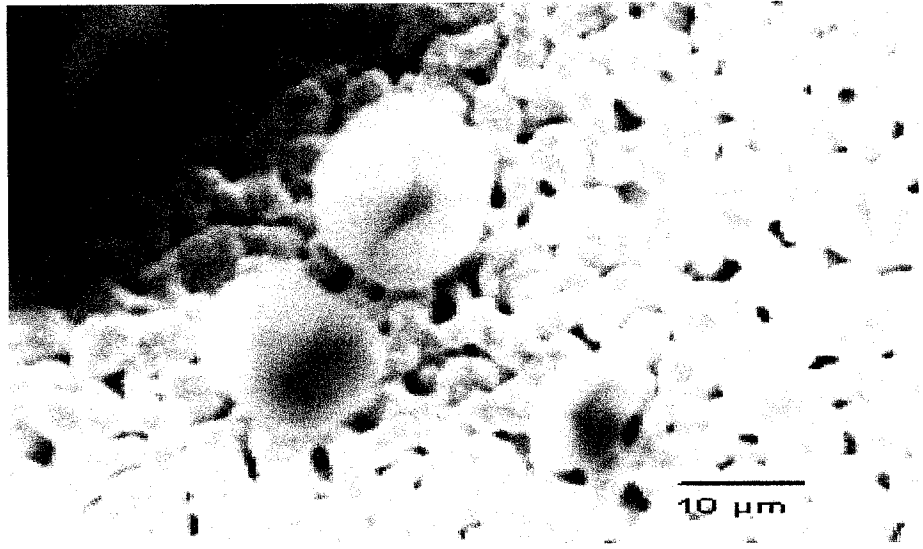


Figure 16: SEM/EDX analysis of Sample No. 5 collected on silver membranes showing the morphology and elemental composition of the particles

In Figure 17a, the morphology and composition of the particulate sample collected at the intersection of Greenland Avenue and Tennessee Boulevard in Murfreesboro, Tennessee can be examined. The peaks in the EDX spectrum of the oval shaped particles suggest the presence of carbon and oxygen. The particle has a diameter less than 10 microns as shown in the SEM micrograph. Also, consistent with other particles from the area, the morphology is spherical which indicates combustion from automobiles. Elemental maps in picture mode, in Figure 17b, demonstrate that the spherical particle is indeed carbon based. These findings supports that carbonaceous particulate matter are generally observed in areas heavily congested by vehicles.

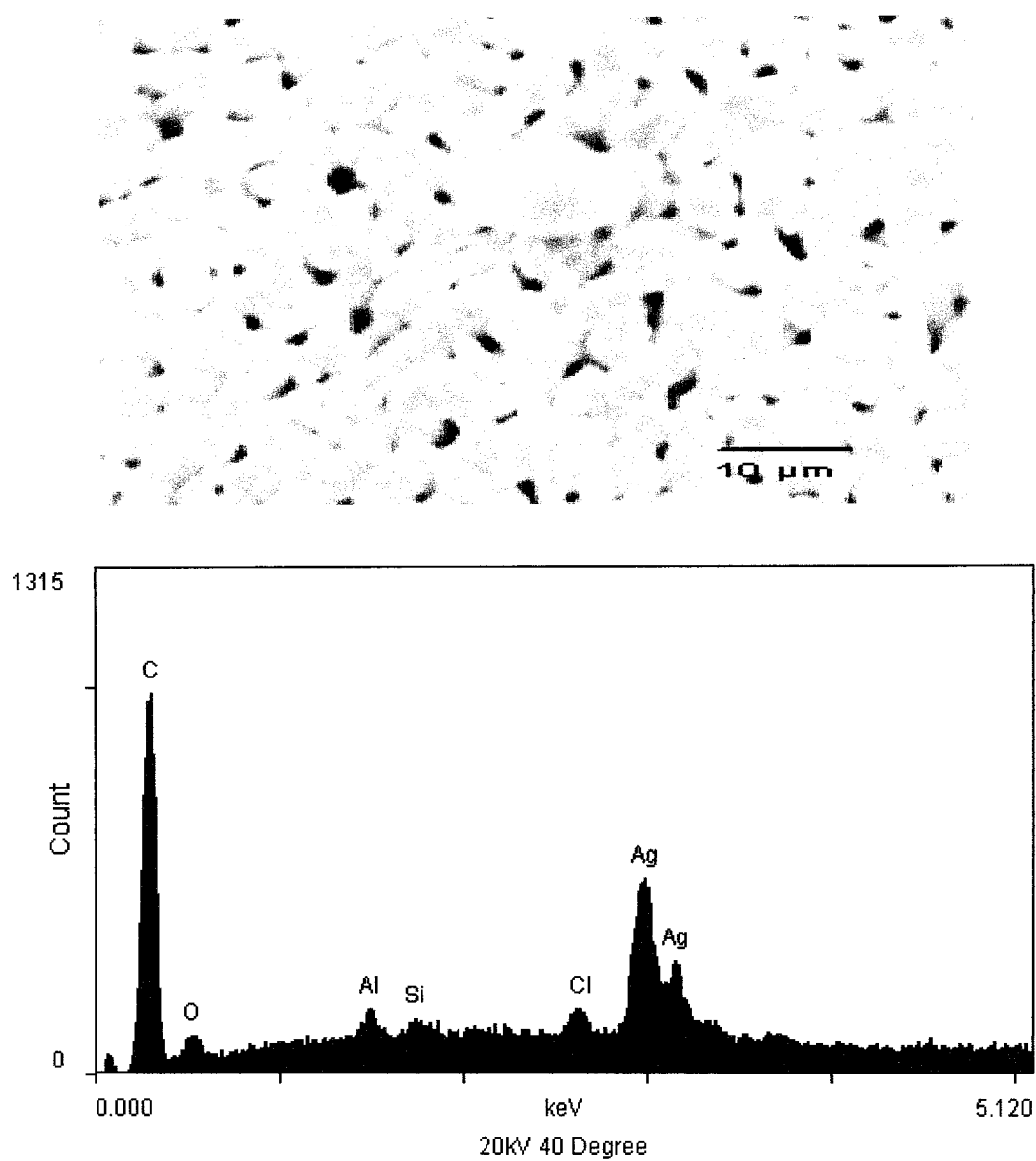


Figure 17a: SEM/EDX analysis of Sample No. 6 collected on silver membranes showing the morphology and elemental composition of the particles

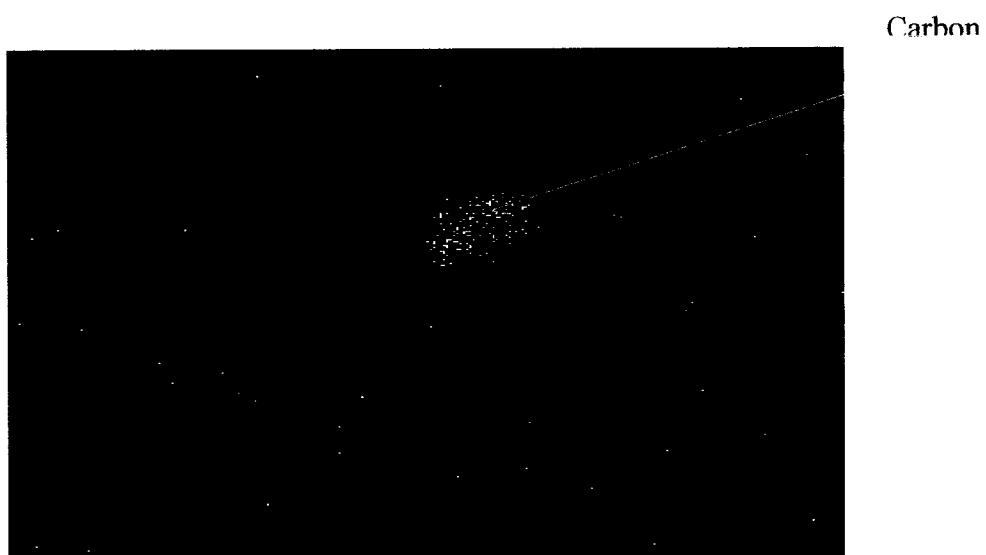


Figure 17b: Elemental map of Sample No. 6 collected on silver membranes showing the distribution of carbon

3.2.1 SEM Monte Carlo Simulation

The SEM Monte Carlo simulation freeware, written by David C. Joy, allows the user to calculate backscattered yields, estimate depth of electron penetration, and examine how electrons lose energy as they travel through a bulk sample.⁸⁴ This modeling is necessary to demonstrate the need to gold coat substrates consisting of elements which may cause space-charging effects. Backscattered yield increases with increasing atomic number, thereby indicating that substrates made of elements such as carbon and oxygen like the mixed cellulose ester filters would perhaps require gold coating. The gold coating may provide a better substrate for the production of secondary electrons which contribute to the image of the sample collected.

Backscattered electrons originate from the incident electrons when they are scattered out of the sample in the direction of the incident electrons. The backscattered coefficient depends on the energy of the incident beam and the atomic number of the element, and varies across the periodic table with increasing values from carbon to uranium.⁸⁵ The software model can be used to examine the above characteristics in a plural scattering or single scattering mode. Elastic scattering events occur in a sample when there is an attraction between the incident electron and atomic nucleus. The energy of the incident electron remains unaltered, but the electron is deflected through the sample. Inelastic scattering events cause a change in direction and energy of the incident electron upon contact with the sample. With inelastic scattering events, the incident electron could cause removal of an inner shell electron to produce an X-ray or Auger electron, could collide with a valence electron to produce a secondary electron, could interact with lattice to produce phonons, or could give energy to the sample.⁸⁵

Ideally, the plural scattering (PS) should be utilized for bulk samples at an energy level less than 20 keV. In the PS mode, the simulation computes the net effect produced by successive scattering events within the sample. This mode assumes that every electron will travel the exact total path length in the sample before coming to a halt.⁸⁵ Similarly, single scattering (SS) mode is performed under the same conditions except that more detailed calculations are followed thus providing more accurate results. The SS model is the most accurate representation of interactions between the incident electron and the sample. The model calculates the pathway of the electron through the sample by examining the electron from one interaction to the next interaction. Like the PS mode, there are assumptions to this model. In SS mode, only elastic scattering events are considered.⁸⁵ It should be noted that the simulation model can only be examined for pure elements such as carbon, iron, gold, silver, copper, aluminum, titanium, and silicon. The model has no provision for modeling alloys or samples with multiple elements. In table 23, the Monte Carlo simulation results for PS and SS mode are reported for 1000 trajectories. Table 24 reports the results for the simulation for 500 trajectories, and Table 25 reports for 250 trajectories. The trajectories were varied as well to examine any possible effects in depth of penetration and backscattering yield.

Table 23: Monte Carlo simulations for elements in PS and SS modes

at 20 keV, 40° for 1000 trajectories

Element	Mode	Backscattered Yield	Depth Estimation (μm)
Titanium	PS	0.32	2.46
Titanium	SS	0.26	2.111
Aluminum	PS	0.24	4.000
Aluminum	SS	0.15	3.5454
Copper	PS	0.38	1.2917
Copper	SS	0.32	1.0277
Gold	PS	0.55	0.6943
Gold	SS	0.49	0.4375
Iron	PS	0.35	1.4091
Iron	SS	0.31	1.121
Carbon	PS	0.09	4.111
Carbon	SS	0.04	4.111
Silver	PS	0.48	1.0833
Silver	SS	0.46	1.000
Silicon	PS	0.25	4.375
Silicon	SS	0.19	4.000

Table 24: Monte Carlo simulations for elements in PS and SS modes

at 20 keV, 40° for 500 trajectories

Element	Mode	Backscattered Yield	Depth Estimation (μm)
Titanium	PS	0.37	2.3846
Titanium	SS	0.28	2.111
Aluminum	PS	0.23	3.8889
Aluminum	SS	0.16	3.4545
Copper	PS	0.38	1.1667
Copper	SS	0.33	0.9999
Gold	PS	0.57	0.6943
Gold	SS	0.52	0.4500
Iron	PS	0.34	1.3181
Iron	SS	0.28	1.1293
Carbon	PS	0.09	4.0000
Carbon	SS	0.04	4.222
Silver	PS	0.46	1.2083
Silver	SS	0.43	0.8181
Silicon	PS	0.22	4.2500
Silicon	SS	0.17	3.8889

Table 25: Monte Carlo Simulations for elements in PS and SS modes
at 20 keV, 40° for 250 trajectories

Element	Mode	Backscattered Yield	Depth Estimation (μm)
Titanium	PS	0.32	2.370
Titanium	SS	0.28	2.055
Aluminum	PS	0.27	3.8889
Aluminum	SS	0.16	3.3636
Copper	PS	0.37	1.375
Copper	SS	0.36	0.9999
Gold	PS	0.58	0.7222
Gold	SS	0.55	0.4000
Iron	PS	0.34	1.3636
Iron	SS	0.31	1.0302
Carbon	PS	0.13	4.222
Carbon	SS	0.08	3.8889
Silver	PS	0.43	1.0416
Silver	SS	0.38	0.7727
Silicon	PS	0.24	4.2500
Silicon	SS	0.23	3.7778

As electrons travel through a bulk sample, they lose energy and therefore may not penetrate the sample. For example, when running the simulation for carbon in the plural scattering mode, as the number of trajectories decreased, there was an increase in depth. The number of trajectories represents the requirement of the Monte Carlo simulation. The number of trajectories can be varied in order to more accurately determine the backscattered yield for the elements in question.

Backscattered electrons are returned from the sample with energy greater than 50 eV after incidence.⁸⁵ The beam electrons penetrate the sample prior to being backscattered. Thus, elemental information of the X-rays is derived from the specimen through a range of depths. If the thickness of the sample material is greater than the depth calculated by the Monte Carlo program, the X-ray photons from the sample in question and not the substrate will be detected.⁸⁶ Hence, the information provided will be solely due to the sample material.

It should be noted that backscattered yield increases with increasing atomic number. As seen in the Tables No. 23 to No. 25, the yield increases as the atomic number increases for all trajectories. For example, gold, with atomic number 79, has a backscattering yield of 0.55 for 1000 trajectories. On the other hand, copper, with an atomic number 29, has a yield of 0.38 for 1000 trajectories. For carbon, with atomic number 6, the backscattered yield was 0.09 and 0.04 for 1000 trajectories. Therefore this indicates that elements with lower atomic numbers have less backscattered electrons. Furthermore, this indicates that the topographical image for specimens

containing carbon for example will be poor unless it is coated or collected on a conductive material.

The simulation can also be used to explain differences seen between lower and higher atomic mass elements. For example, with carbon in the single scattering mode, the depth estimated is 4.111, 4.222, and 4.222 for trajectories equal to 1000, 500, and 250 respectively. On the other hand for gold in the single scattering mode, the depth estimated is 0.4375, 0.4500, and 0.4000 for trajectories equal to 1000, 500, and 250, respectively.

CHAPTER 4

4. CONCLUSIONS

4.1 Environmental Quality Survey Utilizing TRI Explorer and USGS Water Data

This research proposed the use of the TRI inventory and USGS online water quality database to investigate a possible correlation between the two databases for the release of chemical pollutants in air, water, and land. Several counties surrounding major metropolitan areas in Tennessee as well as Houston, Texas, Atlanta, Georgia, Washington D.C., New York, New York, and Los Angeles, California were examined. With the establishment of several government agencies and the need for congruency between those agencies, it is important to determine if there is a correlation between the EPA and USGS report data, perhaps leading to the establishment of stricter laws for reporting disposals or accidental releases of chemicals.

This study finds that the data obtained from the TRI inventory reports chemicals released to air, water, and land by industries within a given county have decreased for chemicals addressed in legislative acts, such as the classes of HCFCs in the Montreal Protocol. The data are reported in pounds released. These data do not provide an explanation for the fate of the chemicals released. On the other hand, the USGS survey details the amount of chemical pollutant determined at testing sites. The data does not consider many volatile organic compounds, which were heavily reported in the TRI report. There was not a correlation between TRI Explorer and USGS data for land, air, and water releases from 1988 to 2004 for the counties included in the study. This lack of correlation may be due to the transport and fate processes involved with the releases of such chemicals. For example, after examining the processes which may happen, it was

speculated that some pollutants are quickly degraded in the atmosphere by reaction with hydroxyl radicals. Therefore, these pollutants may not be deposited via rain deposition, and not detected at USGS testing sites. With the further development of regulations and stricter penalties, concentrations of chemicals, such as HCFCs, have decreased.

4.2 Analysis and Characterization of Particulate Matter using Scanning Electron Microscopy

This project has been developed to characterize particulate matter collected on two types of filters, mixed cellulose ester and silver membrane filters. SEM/EDX analysis of the mixed cellulose ester filters provided an understanding of the sources of particulate matter at the residential location. The morphology of the particles, with an aerodynamic diameter less than 10 μm , is consistent with cylindrical morphology usually observed from weathering processes. The elemental analysis suggests that the particles may consist of aluminum, silicon, carbon and oxygen, indicating origination from dust from weathering processes.

Characterizations of the particles collected on silver membranes provide insight into the source of pollution within the sampling areas. It should be noted that with previous sampling methods, for example on quartz filters, extensive sample preparation was needed. This sample preparation may have altered the morphology of the particles. However, the technique of collection on silver membranes provides a more accurate vision of the morphology and composition of the particles. Samples 5 and 6 (Figures 16 and 17a) clearly are spherical, with high carbon to oxygen ratios, which suggests the particulate originated from combustion sources, such as automobile exhaust.

This project clearly shows a more efficient mechanism for the collection of particulate matter. In contrast to EPA methods for particulate analysis, the preparation of samples for SEM/EDX analysis is quite simple and yet still reveals substantial morphology and elemental information of samples. SEM simulation demonstrates the depth of electron beam penetration for various elements. For samples coated with gold,

as in the mixed cellulose ester filters, the electron beam may not readily penetrate the bulk sample. Hence, the information provided concerning elemental analysis may not be accurate. For samples not coated with gold, the beam can easily penetrate the sample and provide adequate analysis for light elements such as carbon. This is truly significant considering particulate matter generated from automobile exhaust, which is primarily oxygen and carbon, is of concern for the health of the environment and humankind.

Further research in the area of environmental quality surveys can be done to investigate correlations in data sets. For example, it may be done through examining the locale of the industries in relation to USGS test sites to further investigate fate and transport of chemical pollutants. Further research may include the investigation of the degradation products of the chemical pollutants released by industries. As for SEM/EDX of particulate matter, studies may include further examination of particles collected in urban areas with high commuter and industrial traffic. The silver membranes used in this study were no longer being produced; therefore further research may implement the use of other filters in order to decrease preparation time. Finally, for the comparison of ionization methods and subsequent energy calculations using molecular modeling, other chemical pollutants could be examined, such as from cigarette smoke.

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APPENDIX 1

Experiment #1

Examining the pH of Various Food and Environmental Samples

Introduction

Throughout time, chemists have been able to identify acids by using common properties such as sour taste, color changes with indicators, and reactions with carbonate containing chemicals. Undoubtedly tasting chemicals is not a safe procedure, but you may recall the sour taste of vinegar or of citrus fruit.

Acids are substances that release hydrogen ions in an aqueous solution. A hydrogen atom consists of one electron and one proton, and is therefore neutral. When an electron is lost, the hydrogen acquires a positive charge, H^+ , and is sometimes referred to as a proton. A base is any compound that produces hydroxide ions, OH^- , in aqueous solutions. Bases, unlike acids, generally taste bitter. When dissolved in water, bases feel slippery and soapy.

Reactions of acids and bases are called neutralization reactions. During the reaction, the hydrogen ions from an acid combine with the hydroxide ions from the base to form water molecules. For complete neutralization, there is a need for equal concentrations of H^+ and OH^- . When a solution is acidic, the concentration of H^+ ions is greater than the concentration of OH^- ions. In basic solutions, the concentration of OH^- ions is more than H^+ ions.

The concept, pH, indicates the acidity of a solution. The value is between 0 and 14. As the pH value decreases the acidity increases. For example, a sample of rainwater may have a pH of 5 and is more acidic than a sample with a pH of 6. As the pH decreases by one unit, the acidity increases by a factor of ten (that is the

sample is ten times more acidic than the sample with a pH of 6). At pH 7, there is a separation between acidic and basic solutions. Solutions that have a pH less than 7 are acidic, and solutions that have pH greater than 7 are considered basic (or alkaline). If a solution has a pH of 7, then it is considered neutral.

Rain is only one of the several ways acids may be delivered to the earth. Acid deposition is another term, which may be used, and it represents fog, mist, and cloud-like suspensions containing microscopic water droplets. Snow may also deliver acid to the surface of the earth. The pH of rainwater or other aqueous solution is regularly determined using a pH meter. The device is a probe capped with an H^+ sensitive membrane that is immersed into the sample. The ions generate a voltage across the membrane, and the voltage is measured and converted to pH.

Why such a concern for acidic deposition? In the 1980s, the United States Congress sponsored a research effort called the National Acid Precipitation Assessment Program. With the aid of \$500 million, the project was completed in 1990 and a volume of reports was prepared. These reports detailed the damaging effects of acid rain on material, visibility, and human health. Sulfur dioxide and nitrogen oxides in the air may have led to an increase in deaths from lung disorders and an increase in the deterioration of cardiovascular systems in humans. Acid surface waters have lowered the survivability of animal and aquatic life in lakes and streams. Fish and other organisms may be completely eliminated due to acidity of bodies of water. In forests, leaching and depletion of natural nutrients in the soil has occurred. Tree growth is severely hampered, and there is an increase in insect infestation and winter injury. Deposition contributes to corrosion and deterioration

of buildings, monuments, and cars. Since many landmarks, such as the Lincoln Memorial, are made of limestone, which is composed of primarily calcium carbonate, they slowly dissolve in the presence of hydrogen ions. The Parthenon in Greece, the Taj Mahal in India, and the Mayan Ruins are showing signs of erosion, due to the nitrogen oxides produced by traffic. Sulfur dioxide and nitrogen oxides form sulfate and nitrate particles, which impair visibility. This is occurring in the Great Smokey Mountains National Park, where visibility on a clear day may be 100 miles, but on a hazy day the visibility may be less than 20 miles.

Pre Lab Questions

1. Indicate whether the following solutions are considered strongly acidic, weakly acidic, neutral, weakly basic, or strongly basic.
 - a. Orange juice, pH 4.5
 - b. Eggs, pH 7.5
 - c. Oven cleaner, pH 13.5
 2. Indicate whether each of the following properties corresponds to an acid or a base.
 - a. Sour taste
 - b. Slippery feel
 - c. pH greater than 7
 - d. pH equal to 7
 3. What is a neutralization reaction?
-
4. Define acid deposition.

Objectives

This lab is an introduction to the concept pH. You will be measuring the pH of common substances found in the laboratory and in the home. You will be collecting water samples from around the campus and measuring their pH as well. You will also examine the buffering effects in ponds and streams. Additionally, you will examine the effects of acids on metals.

Safety

Goggles and gloves should be worn in this laboratory.

Materials

Vinegar

Deionized Water

Ammonia

Assorted fresh fruits and fruit juices

Cola

Non-cola

Milk

Borax

Water samples taken from various sites (i.e. pond water, tap water, rain water)

Calcium carbonate (limestone)

Pennies (mint year prior to 1983) pH

meters and pH paper

Beakers

Spatula

Procedure

There are five sections to this procedure. Please read each section carefully. Please wear your safety goggles and gloves. You will be collecting water samples from the campus, so make sure that your collection containers are clean and dry. You may feel that it is necessary to construct tables for recording the pH of the samples.

1. Measuring pH

- i) Test the pH of three solutions containing vinegar and water, ammonia and water, and baking soda and water. Record and indicate in your results the amount used in each solution.
- ii) Record the pH of each sample using a pH meter, and also pH paper indicating acidic or basic for each sample in your results.

2. pH of Common Substances

- i) Test pH of fruit and fruit juice and record.
- ii) Label three beakers cola, non-cola, and milk. iii) Determine the pH and record your notebook.
- iv) Add to a fourth beaker small amount on end of spatula of borax to 60 mL water. Stir.
- v) Determine pH and record.

3. Measuring pH of Natural Waters

- i) If there is no water available, please obtain a plastic (clean and dry) container, and obtain water sample from the campus, preferably the school pond.
- ii) Determine the pH of the class's water samples.
- iii) Record the location of the sample, time and date the sample was obtained.

4. Observing Buffers in Lakes, Ponds, and Streams

- i) Label two beakers: vinegar and vinegar/limestone
- ii) Put 60 mL (1/4 cup) of limestone into one beaker
- iii) Pour 5 mL vinegar into 480 mL water. Stir and record pH
- iv) Pour 237 mL vinegar/water mixture over the limestone. Stir
- v) Pour remaining vinegar/water into the other beaker
- vi) Check and record the pH of the vinegar/water mixture over the limestone and the remaining vinegar/water solution.
- vii) Cover each beaker
- viii) Over a five day period, stir and record the pH

5. Looking at Acid's effects on Metals

- i) Label two beakers- water and vinegar (or lemon juice)
- ii) Place a penny in each (mint year before 1983)
- iii) Barely cover the penny with vinegar (or lemon juice)
- iv) Add water to cover the penny in the second beaker
- v) Record the pH
- vi) Cover
- vii) Observe next lab period and record the pH

Post Lab Questions-Please provide data and answers to these questions neatly on separate paper.

1. Summarize the findings for each section of the procedure. Construct data tables for each section of the procedure detailing the sample type and pH for the samples.
2. Why is distilled water not easily obtained (think about the gases that may dissolve in the water)?
3. You should have found that borax is alkaline. Explain why some people may find it useful for cleaning laundry?
4. What is a buffer? By examining your data, how can buffers be used to combat pollution in bodies of water such as lakes, streams, or ponds?
5. Describe acid rain and its effects in a brief paragraph. You may use your textbook or other source. Responses should be in your own words.
6. Since you have recorded the vegetation in the area where you collected the water sample, what affects may the water have on the surroundings? How would acid rain affect these plants and animals?
7. Nitric acid neutralizes a solution of ammonium hydroxide. Write the equation and label the acid, base, and resulting product.
8. Lemon juice has a pH of 2. What is the concentration of hydrogen ions?
9. The hydrogen ion concentration of vinegar is 0.100 M, what is the pH? If you were to increase the volume of vinegar in the solution, what would the resulting pH be (higher or lower)? Explain.

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Lesson Plan Examining the pH of Various Food and Environmental Samples

Goal

To introduce the students to the concept of pH and the effects of acids and bases in the environment

Objective

The students will be able to use Logger Pro equipped with Vernier pH probes to find the pH of various substances in order to classify samples based upon pH and to draw conclusions about the effects of acids and bases in the environment.

Warm-up and Focusing Activity

Students will participate in K-W-L activity

Steps:

1. As a class, identify what you know about pH
2. As a class, identify what you want to learn about pH
3. At the end of lab, identify what you have learned about pH

Time: 5 minutes

Materials: chalkboard

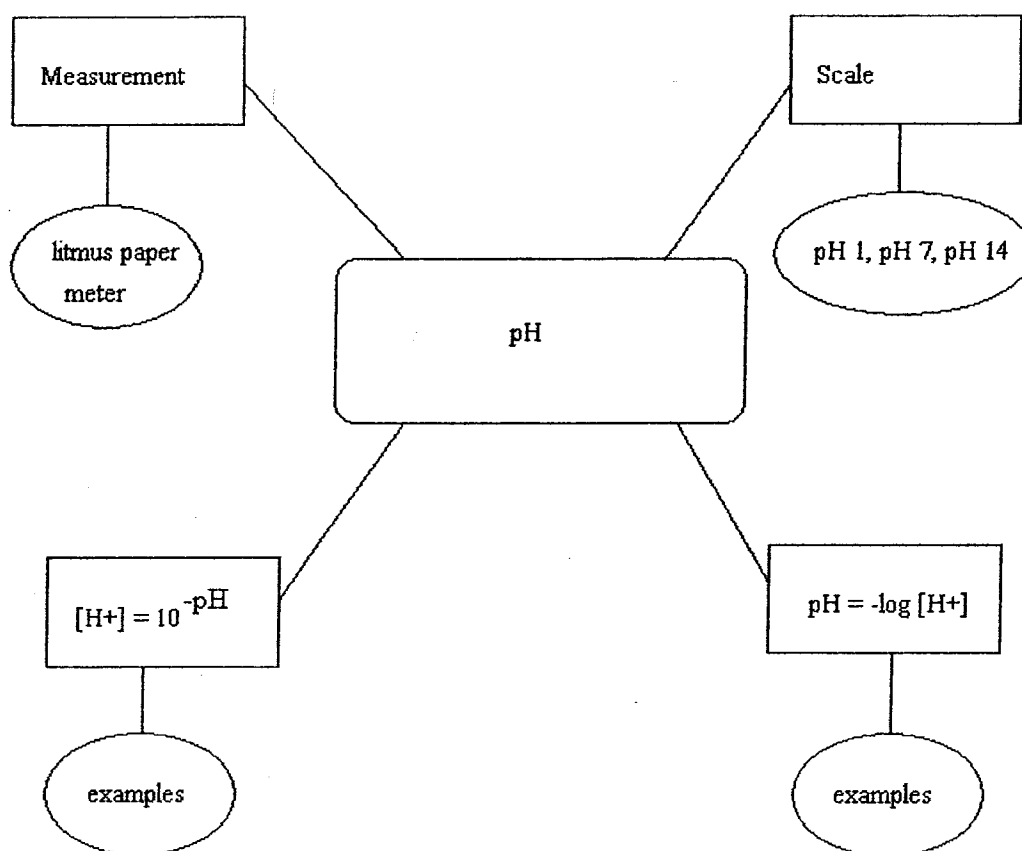
Introductory Activity

Topics to cover in introductory activities are the definitions of acids and bases, methods for measuring pH, and use of system analysis to investigate the effects in the environment.

Definitions of Acids and Bases: Arrhenius Acids and Bases, Bronsted-Lowry Acids and Bases, Lewis Acids and Bases

Methods for measuring pH: Litmus paper, pH meter or probe

Use of concept pattern to introduce the topics



Use of System Analysis to investigate the effects of acids and bases in the environment

System Analysis steps (students were asked the following questions):

What are the parts of the system?

What parts are related but not part of the system?

How do the parts influence each other?

What would happen if the parts stopped or changed?

Time: 20 minutes

Materials: chalkboard

Guided Activity

As a demonstration, pH measurements were obtained using oven cleaner as an example.

The students should obtain a food sample and find the pH level using litmus paper and the probes.

Time: 15 minutes

Materials: oven cleaner, litmus paper, pH probes and computer with Logger Pro, food and drink samples

Independent Activity

Students will complete the laboratory assignment with a partner and answer the post laboratory questions. The students will record the results for the natural water sample on the board for the class.

Time: 60-90 minutes

Materials: chalkboard, materials listed in lab procedure

Assessment

Pre laboratory and post laboratory questions

Closure

As a class the students will review the pH levels of the natural water samples. The class will also complete the K-W-L activity.

Time: 5 minutes

Materials: chalkboard

Experiment #2

Determining Partition Coefficients of Organic Pollutants

Introduction

Partition coefficients have been used in environmental science to predict the biological effects of organic compounds, toxicity effects, bioconcentration factors, and water solubility.^{1,2} Partition coefficients is a measurable quantity of how chemical substances become dispersed in systems.³ The systems may be living, such as the human body when investigating medicinal substances, or the systems may be environmental, such as water when examining pollutants in a body of water. Specifically, organic compounds have a partition coefficient that has been determined by examining the partitioning of the compound between 1-octanol and water. There has also been substantial research investigating partitioning of organic compounds between air and octanol.^{4,5}

There has been extensive exploration in the ability to determine partition coefficients in the laboratory. Although, there may exist serious problems with laboratory determined values. A primitive method for determining partition coefficients (Log P) is the shake flask method followed by instrumental analysis. In this method the chemical of interest is mixed with n-octanol and water and shaken until equilibrium is reached. The concentration of the compound is determined in each phase and Log P is calculated. If the Log P is larger than 4, the value is not as reliable.¹ Emulsions may form as a result of the shaking, and hence increasing the equilibrium time. On the other

hand, the stir flask method eliminates the possible formation of emulsions, but the equilibrium time is two to five days?

A generator column method for determining Log P overcomes the issues associated with the former methods. A column is filled with a solid support which is coated with water saturated octanol containing a known concentration of the analyte. Water is pumped through this column, and the appropriate data is obtained to determine the concentration of the analyte in the aqueous and octanol phase? As may be implied with this method, the hardware is elaborate and therefore, the method is relatively expensive.

Indirect Log P determinations and predictions may also be utilized. Leo and Hansch developed a mathematical model which allows for the prediction of Log P for substances.⁶ The method consists of determining the contribution of structural and functional groups to the overall Log P value. Although this method is useful for the prediction of Log P values, it is weak when dealing with unknown identities of pollutants, as well as substances that contain phosphorous and sulfur. Hence, for drug and pesticide analysis, the method is not suitable.

Chromatographic data can also be used in the determination of Log P of structurally similar compounds. By separating structurally similar compounds, the Log of retention time versus Log P can be used to predict the partitioning of similar compounds not analyzed via chromatography. Anderson found that reversed phase HPLC enabled the subsequent determination of Log P for a series of compounds.² There were outliers due to interactions between the solute methanol/water- and the

stationary phase-1-octanol substituted column.² Molecular modeling programs can also lead to indirect determinations of Log P for compounds.

Pre Lab Questions

1. Define in your own words partition coefficient.
2. Compare two methods for determining partition coefficients.
3. Why is Log P an important parameter when examining the fate and transport of BTEX compounds?
4. Do you believe that MTBE should be removed from gasoline? Support your position.

Objectives

In this exercise, you will utilize the CaChe molecular modeling program to investigate the Log P of the following organic pollutants-benzene, toluene, ethyl benzene, *ortho-xylene*, *meta-xylene*, and *para-xylene*. You will examine how structural differences may alter the Log P of these compounds. You will also examine the correlation between the Log P values (literature, shake flask method with refractometry, and Cache calculated values) to retention times obtained from Excel worksheet of Restak reported values.

Necessary data will available through email and handouts.

Materials

Computer with CaChe molecular modeling program installed

Operating procedures for molecular modeling program

Data obtained through email and handouts

Procedure

1. Using the modeling program, draw the following compounds, on the tool bar click beautify comprehensive for each compound and save with your initials and name of the compound.
 - a. toluene
 - b. ethylbenzene
 - c. benzene
 - d. *meta*-xylene
 - e. *ortho*-xylene
 - f. *para*-xylene
2. Print each structure and attach to post lab results and questions.
3. Open Project Leader Program.
4. Construct a table with the following headings-chemical sample, molecular weight, Log P CaChe, Log P Shake flask method, Log P literature value, and retention time 1, retention time 2, and retention time 3. The retention times are reported by Restak for three different columns. The instructor will demonstrate how to use project leader with the students.
5. Evaluate Log P CaChe and molecular weight for each compound.
6. To obtain the remaining data to be placed into the table, locate the information and complete the table using email documents and handouts.
7. Save the table with your first initial and last name.

8. Print one copy of the Project Leader table, attach to the results to be handed in to the instructor.
9. Using Project Leader, find the view window and print the scatter plot for your data. You should have 3 graphs, each comparing the Log P with retention times for each compound. Using the knowledge you have learned, decided which axis is Log P and which is retention time.

Post Laboratory Questions

1. Attach the Project Leader table and graphs to the post lab questions.
2. What is the relationship between Log P and retention time? Explain.
3. Is there a difference in the calculated Log P values and experimental Log P values? Explain.
4. Using your graphs, predict the Log P for 1,4-difluorobenzene that has a retention time of 19.061 on RTX-1 column.
5. Using CaChe, draw the following compounds chlorpyrifos, Diazinon, parathion, and ronnel. You will first need to use chemical literature to find the structures for these pesticides. Calculate Log P using CaChe. Explain the differences and similarities of these pesticides and the differences and/or similarities of Log P.
6. Why is Log P important when examining pesticides?
7. In the Baltimore county area in 2004, there was concern with the compound MTBE in well water supplies. Explain how log P could help scientists

determine the significance of this finding. Could this support the removal of MTBE from gasoline? Explain and support your argument.

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Lesson Plan The Determination of Partition Coefficients of Organic Pollutants

Goal

To introduce the students to the concept of partition coefficients and have them correlate the literature values, values reported via chromatography, values reported via shake flask experimentation, and values obtained using CaChe and Project Leader

Objective

The students will be able to use CaChe molecular modeling and Project Leader to find the partition coefficients for organic pollutants in order to describe relationships between structure, partitioning and retention times.

Warm-up and Focusing Attention

The following questions were asked and discussed as class during the warm-up. The students will be asked to review what they knew about stationary and mobile phases in chromatography. The class will be asked how partitioning relate to mobile and stationary phases.

Time: 5 minutes

Materials: chalkboard

Introductory Activity

The students should introduced to the organic nomenclature of the BTEX compounds. The students will also be asked to use chemfinder.com to find the structures of the compounds. The concepts of mobile and stationary phases will be reintroduced in order to include the examples of 1-octanol and water in respect with this activity. The teacher will describe the methods that have been used to calculate partition coefficients.

Time:20 minutes

Materials: chalkboard

Guided Activity

The teacher will demonstrate how to use the modeling program to draw a simple molecule such as methane. After the students have drawn the molecule, they will then be asked to draw benzene. The teacher will be walking around the room to inspect the progress of the students. After the students have drawn successfully benzene, the instructor will guide them through Project Leader for the calculations.

Time: 30 minutes

Materials: computer with CaChe molecular modeling and Project Leader programs

Independent Activity

After successfully using the program with the benzene example, the students will proceed through the remainder of the activity.

Time: 60-90 minutes

Materials: computer with CaChe Molecular modeling and Project Leader programs

Assessment

The teacher will be walking through the lab to ensure that the students are using the program correctly and drawing the correct compounds. Pre and post laboratory questions will be examined.

Closure

The teacher will ask the students what they learned in this activity and it's importance.

Time: 5 minutes

Materials: no materials

Part 1: Investigating the effects of UV Light and Sunscreen

Part 2: Investigating Detectors for Ozone and Carbon Dioxide

Introduction

Criteria Air Pollutants

Particulate matter, ozone, sulfur dioxide, nitrogen oxides, carbon monoxide and lead are six criteria air pollutants that are regulated by the EPA. These pollutants are persistent in the United States and are known or suspected to be harmful to public health and the environment.¹ As a result, maximum concentrations for the six criteria air pollutants have been instituted according to the NAAQS, National Ambient Air Quality Standards.

Carbon monoxide reduces the delivery of oxygen to organs and tissues upon entering the bloodstream. Therefore, carbon monoxide may impair visual perception, dexterity, and learning ability after exposure. In urban areas, vehicle exhaust may contribute to 77% of emissions. Wood burning stoves, incinerators, and industries also contribute to the emission of carbon monoxide. The NAAQS criteria for carbon monoxide is 9 ppm (8 hour average) and 35 ppm (1 hour average).²

Lead can be found in gasoline additives, non-ferrous smelters and battery manufacturing plants. In 1985, nearly 81% of lead emissions were due to transportation. After the removal of lead from gasoline, the emission by transportation sources decreased to 33% in 1993. This remaining percentage may originate from stationary source fuel combustion, incineration, steel mills and foundries, or aircraft fuel combustion. The emission standard for quarterly average for lead as instituted by NAAQS is 1.5 $\mu\text{g}/\text{m}^3$.^{1,3} Lead may cause damage to the nervous, reproductive, and digestive systems.

Nitrogen oxides are formed when fuels are burned at high temperatures.

Transportation and stationary combustion sources contribute to the emission of nitrogen oxides into the atmosphere. NAAQS criteria for NO_2 is 0.053 ppm (annual mean).⁴ Lung irritation, bronchitis, and pneumonia are health problems associated with the exposure to nitrogen oxides. NO_x play a crucial role in atmospheric reactions that produce ozone and acid rain.

Ozone in the upper atmosphere shields the earth from most of the ultraviolet rays of the sun. In contrast, ozone at ground level is a health and environmental concern. Ozone causes irreversible lung tissue damage and increases the likelihood of further damage to lung tissue by other irritants. In the presence of sunlight, precursor compounds such as volatile organic compounds (VOCs) and NO_x react to form ozone. Ultraviolet radiation and higher temperatures increase the probability of the formation of ozone. Ozone concentrations are higher during the summer months and in the early afternoon hours. Because of ozone removal by NO , the concentration is also higher in remote and suburban areas rather than in urban locations.⁶ Ozone concentrations also increase with increasing altitude. The NAAQS criteria for ozone is 0.12 ppm for 1-hour average and 0.08 ppm for 8-hour average.⁵

Ozone is a reactive compound, which can be easily detected by chemists. In fact, ozone reacts readily with potassium iodide to produce potassium hydroxide. In order to detect the presence of ozone at ground level, there is a medium needed in which a change can be observed. For instance, iodine when in the presence of corn starch turns a medium such as paper a shade of purple to blue. Starch iodide paper is readily available in the laboratory, but can be easily produced. By constructing an ozone detector with

potassium iodide and corn starch, a chemist can determine the presence of ozone in the troposphere.

Sulfur dioxide is a main contributor to acid rain. Sulfur dioxide and nitrogen oxides react with other substances in the atmosphere causing the formation of acidic compounds. During meteorological patterns, the acidic compounds are deposited via rain, fog, snow, or dust causing substantial damage to the environment. The presence of sulfur dioxide in the atmosphere causes visibility impairments such as those seen in national forests from the formation of particles from chemical reactions of SO_2 and NO_x . The acid rain also inhibits the ability of trees to grow and fight disease. Essential nutrients in the soil are depleted, causing a decrease in forest growth. Through acidification, there is an impairment of the ability certain types of fish and water plants to reproduce, grow, and survive. Property damage, due in part to sulfur dioxide, is another consequence of pollution. The corrosion of metals and the deterioration of stone and paint on structures may in part be due to acid rain. Stationary sources such as coal and oil fired power plants, paper and pulp mills and refineries contribute to sulfur dioxide emissions. Respiratory function and pre-existing respiratory conditions are irritated with exposure to SO_2 . The NAAQS criteria for sulfur dioxide for different averaging periods are 0.03 ppm for the annual mean, 0.14 ppm for the 24-hour average, and 0.50 ppm for the 3-hour average.⁷

Particulate matter (PM) is composed of solid or liquid aerosol particles, which are suspended in the air. In general, particulate matter includes dust, soot, dirt, smoke, and droplets of liquid emitted into the atmosphere. Fine particulate matter is present in two size fractions that are significant with regard to human health. $\text{PM}_{2.5}$ refers to particles that have an aerodynamic diameter less than $2.5 \mu\text{m}$ (micrometer, 10^{-6} m), and PM_{10}

refers to the particles with an aerodynamic diameter less than 10 μm . The current NAAQS criteria include annual and daily average standards of 50 $\mu\text{g}/\text{m}^3$ and 150 $\mu\text{g}/\text{m}^3$ for PM_{10} and 15 $\mu\text{g}/\text{m}^3$ and 65 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$, respectively.⁸ $\text{PM}_{2.5}$ are fine particles that originate from combustion sources such as automobiles and power plants. PM_{10} are also known as coarse particles. These coarse particles occur due to mechanical crushing, grinding, or abrasion of surfaces. PM_{10} may be suspended and dispersed by wind and anthropogenic activities. The particles in the particulate matter fraction may be inhaled into the lungs causing damage to the tissues and decreased respiratory function. Along with the other criteria air pollutants, particulate matter causes a decrease in visibility, deterioration of plant life and reduced crop yields.

UV Radiation and its Effects

Photons in the UV region of the electromagnetic spectrum have significant energy that enables them to excite electrons from atoms and molecules. Shorter UV wavelength photons are able to break bonds causing molecules to come apart. This is a significant effect in living things, in the matter that these changes disrupt cells potentially causing genetic defects and cancer. The stratospheric ozone layer provides a shield from the damaging effects of incoming UV radiation. Not only does the ozone layer in the stratosphere provide protection, but sunscreens are an additional way to protect the skin against damage.

The National Oceanographic and Atmospheric Administration, NOAA, report UV indices which provide guidelines for skin exposure to damaging rays depending on latitude, day of the year, time of day, amount of ozone above the area of interest, elevation, and predicted weather conditions. Table one illustrates the UV index and

exposure levels.

Table 1: UV Index

UV Index	Exposure Level	Minutes for damage to occur for light skinned individuals who never tan	Minutes for damage to occur for dark skinned individuals who never tan
0-2	Minimal	30	>120
3-4	Low	15-20	75-90
5-6	Moderate	10-12	50-60
7-9	High	7-8.5	33-40
10-15	Very high	4-6	20-30

Greenhouse Gases: Carbon Dioxide

Even though carbon dioxide is not considered a criteria air pollutant, it is an important gas when examining the phenomena, global warming. In addition to carbon dioxide, nitrous oxides and methane are also greenhouse gases that contribute to build up in the upper atmosphere and global changes in climate. Carbon dioxide emissions arise from combustion processes for transportation uses and energy uses. The effects of the rise in gases in the atmosphere include rises in temperature, disruption of climate patterns, and disruption in agriculture.

Just as with ozone, carbon dioxide can be readily detected in the laboratory using

indicators. Acid/base indicators, such as bromothymol blue, can be used to test for the presence and relative concentration of carbon dioxide in an air sample. The pH ranges from 6.0 (yellow) to 7.6 (blue). When carbon dioxide is present, carbonic acid is created, causing color changes from blue to green to yellow, depending upon the concentration of carbonic acid formed. By adding ammonia, the concentration of carbon dioxide can be estimated. The more drops of ammonia needed to be added to a solution to return the solution to the original blue, the more carbon dioxide present in the resulting solution.

Pre Lab Questions

1. The morning weather report indicates a UV index of 2. What does this mean regarding exposure levels and time it might take for a person to tan?
2. There are three categories of UV radiation-UV A, UV B and UV C. UV A is the least energetic with a wavelength of 320-400 nm. UV B is more energetic with a wavelength range of 280-320 nm. UV C is the most energetic with a wavelength range of 200-280 nm. The focus of attention regarding damaging is with UV A and UV B radiation. Why is the focus not on any possible damaging effects with UV C radiation?
3. Draw the reaction between ozone, potassium iodide and water. Make sure to balance the reaction.
4. Predict which activity will produce the most carbon dioxide. Rank from 1 (least) to 4 (most). In one to two paragraphs, support your answer.

Gas from your breath

Gas from the room

Gas from a chemical reaction of baking soda and vinegar

Gas from car exhaust

Objectives

This laboratory is divided into two sections. Part one, The Investigation of the Effects of UV Light and Sunscreen will be examined. You will be investigating the extent to which benzophenone interacts with UV radiation through absorption without sunscreen and with sunscreen applied to the test container. Part two, Investigating Detectors for Ozone and Carbon Dioxide, you will be designing, constructing, and utilizing detectors with available materials in the laboratory.

Safety

Safety goggles and gloves should be worn and used for this experiment. Signs should be prepared indicating the instructor's name and contact number for experimental apparatus for part one of the experiment.

Materials

Test tubes and rack
Stoppers
Aluminum foil
Isopropyl alcohol
Benzophenone
Glacial acetic acid
Sunscreen products
Ultraviolet lamp
Stirring rods
Spatulas
Erlenmeyer flasks
Funnel
Filter paper
Deionized water
Corn starch
Potassium iodide
250 mL beaker
Watch glass
Rubber policeman

Sealable plastic bags
Bromothymol blue
Ammonia (10% solution)
Distilled vinegar
Baking soda
Rubber tubing
Graduated cylinders
Pipets
Bottle
Air pump
Balloons and sizer (provided by instructor)

Procedure

Part 1: Investigating the effects of UV Light and Sunscreen

Weigh out 3 g of benzophenone and transfer into a large test tube. To the test tube, add 20 mL of isopropyl alcohol. Dissolve the benzophenone in hot water bath not to exceed 70°C. After the benzophenone has dissolved, add one drop of glacial acetic acid and stir. Fill the test tube with more isopropyl alcohol until the level is high enough to meet the bottom of a tight fitting stopper. If stoppers are unavailable, plastic wrap can be used. Repeat the procedure for one additional sample. One test tube will be the control, and the second will be coated uniformly with an available sunscreen product. Place the test tube rack to the source of UV light that you have chosen, making sure to include a sign for contact information and do not disturb. These will be provided by the instructor. After two hours, observe and record any changes. If there are changes, remove the rack and continue the experiment. After four hours remove the rack and continue the experiment. After returning to the laboratory, set up a gravity filtration system and filter the control and experimental tubes. Allow the paper to dry overnight, and record the mass of crystals obtained the following lab period. Access NOAA's website and record the UV index for the day.

Part 2: Investigating Detectors for Ozone and Carbon Dioxide

Carbon Dioxide Detector

Design an experiment to test for the presence of carbon dioxide in air from your breath, air from the room, and air from chemical reaction between vinegar and baking soda. The class will discuss the design as a group. To get you started, there should be control. The control is made by adding 10 mL water and 20 drops of bromothymol blue to a test tube and recording the color. Record observations-color changes and relative concentration of carbon dioxide in the samples.

Ozone Detector

Design the ozone detector using the information provided in the pre lab readings. Discuss your design with the instructor. After discussing, construct the detector and test the ozone level in your area for eight hours. After testing, wrap the detector in a paper towel and place in sealable bag. It is your decision for where you would like to test. Keep in mind you can wear these detectors. The detector should not be exposed to direct sunlight for long periods of time. Record the weather conditions for the day, as well as the ozone level for the day, which is available through NOAA and AIRNOW. After eight hours, compare the color of the detector to the scale available in the laboratory.

Post Lab Questions

1. Calculate the mass of the products collected on the filter paper for part one of the experiment. What is the UV index reported for the sample day?
2. How does the mass of the product in the control test tube compare to the test

- tube covered with the sunscreen product?
3. Explain in general terms what happens chemically in the test tube when the solution is exposed to ultraviolet light? How does this relate to the amount of product formed?
 4. In part two, you designed experiments for the detection ozone and carbon dioxide. Just as your laboratory assignments have done, write the procedure that you used to detect carbon dioxide and the procedure that you used to detect ozone. Do not use any pronouns.
 5. Prepare a data table for the detection of carbon dioxide in the four samples, include observations (color and drops of ammonia needed) and relative concentration of carbon dioxide. Rank the four activities from the most to the least carbon dioxide formed. How did this compare with your prediction in the pre lab questions?
 6. What was the level of ozone detected? How does this compare to the ozone level indicated by AIRNOW or NOAA? How would the weather conditions alter the levels of ozone detected?
 7. How does NO_x aid in the formation of ground level ozone?

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Lesson Plan Air Pollution-UV Radiation and Ground Level Ozone

Goal

To have the students develop a detector for the detection of ground level ozone.
To have students carry out a photochemical reduction of benzophenone to benzopinacol.

Objective

The students will be able to construct an ozone detector using their knowledge about indicators and criteria air pollutants in order to quantify a relative amount of ground level ozone in the Towson area. The students will be able to synthesize benzopinacol through photochemical reduction in order to determine yield.

Warm-Up and Focusing Attention

K-W-L activity:

1. Ask students what they know about ultraviolet light and its effects and the role of ozone?
2. Ask the students what they want to learn about ground level ozone and ultraviolet radiation?
3. At the end of the session, ask the students what they learned about ground level ozone and ultraviolet radiation?

Time: 5 minutes

Materials: Chalkboard

Introductory Activities

Topics to cover:

1. The difference between ground level ozone and ozone in the upper atmosphere
2. UV and exposure
3. Prediction of which source has higher carbon dioxide levels-breath, room air, or a chemical reaction between vinegar and baking soda

Time: 15 minutes

Materials: Chalkboard

Guided Activities

The teacher will guide the students through the development of a procedure for the detection of carbon dioxide in breath, room, and reaction between vinegar and carbon dioxide. The class will carry out each procedure as the teacher demonstrates.

Time: 30-45 minutes

Materials: balloons, vinegar, baking soda, pump, test tubes, test tube rack, 10% ammonia solution to determine relative amount of carbon dioxide in sample, bromothymol blue indicator, distilled water

Independent Activities

The students will complete the carbon dioxide section of the activity. The students will begin the UV portion of experiment by weighing out appropriate amount of benzophenone and dissolving in warm isopropanol into two test tubes. After dissolution,

the students will proceed by coating one tube with sunscreen product and leaving one tube uncoated. The tubes should be placed at the UV source overnight or until crystals form. After completion of part one of the UV activity, the students with a lab partner should develop the procedure for the ozone detector. After obtaining approval, the detector should be constructed. To finish the UV activity, the students should filter and weigh the crystals obtained. The students should also use the ozone handouts to quantify the level of ozone detected by their sampler.

Time: 1-2 hours preparation time, 8 hours sampling for ozone, up to 24 hours for photochemical reduction

Materials: ozone handouts, benzophenone, isopropanol, hot plates, beakers, test tubes, various sunscreen products, UV light source, filter paper, funnels, flasks, potassium iodide, liquid corn starch, rubber policeman, and stir rods

Assessment

Assessment will be done throughout the activity, as well as through pre- and post-laboratory questions.

Closure

The students will be asked what they learned throughout the activity about ozone and ultraviolet radiation. The class will also review their findings in the photochemical reduction of benzophenone.

Time: 5 minutes

Materials: none

EBAPS Instrument**Part 1**

DIRECTIONS: For each of the following items, please read the statement, and indicate (on the scantron answer sheet) the answer that describes how strongly you agree or disagree.

A: Strongly disagree B: Somewhat disagree C: Neutral D: Somewhat agree E: Strongly agree

1. Tamara just read something in her science textbook that seems to disagree with her own experiences. But to learn science well, Tamara shouldn't think about her own experiences; she should just focus on what the book says.
2. When it comes to understanding physics or chemistry, remembering facts isn't very important.
3. Obviously, computer simulations can predict the behavior of physical objects like comets. But simulations can also help scientists estimate things involving the behavior of *people*, such as how many people will buy new television sets next year.
4. When it comes to science, most students either learn things quickly, or not at all.
5. If someone is having trouble in physics or chemistry class, studying in a better way can make a big difference.
6. When it comes to controversial topics such as which foods cause cancer, there's no way for scientists to evaluate which scientific studies are the best. Everything's up in the air!
7. A teacher once said, "I don't *really* understand something until I teach it." But actually, teaching doesn't help a teacher understand the material better; it just reminds her of how much she already knows.
8. Scientists should spend almost all their time gathering information. Worrying about theories can't really help us understand anything.
9. Someone who doesn't have high natural ability can still learn the material well even in a hard chemistry or physics class.
10. Often, a scientific principle or theory just doesn't make sense. In those cases, you have to accept it and move on, because not everything in science is supposed to

make sense.

11. When handing in a physics or chemistry test, you can generally have a sense of how well you did even before talking about it with other students.
12. When learning science, people can understand the material better if they relate it to their own ideas.
13. If physics and chemistry teachers gave *really clear* lectures, with plenty of real-life examples and sample problems, then most good students could learn those subjects without doing lots of sample questions and practice problems on their own.
14. Understanding science is really important for people who design rockets, but not important for politicians.
15. When solving problems, the key thing is knowing the methods for addressing each particular type of question. Understanding the “big ideas” might be helpful for specially-written problems, but not for most regular problems.
16. Given enough time, almost everybody could learn to think more scientifically, if they really wanted to.
17. To understand chemistry and physics, the formulas (equations) are really the main thing; the other material is mostly to help you decide which equations to use in which situations.

Part 2

DIRECTIONS: *Multiple choice. On the answer sheet, fill in the answer that best fits your view.*

18. If someone is trying to learn physics, is the following a good kind of question to think about?

Two students want to break a rope. Is it better for them to (1) grab opposite ends of the rope and pull (like in tug-of-war), or (2) tie one end of the rope to a wall and both pull on the other end together?

- (a) *Yes, definitely.* It’s one of the best kinds of questions to study.
- (b) *Yes, to some extent.* But other kinds of questions are equally good.
- (c) *Yes, a little.* This kind of question is helpful, but other kinds of questions are more helpful.
- (d) *Not really.* This kind of question isn’t that great for learning the main ideas.
- (e) *No, definitely not.* This kind of question isn’t helpful at all.

19. Scientists are having trouble predicting and explaining the behavior of thunder storms. This could be because thunder storms behave according to a very complicated or hard-to-apply set of rules. Or, that could be because some thunder storms don't behave consistently according to *any* set of rules, no matter how complicated and complete that set of rules is.

In general, why do scientists sometimes have trouble explaining things? Please read all options before choosing one.

- (a) Although things behave in accordance with rules, those rules are often complicated, hard to apply, or not fully known.
 - (b) Some things just don't behave according to a consistent set of rules.
 - (c) Usually it's because the rules are complicated, hard to apply, or unknown; but sometimes it's because the thing doesn't follow rules.
 - (d) About half the time, it's because the rules are complicated, hard to apply, or unknown; and half the time, it's because the thing doesn't follow rules.
 - (e) Usually it's because the thing doesn't follow rules; but sometimes it's because the rules are complicated, hard to apply, or unknown.
20. In physics and chemistry, how do the most important formulas relate to the most important concepts? Please read all choices before picking one.
- (a) The major formulas summarize the main concepts; they're not really separate from the concepts. In addition, those formulas are helpful for solving problems.
 - (b) The major formulas are kind of "separate" from the main concepts, since concepts are *ideas*, not equations. Formulas are better characterized as problem-solving tools, without much conceptual meaning.
 - (c) Mostly (a), but a little (b).
 - (d) About half (a) and half (b).
 - (e) Mostly (b), but a little (a).
21. To be successful at *most things in life*...
- (a) Hard work is much more important than inborn natural ability.
 - (b) Hard work is a little more important than natural ability.
 - (c) Natural ability and hard work are equally important.
 - (d) Natural ability is a little more important than hard work.
 - (e) Natural ability is much more important than hard work.

22. To be successful at *science*...
- (a) Hard work is much more important than inborn natural ability.
 - (b) Hard work is a little more important than natural ability.
 - (c) Natural ability and hard work are equally important.
 - (d) Natural ability is a little more important than hard work.
 - (e) Natural ability is much more important than hard work.
23. Of the following test formats, which is best for measuring how well students understand the material in physics and chemistry? Please read each choice before picking one.
- (a) A large collection of short-answer or multiple choice questions, each of which covers one specific fact or concept.
 - (b) A small number of longer questions and problems, each of which covers several facts and concepts.
 - (c) Compromise between (a) and (b), but leaning more towards (a).
 - (d) Compromise between (a) and (b), favoring both equally.
 - (e) Compromise between (a) and (b), but leaning more towards (b).

Part 3

DIRECTIONS: *In each of the following items, you will read a short discussion between two students who disagree about some issue. Then you'll indicate whether you agree with one student or the other*

24.

Brandon: A good science textbook should show how the material in one chapter relates to the material in other chapters. It shouldn't treat each topic as a separate "unit," because they're not really separate.

Jamal: But most of the time, each chapter is about a different topic, and those different topics don't always have much to do with each other. The textbook should keep everything separate, instead of blending it all together.

With whom do you agree? Read all the choices before circling one.

- (a) I agree almost entirely with Brandon.
- (b) Although I agree more with Brandon, I think Jamal makes some good points.
- (c) I agree (or disagree) equally with Jamal and Brandon.
- (d) Although I agree more with Jamal, I think Brandon makes some good points.
- (e) I agree almost entirely with Jamal.

25.

Anna: I just read about Kay Kinoshita, the physicist. She sounds naturally brilliant.

Emily: Maybe she is. But when it comes to being good at science, hard work is more important than “natural ability.” I bet Dr. Kinoshita does well because she has worked really hard.

Anna: Well, maybe she did. But let’s face it, some people are just smarter at science than other people. Without natural ability, hard work won’t get you anywhere in science!

- (a) I agree almost entirely with Anna.
- (b) Although I agree more with Anna, I think Emily makes some good points.
- (c) I agree (or disagree) equally with Anna and Emily.
- (d) Although I agree more with Emily, I think Anna makes some good points.
- (e) I agree almost entirely with Emily.

26.

Justin: When I’m learning science concepts for a test, I like to put things in my own words, so that they make sense to me.

Dave: But putting things in your own words doesn’t help you learn. The textbook was written by people who know science really well. You should learn things the way the textbook presents them.

- (a) I agree almost entirely with Justin.
- (b) Although I agree more with Justin, I think Dave makes some good points.
- (c) I agree (or disagree) equally with Justin and Dave.
- (d) Although I agree more with Dave, I think Justin makes some good points.
- (e) I agree almost entirely with Dave.

27.

Julia: I like the way science explains how things I see in the real world.

Carla: I know that’s what we’re “supposed” to think, and it’s true for many things. But let’s face it, the science that explains things we do in lab at school can’t really explain earthquakes, for instance. Scientific laws work well in some situations but not in most situations.

Julia: I still think science applies to almost all real-world experiences. If we can’t figure out how, it’s because the stuff is very complicated, or because we don’t know enough science yet.

- (a) I agree almost entirely with Julia.
- (b) I agree more with Julia, but I think Carla makes some good points.

- (c) I agree (or disagree) equally with Carla and Julia.
- (d) I agree more with Carla, but I think Julia makes some good points.
- (e) I agree almost entirely with Carla.

28.

Leticia: Some scientists think the dinosaurs died out because of volcanic eruptions, and others think they died out because an asteroid hit the Earth. Why can't the scientists agree?

Nisha: Maybe the evidence supports both theories. There's often more than one way to interpret the facts. So we have to figure out what the facts mean.

Leticia: I'm not so sure. In stuff like personal relationships or poetry, things can be ambiguous. But in science, the facts speak for themselves.

- (a) I agree almost entirely with Leticia.
- (b) I agree more with Leticia, but I think Nisha makes some good points.
- (c) I agree (or disagree) equally with Nisha and Leticia.
- (d) I agree more with Nisha, but I think Leticia makes some good points.
- (e) I agree almost entirely with Nisha.

29.

Jose: In my opinion, science is a little like fashion; something that's "in" one year can be "out" the next. Scientists regularly change their theories back and forth.

Miguel: I have a different opinion. Once experiments have been done and a theory has been made to explain those experiments, the matter is pretty much settled. There's little room for argument.

- (a) I agree almost entirely with Jose.
- (b) Although I agree more with Jose, I think Miguel makes some good points.
- (c) I agree (or disagree) equally with Miguel and Jose.
- (d) Although I agree more with Miguel, I think Jose makes some good points.
- (e) I agree almost entirely with Miguel.

30.

Jessica and Mia are working on a homework assignment together...

Jessica: O.K., we just got problem #1. I think we should go on to problem #2.

Mia: No, wait. I think we should try to figure out why the thing takes so long to reach the ground.

Jessica: Mia, we know it's the right answer from the back of the book, so what are you worried about? If we didn't understand it, we wouldn't have gotten the right answer.

Mia: No, I think it's possible to get the right answer without really understanding what it means.

- (a) I agree almost entirely with Jessica.
- (b) I agree more with Jessica, but I think Mia makes some good points.
- (c) I agree (or disagree) equally with Mia and Jessica.
- (d) I agree more with Mia, but I think Jessica makes some good points.
- (e) I agree almost entirely with Mia.

APPENDIX 2

Table 26: Top three TRI chemical releases to air in Davidson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	methanol	455020	hydrochloric acid	295628	sulfuric acid	154823
2001	methanol	543703	hydrochloric acid	308196	sulfuric acid	137599
2000	methanol	469380	hydrochloric acid	284262	acetaldehyde	197318
1999	methanol	547233	hydrochloric acid	239225	acetaldehyde	165035
1998	methanol	564811	hydrochloric acid	395662	acetaldehyde	224385
1997	methanol	581500	dichloromethane	503208	hydrochloric acid	430000
1996	methanol	452150	hydrochloric acid	270000	trichloroethylene	169077
1995	hydrochloric acid	700000	methanol	452450	1,1,1-trichloroethane	259167
1994	hydrochloric acid	701000	methanol	600000	1,1,1-trichloroethane	380409
1993	hydrochloric acid	671000	1,1,1-trichloroethane	484966	acetone	315290
1992	hydrochloric acid	576755	1,1,1-trichloroethane	404846	methanol	347005
1991	1,1,1-trichloroethane	1060178	hydrochloric acid	540780	acetone	291747
1990	1,1,1-trichloroethane	1299637	acetone	549607	hydrochloric acid	406380
1989	methanol	2019800	1,1,1-trichloroethane	1854480	acetone	715385
1988	1,1,1-trichloroethane	1718212	acetone	792242	methanol	561000

Table 27: Top three TRI chemical releases to land in Davidson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	62439	copper	29346	lead compounds	25815
2001	dicabromodiphenyl oxide	18137	antimony compounds	7599	zinc compounds	1219
2000	dicabromodiphenyl oxide	14599	antimony compounds	8963		
1999	dicabromodiphenyl oxide	11279	antimony compounds	1997	zinc compounds	1179
1996	ammonia	4788	---a	---a	---a	---a
1995	ammonia	6775	---a	---a	---a	---a
1994	certain glycol ethers	2978	ammonia	2000	---a	---a
1993	ammonia	4500	chromium	250	nickel	250
1992	ammonia	2450	chromium	250	nickel	250
1991	1,1,1-trichloroethane	360	chromium	250	n-butyl alcohol	3200
1990	hydrochloric acid	21010	ammonia	3000	1,1,1-trichloroethane	255
1989	chromium compounds	250	---a	---a	---a	---a
1988	aluminum oxide (fibrous)	180000	manganese compounds	35000	terephthalic acid	26000

^aBlank cells indicate that data not available because less than three chemicals were released

Table 28: Top three TRI chemical releases to water in Davidson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	ethylene glycol	109285	nitrate compounds	106971		
2000	zinc compounds	36000	ethylene glycol	23650	o-xylene	2360
1999	zinc compounds	19000	ethylene glycol	12376	cobalt compounds	1766
1998	methanol	40000	zinc compounds	28000	1,4-dioxane	7377
1997	ethylene glycol	3850	manganese compounds	1400	cobalt compounds	1200
1996	ammonia	11000	cobalt compounds	1100	ethylene glycol	750
1995	zinc compounds	32000	ammonia	5400	cobalt compounds	1300
1994	zinc compounds	33000	manganese compounds	3200	cobalt compounds	3200
1993	zinc compounds	34000	ammonia	9000	cobalt compounds	2000
1992	2-methoxyethanol	120000	ammonia	7800	1,4-dioxane	3400
1991	2-methoxyethanol	250000	ammonia	8500	cobalt compounds	1500
1990	manganese compounds	2300	ammonia	2200	cobalt compounds	2200
1989	ethylene glycol	22000	zinc compounds	10000	manganese compounds	800
1988	ethylene glycol	23000	aluminum oxide (fibrous)	6800	p-xylene	900

Table 29: USGS water quality data for top three chemicals detected in Davidson County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 17'39"/86° 41'45"	1990	Surface	zinc	290 µg/L	lead	48 µg/L	chromium	43 µg/L
36° 17'39"/86° 41'45"	1990	Surface	zinc	110 µg/L	lead	14 µg/L	chromium	14 µg/L
36° 17'39"/86° 41'45"	1992	Surface	zinc	170 µg/L	lead	32 µg/L	copper	16 µg/L
36° 17'39"/86° 41'45"	1992	Surface	zinc	130 µg/L	lead	15 µg/L	copper	12 µg/L
36° 09'07.93"/86° 39'00.59"	1990	Surface	zinc	10 µg/L	lead	5 µg/L	copper	3 µg/L
36° 09'07.93"/86° 39'00.59"	1990	Surface	zinc	140 µg/L	lead	43 µg/L	chromium	24 µg/L
36° 09'07.93"/86° 39'00.59"	1991	Surface	zinc	40 µg/L	copper	38 µg/L	lead	8 µg/L
36° 09'07.93"/86° 39'00.59"	1991	Surface	zinc	20 µg/L	copper	10 µg/L	lead	5 µg/L
36° 09'07.93"/86° 39'00.59"	1992	Surface	zinc	100 µg/L	copper	9 µg/L	chromium	6 µg/L
36° 07'02" /86° 43'37"	1990	Surface	zinc	20 µg/L	phenol	<5.0 µg/L	copper	3 µg/L
36° 07'02" /86° 43'37"	1990	Surface	zinc	190 µg/L	lead	34 µg/L	copper	12 µg/L
36° 07'02" /86° 43'37"	1990	Surface	zinc	110 µg/L	lead	27 µg/L	copper	9 µg/L
36° 07'02" /86° 43'37"	1990	Surface	zinc	130 µg/L	phenol	<5.0 µg/L	chromium	3 µg/L
36° 05'39"/ 86° 47'38"	1992	Surface	zinc	<10 µg/L	phenol	<5.0 µg/L	chromium	4 µg/L

Table 29: USGS water quality data for top three chemicals detected in Davidson County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 05'39"/ 86° 47'38"	1992	Surface	zinc	<10 µg/L	copper	2 µg/L	nickel	1 µg/L
36° 05'39"/ 86° 47'38"	1992	Surface	zinc	20 µg/L	lead	5 µg/L	nickel	3 µg/L
36° 05'39"/ 86° 47'38"	1992	Surface	zinc	20 µg/L	phenol	<5 µg/L	copper	3 µg/L
36° 08'39"/86° 45'04"	1990	Surface	zinc	170 µg/L	lead	25 µg/L	copper	19 µg/L
36° 08'39"/86° 45'04"	1990	Surface	zinc	340 µg/L	lead	68 µg/L	copper	47 µg/L
36° 08'39"/86° 45'04"	1990	Surface	zinc	320 µg/L	lead	54 µg/L	copper	38 µg/L
36° 08'39"/86° 45'04"	1990	Surface	zinc	380 µg/L	lead	73 µg/L	copper	39 µg/L
36° 08'39"/86° 45'04"	1990	Surface	zinc	360 µg/L	lead	37 µg/L	copper	34 µg/L
36° 08'39"/86° 45'04"	1990	Surface	zinc	300 µg/L	lead	43 µg/L	copper	22 µg/L
36° 11'46"/ 86° 41'25"	1989	Well	manganese	3900 µg/L	zinc	41 µg/L	copper	2 µg/L
36° 11'46"/ 86° 41'25"	1990	Well	manganese	4200 µg/L	zinc	22 µg/L	phenol	<5 µg/L
36° 18'24.64"/86° 48'00.70"	1990	Surface	zinc	<10 µg/L	phenol	<5 µg/L	copper	2 µg/L
36° 18'24.64"/86° 48'00.70"	1990	Surface	zinc	10 µg/L	phenol	<5 µg/L	copper	4 µg/L
36° 03'10"/86° 46'19"	1989	Well	nitrite and nitrate	0.51 mg/L	ammonia	<0.20 mg/L	manganese	<10 µg/L
36° 09'02"/86° 54'04"	1989	Well	nitrite and nitrate	4.80 mg/L	manganese	<10 µg/L	---	---

Table 30: Top three TRI chemical releases to air in Sumner County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	hydrochloric acid	758817	--- ^a	--- ^a	--- ^a	--- ^a
2001	hydrochloric acid	1608817	toluene	417985	sulfuric acid	150005
2000	hydrochloric acid	4308817	sulfuric acid	550005	toluene	517676
1999	hydrochloric acid	4708817	toluene	980624	sulfuric acid	780005
1998	hydrochloric acid	2300005	toluene	1000038	sulfuric acid	790005
1997	toluene	725264	xylenes	92691	methanol	81169
1996	toluene	1238292	methanol	136390	n-butyl alcohol	34038
1995	toluene	1500599	methanol	151705	xylenes	145734
1994	toluene	1453610	methanol	170705	n-butyl alcohol	46723
1993	toluene	1370456	xylenes	209621	methanol	182160
1992	toluene	1302790	xylenes	165001	methanol	154151
1991	toluene	1685439	methanol	132554	xylenes	131076
1990	toluene	1689089	xylenes	179655	methanol	170479
1989	toluene	2546654	xylenes	230986	methanol	152815
1988	toluene	2815249	xylenes	248321	methanol	169183

^aBlank cells indicate that data not available because less than three chemicals were released

Table 31: Top three TRI chemical releases to land in Sumner County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	barium compounds	1468850	--- ^a	--- ^a	--- ^a	--- ^a
2001	barium compounds	1202000	vanadium compounds	100250	manganese compounds	98250
2000	barium compounds	748000	vanadium compounds	201000	zinc compounds	156000
1999	barium compounds	837000	copper compounds	154000	zinc compounds	154000
1998	barium compounds	660000	zinc compounds	140000	manganese compounds	138000
1995	phosphoric acid	29033	--- ^a	--- ^a	--- ^a	--- ^a
1990	nickel compounds	250	copper compounds	250	--- ^a	--- ^a
1988	hydrochloric acid	4800	--- ^a	--- ^a	--- ^a	--- ^a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 32: Top three TRI chemical releases to water in Sumner County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	barium compounds	8600	vanadium compounds	3800	manganese compounds	3600
2000	vanadium compounds	10000	barium compounds	7700	manganese compounds	3100
1999	barium compounds	9000	manganese compounds	8600	copper compounds	2000
1998	barium compounds	22000	manganese compounds	5900	nickel compounds	2700
1997	zinc compounds	250	---a	---a	---a	---a
1996	zinc compounds	19	copper	19	copper compounds	5
1995	zinc compounds	161	copper	9	lead compounds	8
1994	copper	11	copper compounds	5	---a	---a
1993	copper	8	copper compounds	5	---a	---a
1992	styrene	100	acetone	100	copper compounds	5
1991	styrene	120	acetone	120	copper compounds	5

^aBlank cells indicate that data not available because less than three chemicals were released

Table 33: USGS water quality data for top three chemicals detected in Sumner County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 26'27"/86° 28'38"	1989	Well	nitrite and nitrate	2.00 mg/L	manganese	<10 µg/L	nitrite	<0.01 mg/L

Table 34: Top three TRI chemical releases to air in Rutherford County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	xylenes	459898	methyl ethyl ketone	384669	methyl isobutyl ketone	356381
2001	xylenes	344470	certain glycol ethers	326997	styrene	129536
2000	methyl isobutyl ketone	545244	certain glycol ethers	431621	styrene	291322
1999	certain glycol ethers	445484	styrene	386179	xylenes	375026
1998	certain glycol ethers	545366	styrene	369470	xylenes	318535
1997	certain glycol ethers	694843	xylenes	375318	methyl isobutyl ketone	343204
1996	certain glycol ethers	595239	xylenes	408655	styrene	391894
1995	certain glycol ethers	760444	xylenes	652403	methyl isobutyl ketone	542855
1994	certain glycol ethers	918809	xylenes	799093	styrene	320114
1993	certain glycol ethers	772827	xylenes	946262	acetone	369150
1992	xylenes	1247275	certain glycol ethers	997320	acetone	388971
1991	certain glycol ethers	834484	xylenes	776522	methanol	361474
1990	certain glycol ethers	944820	xylenes	759663	methyl isobutyl ketone	565672
1989	certain glycol ethers	918790	acetone	766714	toluene	607596
1988	methanol	937888	certain glycol ethers	842928	acetone	632659

Table 35: Top three TRI chemical releases to land in Rutherford County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	214543	nickel compounds	8739	--- ^a	--- ^a
2001	nickel	250	chromium	250	manganese	250
2000	chromium	250	manganese	250	nickel	250
1999	chromium	250	manganese	250	nickel	250
1998	chromium	5	--- ^a	--- ^a	--- ^a	--- ^a
1996	nickel	250	chromium	250	--- ^a	--- ^a
1995	nickel	750	chromium	750	--- ^a	--- ^a
1994	toluene	30289	xylenes	2221	--- ^a	--- ^a
1993	toluene	25685	xylenes	2569	copper	102
1992	toluene	24292	copper	102	--- ^a	--- ^a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 36: Top three TRI chemical releases to water in Rutherford County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	nitrate compounds	81	zinc compounds	50	ammonia	20
2000	nitrate compounds	300	nickel compounds	250	zinc compounds	69
1999	ammonia	470	nitrate compounds	260	zinc compounds	254
1998	nitrate compounds	290	zinc compounds	255	nickel compounds	250
1997	zinc compounds	60	nickel	5	---	---
1996	zinc compounds	60	copper	10	---	---
1995	copper	20	nickel	6	zinc (fume or dust)	6
1994	copper	16	zinc (fume or dust)	6	---	---
1993	copper	16	zinc (fume or dust)	6	---	---
1991	---	---	---	---	---	---
1990	copper	100	---	---	---	---
1989	copper	5	---	---	---	---
1988	zinc compounds	250	---	---	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 37: USGS water quality data for top three chemicals detected in Rutherford County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 52'16"/86° 25'53"	2001	Surface	nickel	1 µg/L	copper	0.3 µg/L	lead	0.2 µg/L
35° 52'08"/86° 28'04"	1989	Well	manganese	10 µg/L	--- ^a	--- ^a	--- ^a	--- ^a
35° 51'37"/86° 24'38"	2000	Surface	copper	2.9 µg/L	chromium	1.4 µg/L	nickel	0.4 µg/L
35° 51'37"/86° 24'38"	2001	Surface	chromium	3.4 µg/L	nickel	1.1 µg/L	copper	0.5 µg/L
35° 51'37"/86° 24'38"	2001	Surface	chromium	2 µg/L	nickel	0.3 µg/L	copper	0.3 µg/L
35° 51'37"/86° 24'38"	2001	Surface	chromium	4 µg/L	nickel	2.1 µg/L	copper	0.8 µg/L
35° 53'05"/86° 25'25"	2000	Surface	copper	5.3 µg/L	chromium	2.2 µg/L	nickel	0.2 µg/L
35° 53'05"/86° 25'25"	2001	Surface	copper	2.6 µg/L	nickel	1.1 µg/L	arsenic	0.5 µg/L
35° 53'05"/86° 25'25"	2001	Surface	chromium	2 µg/L	nickel	0.5 µg/L	copper	0.4 µg/L
35° 53'05"/86° 25'25"	2001	Surface	copper	2 µg/L	nickel	1.5 µg/L	arsenic	1.2 µg/L
35° 53'19"/86° 25'26"	2000	Surface	copper	4.4 µg/L	chromium	1.8 µg/L	lead	0.5 µg/L
35° 53'19"/86° 25'26"	2001	Surface	chromium	3.2 µg/L	nickel	1.2 µg/L	copper	0.7 µg/L
35° 53'19"/86° 25'26"	2001	Surface	chromium	2 µg/L	copper	0.7 µg/L	nickel	0.4 µg/L
35° 53'19"/86° 25'26"	2001	Surface	chromium	3 µg/L	nickel	2 µg/L	copper	0.8 µg/L

Table 38: Top three TRI chemical releases to air in Williamson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	N-methyl-2-pyrrolidine	29054	phenol	11556	xylenes	5825
2001	N-methyl-2-pyrrolidine	30747	phenol	7250	xylenes	4386
2000	N-methyl-2-pyrrolidine	40918	certain glycol ethers	39400	xylenes	5975
1999	N-methyl-2-pyrrolidine	39617	toluene	19951	phenol	11943
1998	N-methyl-2-pyrrolidine	52347	phenol	34403	n-butyl alcohol	19644
1997	xylenes	65965	phenol	64800	N-methyl-2-pyrrolidine	36726
1996	xylenes	97200	phenol	66514	N-methyl-2-pyrrolidine	23339
1995	xylenes	113499	phenol	77349	N-methyl-2-pyrrolidine	12911
1994	xylenes	86741	phenol	44035	toluene	15670
1993	xylenes	77179	phenol	34763	acetone	27600
1992	xylenes	69022	phenol	32355	acetone	22100
1991	xylenes	126401	acetone	52896	toluene	46814
1990	toluene	115634	xylenes	78477	phenol	43137
1989	xylenes	118428	toluene	89266	acetone	68151
1988	toluene	110094	methyl ethyl ketone	72867	xylenes	70167

Table 39: Top three TRI chemical releases to land in Williamson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	lead	490000	copper	3439	---	---
1991	lead	18800	---	---	---	---
1990	lead	4200	---	---	---	---
1989	lead	12600	---	---	---	---
1988	lead	40000	---	---	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 40: Top three TRI chemical releases to water in Williamson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	copper	9	---	---	---	---
2000	copper	6	---	---	---	---
1999	copper	9	---	---	---	---
1998	copper	12	---	---	---	---
1997	copper	28	phenol	13	---	---
1996	copper	25	phenol	18	lead	5
1995	sulfuric acid	5	lead	5	copper	2
1994	lead	5	copper	1	---	---
1993	copper	6	lead	5	---	---
1992	lead	5	---	---	---	---
1991	lead	5	---	---	---	---
1990	toluene	250	lead	250	---	---
1989	lead	250	---	---	---	---
1988	toluene	250	lead	250	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 41: USGS water quality data for top three chemicals detected in Williamson County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 52'59"/86° 48'38"	1989	Surface	nitrite and nitrate	0.40 mg/L	manganese	20 µg/L	---a	---a
35° 53'50"/87° 08'50"	1990	Ground	barium	<100 µg/L	manganese	<10 µg/L	zinc	<10 µg/L
35° 53'51"/86° 53'13"	1989	Well	barium	13 µg/L	zinc	9 µg/L	manganese	2 µg/L
35° 53'51"/86° 53'13"	1990	Well	zinc	29 µg/L	barium	14 µg/L	manganese	9 µg/L
35° 56'16"/86° 58'20"	1989	Well	nitrite and nitrate	0.30 mg/L	manganese	20 µg/L	---a	---a
35° 59'17"/86° 41'11"	1988	Surface	ammonia	0.110 mg/L	manganese	6 µg/L	---a	---a
35° 59'24"/86° 41'14"	1988	Surface	nitrite and nitrate	0.650 mg/L	manganese	19 µg/L	---a	---a
35° 59'24"/86° 41'14"	1988	Surface	nitrite and nitrate	2.2 mg/L	manganese	<10 µg/L	---a	---a
35° 59'29"/86° 41'38"	1988	Surface	ammonia	0.30 mg/L	manganese	94 µg/L	---a	---a
35° 59'29"/86° 41'38"	1989	Surface	ammonia	0.55 mg/L	manganese	40 µg/L	---a	---a
35° 59'13"/86° 41'25"	1988	Surface	ammonia	1.8 mg/L	nitrite and nitrate	1.5 mg/L	manganese	93 µg/L
35° 59'13"/86° 41'25"	1988	Surface	nitrite and nitrate	2.70 mg/L	ammonia	0.52 mg/L	manganese	10 µg/L
35° 59'13"/86° 41'25"	1989	Surface	nitrite and nitrate	1.40 mg/L	ammonia	0.33 mg/L	manganese	100 µg/L
35° 59'14"/86° 41'20"	1988	Surface	nitrite and nitrate	1.40 mg/L	ammonia	0.64 mg/L	manganese	10 µg/L
35° 59'14"/ 86° 41'20"	1988	Surface	nitrite and nitrate	0.37 mg/L	ammonia	0.20 mg/L	manganese	10 µg/L
35° 59'14"/86° 41'21"	1988	Well	ammonia	2.8 mg/L	manganese	10 µg/L	---a	---a
35° 59'14"/86° 41'21"	1989	Well	ammonia	0.51 mg/L	nitrite and nitrate	0.18 mg/L	manganese	30 µg/L

Table 41: USGS water quality data for top three chemicals detected in Williamson County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 58'56"/86° 41'24"	1989	Surface	ammonia	0.34 mg/L	manganese	10 µg/L	---	---
35° 58'57"/86° 41'23"	1988	Well	ammonia	0.83 mg/L	nitrite and nitrate	0.61 mg/L	manganese	10 µg/L
35° 58'57"/86° 41'23"	1989	Well	ammonia	0.21 mg/L	nitrite and nitrate	0.21 mg/L	manganese	10 µg/L
35° 59'10"/86° 41'29"	1988	Surface	nitrite and nitrate	0.83 mg/L	ammonia	0.20 mg/L	manganese	4 µg/L
35° 58'54"/86° 41'22"	1988	Well	ammonia	0.70 mg/L	manganese	18 µg/L	---	---
35° 56'31"/87° 09'04"	1989	Well	zinc	12 µg/L	barium	10 µg/L	copper	2 µg/L
35° 56'31"/87° 09'04"	1990	Well	zinc	13 µg/L	barium	11 µg/L	copper	2 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 42: Top three TRI chemical releases to air in Shelby County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	ammonia	3917660	toluene	1742978	hydrochloric acid	693791
2001	ammonia	3998694	toluene	2203569	hydrochloric acid	667384
2000	ammonia	3859248	toluene	1765420	hydrochloric acid	724084
1999	ammonia	4937608	toluene	1514783	hydrochloric acid	719523
1998	ammonia	5549762	toluene	1118374	methanol	676309
1997	ammonia	5418443	toluene	1049391	n-hexane	913999
1996	ammonia	4557521	toluene	1630197	n-hexane	1063909
1995	ammonia	4299698	toluene	1865878	methanol	1041643
1994	sulfuric acid	7196192	ammonia	4897657	toluene	2218148
1993	ammonia	4568212	toluene	2400388	methanol	718501
1992	ammonia	7929723	toluene	2371267	methanol	960923
1991	ammonia	4467605	acetone	3582828	methanol	2217940
1990	ammonia	3866379	toluene	1877503	methanol	1327328
1989	toluene	2177565	methanol	1525420	methyl methacrylate	398801
1988	ammonia	3585420	acetone	2272996	toluene	2129611

Table 43: Top three TRI chemical releases to land in Shelby County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	asbestos (friable)	307200	styrene	125033	ethylene glycol	65016
2001	barium compounds	380005	zinc compounds	150005	manganese compounds	16000
2000	barium compounds	700005	zinc compounds	170005	manganese compounds	30000
1999	barium compounds	180030	zinc compounds	110005	manganese compounds	6100
1998	ammonia	540030	zinc compounds	95005	manganese compounds	12000
1997	xylenes	11160	pentachlorophenol	5047	ammonia	279
1996	barium compounds	18959	ammonia	279	formaldehyde	6
1995	xylenes	5300	methanol	250	barium compounds	25
1994	ethylene glycol	250	ammonia	200	barium	15
1993	xylenes	5148	methanol	1705	ethylene glycol	250
1992	sulfuric acid	740	ethylene glycol	250	hydrazine	5
1991	toluene	3850	ammonia	52	zinc compounds	26
1990	lead	440000	antimony	24000	sulfuric acid	8300
1989	sulfuric acid	13000	naphthalene	250	anthracene	250
1988	zinc compounds	250	ammonia	57	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 44: Top three TRI chemical releases to water in Shelby County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	ammonia	10193	zinc compounds	6291	nitrate compounds	5500
2000	nitrate compounds	10000	ammonia	8342	barium compounds	4465
1999	barium compounds	4144	ammonia	3081	nitrate compounds	2900
1998	manganese compounds	15250	barium compounds	4350	ammonia	2746
1997	ammonia	3501	zinc compounds	1019	toluene	60
1996	zinc compounds	13770	ammonia	6532	diethanolamine	1830
1995	nitrate compounds	32828	zinc compounds	9204	ammonia	6331
1994	diethanolamine	5641	ammonia	5601	methanol	1630
1993	ammonia	5001	diethanolamine	3981	methanol	2618
1992	ammonium sulfate	229638	methyl methacrylate	17001	methanol	6004
1991	ammonium sulfate	212624	methyl methacrylate	14625	methanol	7224
1990	ammonium sulfate	240000	methyl methacrylate	20200	methanol	8150
1989	ammonium sulfate	220000	methyl methacrylate	20000	methanol	7500
1988	ammonium sulfate	184000	ammonia	39005	methyl methacrylate	21000

Table 45: USGS water quality data for top three chemicals detected in Shelby County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°00'53"/90°07'08"	1992	Surface	barium	62 µg/L	manganese	9 µg/L	--- ^a	--- ^a
35°00'54"/90°08'04"	1992	Surface	manganese	360 µg/L	--- ^a	--- ^a	--- ^a	--- ^a
35°01'00"/90°07'03"	1992	Surface	barium	68 µg/L	manganese	10 µg/L	--- ^a	--- ^a
35°01'00"/90°07'03"	1995	Surface	barium	61 µg/L	manganese	9.7 µg/L	--- ^a	--- ^a
35°01'00"/90°07'03"	1996	Surface	barium	71 µg/L	manganese	9 µg/L	--- ^a	--- ^a
35°01'00"/90°07'03"	1997	Surface	barium	67.5 µg/L	manganese	9.7 µg/L	--- ^a	--- ^a
35°01'00"/90°07'03"	1998	Surface	barium	65 µg/L	manganese	8.7 µg/L	--- ^a	--- ^a
35°01'00"/90°07'03"	1999	Surface	barium	67.5 µg/L	manganese	18.5 µg/L	--- ^a	--- ^a
35°01'00"/90°07'03"	2001	Surface	barium	56.2 µg/L	manganese	9.5 µg/L	--- ^a	--- ^a
35°01'14"/90°07'03"	1992	Surface	barium	39 µg/L	manganese	2 µg/L	--- ^a	--- ^a
35°20'36"/89°53'45"	1989	Surface	barium	230 µg/L	manganese	140 µg/L	copper	2 µg/L
35°20'36"/89°53'45"	1990	Surface	barium	250 µg/L	manganese	150 µg/L	copper	2 µg/L
35°20'01"/89°52'48"	1995	Surface	barium	75 µg/L	manganese	74 µg/L	--- ^a	--- ^a
35°20'01"/89°52'48"	1995	Surface	barium	120 µg/L	manganese	50 µg/L	--- ^a	--- ^a
35°20'27"/89°51'26"	1995	Surface	barium	120 µg/L	manganese	62 µg/L	--- ^a	--- ^a
35°20'32"/89°51'14"	1995	Surface	barium	39 µg/L	manganese	14 µg/L	--- ^a	--- ^a
35°20'32"/89°51'15"	1995	Surface	manganese	690 µg/L	barium	140 µg/L	--- ^a	--- ^a
35°20'01"/89°52'48"	1995	Surface	barium	110 µg/L	manganese	36 µg/L	--- ^a	--- ^a
35°10'54"/89°51'53"	1998	Surface	barium	36.4 µg/L	manganese	9.9 µg/L	--- ^a	--- ^a
35°10'54"/89°51'53"	1999	Surface	barium	36.4 µg/L	manganese	11.2 µg/L	--- ^a	--- ^a
35°10'54"/89°51'53"	2000	Surface	barium	34.6 µg/L	manganese	10.5 µg/L	--- ^a	--- ^a
35°10'54"/89°51'53"	2001	Surface	barium	34.6 µg/L	manganese	11.7 µg/L	--- ^a	--- ^a
35°08'12"/89°50'59"	1989	Surface	manganese	130 µg/L	barium	77 µg/L	copper	1 µg/L
35°08'12"/89°50'59"	1990	Surface	manganese	190 µg/L	barium	87 µg/L	copper	1 µg/L

Table 45: USGS water quality data for top three chemicals detected in Shelby County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°09'10"/90°01'41"	2000	Surface	barium	37.5 µg/L	manganese	4.7 µg/L	--- ^a	--- ^a
35°09'13"/90°10'08"	1991	Surface	barium	50 µg/L	manganese	8 µg/L	--- ^a	--- ^a
35°09'13"/90°10'08"	2001	Surface	barium	44.7 µg/L	manganese	35.4 µg/L	--- ^a	--- ^a
35°08'04"/89°50'41"	1989	Surface	manganese	1000 µg/L	barium	330 µg/L	xylenes	0.5 µg/L
35°08'04"/89°50'41"	1990	Surface	manganese	1300 µg/L	barium	290 µg/L	xylenes	1.0 µg/L
35°08'07"/89°51'11"	1989	Surface	manganese	220 µg/L	barium	140 µg/L	copper	1 µg/L
35°08'10"/89°50'35"	1989	Surface	manganese	1600 µg/L	barium	170 µg/L	toluene	0.3 µg/L
35°08'10"/89°50'35"	1990	Surface	manganese	1500 µg/L	barium	150 µg/L	toluene	0.8 µg/L
35°07'58"/89°51'01"	1989	Surface	manganese	160 µg/L	barium	61 µg/L	xylenes	6.7 µg/L
35°07'58"/89°51'01"	1990	Surface	manganese	310 µg/L	barium	150 µg/L	lead	1 µg/L
35°08'03"/89°49'59"	1989	Surface	barium	150 µg/L	manganese	1 µg/L	copper	1 µg/L
35°08'04"/89°50'37"	1989	Surface	manganese	190 µg/L	barium	87 µg/L	copper	3 µg/L
35°08'04"/89°50'37"	1990	Surface	manganese	240 µg/L	barium	86 µg/L	toluene	0.2 µg/L
35°08'04"/89°50'35"	1989	Surface	manganese	1900 µg/L	barium	1400 µg/L	toluene	0.2 µg/L
35°08'04"/89°50'35"	1990	Surface	manganese	1600 µg/L	barium	1300 µg/L	copper	1 µg/L
35°07'49"/89°50'53"	1989	Surface	manganese	130 µg/L	barium	43 µg/L	xylenes	13 µg/L
35°07'49"/89°50'53"	1990	Surface	manganese	250 µg/L	barium	38 µg/L	lead	2 µg/L
35°07'49"/89°50'58"	1989	Surface	manganese	120 µg/L	barium	77 µg/L	copper	2 µg/L
35°07'49"/89°50'58"	1990	Surface	manganese	200 µg/L	barium	86 µg/L	copper	1 µg/L
35°07'58"/89°51'01"	1989	Surface	manganese	2200 µg/L	barium	140 µg/L	copper	2 µg/L
35°07'58"/89°51'01"	1990	Surface	manganese	1000 µg/L	barium	66 µg/L	copper	1 µg/L
35°07'42"/89°50'29"	1989	Surface	manganese	190 µg/L	barium	64 µ/L	xylenes	1.4 µg/L
35°07'42"/89°50'29"	1990	Surface	manganese	84 µg/L	barium	51 µg/L	copper	1 µg/L
35°07'49"/89°50'53"	1989	Surface	manganese	1100 µg/L	barium	59 µg/L	--- ^a	--- ^a
35°07'49"/89°50'53"	1990	Surface	manganese	750 µg/L	barium	47 µg/L	copper	1 µg/L

Table 45: USGS water quality data for top three chemicals detected in Shelby County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°07'39"/89°50'27"	1989	Surface	manganese	2800 µg/L	barium	130 µg/L	copper	1 µg/L
35°07'41"/89°49'09"	1988	Surface	barium	70 µg/L	manganese	15 µg/L	---a	---a
35°07'41"/89°49'09"	1989	Surface	barium	60 µg/L	manganese	59 µg/L	copper	2 µg/L
35°07'41"/89°49'09"	1990	Surface	manganese	310 µg/L	barium	40 µg/L	lead	1 µg/L
35°05'07"/89°48'24"	1990	Surface	barium	18 µg/L	copper	2 µg/L	---a	---a
35°05'07"/89°48'24"	1991	Surface	barium	18 µg/L	copper	3 µg/L	---a	---a
35°06'25"/89°55'49"	1992	Surface	barium	25 µg/L	manganese	21 µg/L	---a	---a
35°06'42"/89°55'50"	1988	Surface	barium	21 µg/L	manganese	7 µg/L	---a	---a
35°06'42"/89°55'50"	1989	Surface	barium	25 µg/L	manganese	5 µg/L	---a	---a
35°06'42"/89°55'50"	1990	Surface	barium	21 µg/L	manganese	8 µg/L	---a	---a
35°06'42"/89°55'50"	1991	Surface	barium	20 µg/L	manganese	8 µg/L	---a	---a
35°06'42"/89°55'50"	1992	Surface	barium	20 µg/L	manganese	9 µg/L	---a	---a
35°06'42"/89°55'50"	1993	Surface	barium	20 µg/L	manganese	9 µg/L	---a	---a
35°06'42"/89°55'50"	1994	Surface	barium	20 µg/L	manganese	10 µg/L	---a	---a
35°06'42"/89°55'50"	1995	Surface	barium	22 µg/L	manganese	10 µg/L	---a	---a
35°06'42"/89°55'50"	1996	Surface	barium	22.2 µg/L	manganese	11.4 µg/L	---a	---a
35°06'42"/89°55'50"	1997	Surface	barium	22.8 µg/L	manganese	12.3 µg/L	---a	---a
35°06'42"/89°55'50"	1998	Surface	barium	23.9 µg/L	manganese	14.8 µg/L	---a	---a
35°06'42"/89°55'50"	1999	Surface	barium	20 µg/L	manganese	14 µg/L	---a	---a
35°06'42"/89°55'50"	2000	Surface	barium	23.9 µg/L	manganese	15.6 µg/L	---a	---a
35°06'42"/89°55'50"	2001	Surface	manganese	27.1 µg/L	---a	---a	---a	---a
35°02'13"/90°07'57"	1992	Surface	barium	330 µg/L	manganese	420 µg/L	---a	---a
35°01'56"/90°07'26"	1992	Surface	barium	95 µg/L	manganese	17 µg/L	---a	---a
35°02'07"/90°07'27"	1992	Surface	barium	140 µg/L	manganese	<10 µg/L	---a	---a

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 46: Top three TRI chemical releases to air in Madison County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	582625	--- ^a	--- ^a	--- ^a	--- ^a
2001	zinc compounds	64708	ammonia	33000	methyl ethyl ketone	25671
2000	zinc compounds	84589	ammonia	36000	methyl ethyl ketone	27150
1999	zinc compounds	89457	xylenes	25748	certain glycol ethers	16800
1998	zinc compounds	88492	xylenes	23729	ammonia	23583
1997	zinc compounds	40920	xylenes	27915	zinc (fume or dust)	23817
1996	xylenes	41422	methyl isobutyl ketone	28147	zinc compounds	21481
1995	zinc compounds	42547	xylenes	42371	methyl isobutyl ketone	26577
1994	zinc compounds	36188	xylenes	23730	methyl isobutyl ketone	19448
1993	zinc compounds	40074	methyl isobutyl ketone	36250	xylenes	25837
1992	zinc compounds	38544	ammonia	36000	methyl isobutyl ketone	24040
1991	toluene	72794	zinc compounds	36567	bromomethane	17900
1990	toluene	152255	zinc compounds	40042	styrene	17282
1989	toluene	76900	xylenes	33748	zinc compounds	29340
1988	zinc compounds	42955	xylenes	31021	ammonia	13730

Table 47: Top three TRI chemical releases to land in Madison County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	161854	lead compounds	22231	manganese compounds	13878
2001	zinc compounds	529317	barium compounds	269070	manganese compounds	70576
2000	zinc compounds	492412	barium compounds	250309	manganese compounds	65655
1999	zinc compounds	209907	lead compounds	82958	copper compounds	38752
1997	aluminum (fume or dust)	10	---a	---a	---a	---a
1996	manganese	10	---a	---a	---a	---a
1994	di-(2ethylhexyl)phthalate	729	---a	---a	---a	---a
1993	methyl isobutyl ketone	8000	methyl ethyl ketone	4000	zinc compounds	187
1992	copper	1600	---a	---a	---a	---a
1991	zinc compounds	69800	barium compounds	2800	chromium compounds	1300
1990	manganese compounds	74393	chromium compounds	34008	copper compounds	19130
1989	aluminum oxide (fibrous)	1110985	manganese compounds	345080	chromium compounds	14475
1988	aluminum oxide (fibrous)	803620	chromium compounds	38205	nickel compounds	14645

^aBlank cells indicate that data not available because less than three chemicals were released

Table 48: Top three TRI chemical releases to water in Madison County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	zinc compounds	3414	lead compounds	415	copper compounds	276
2000	zinc compounds	1588	ammonia	250	lead compounds	197
1999	zinc compounds	669	ammonia	250	lead compounds	86
1998	zinc compounds	1392	nickel compounds	295	ammonia	250
1997	certain glycol ethers	8200	zinc compounds	908	nickel compounds	308
1996	zinc compounds	2254	copper compounds	452	lead compounds	438
1995	zinc compounds	1088	lead compounds	365	copper compounds	348
1994	zinc compounds	391	copper compounds	24	lead compounds	24
1993	copper compounds	255	zinc compounds	20	chromium compounds	6
1992	copper compounds	180	zinc compounds	19	---a	---a
1991	copper compounds	180	2-ethoxyethanol	121	barium compounds	97
1990	zinc compounds	191	---a	---a	---a	---a
1989	zinc compounds	250	---a	---a	---a	---a
1988	aluminum oxide (fibrous)	1000	zinc compounds	250	---a	---a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 49: USGS water quality data for top three chemicals detected in Madison County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°35'38"/88°48'52"	1990	Surface	manganese	110 µg/L	zinc	55 µg/L	barium	21 µg/L
35°32'24"/88°49'51"	1990	Surface	barium	17 µg/L	copper	5 µg/L	manganese	3 µg/L
35°36'11"/88°48'16"	1989	Surface	manganese	200 µg/L	barium	50 µg/L	lead	20 µg/L
35°36'12"/88°51'52"	1992	Surface	barium	4 µg/L	copper	3 µg/L	---a	---a
35°36'20"/88°47'45"	1989	Surface	barium	100 µg/L	manganese	3 µg/L	---a	---a
35°36'20"/88°47'45"	1990	Surface	barium	100 µg/L	lead	10 µg/L	manganese	2 µg/L
35°36'27"/88°50'11"	1992	Surface	manganese	1600 µg/L	barium	99 µg/L	nickel	15 µg/L
35°36'27"/88°50'11"	1992	Surface	manganese	260 µg/L	barium	70 µg/L	zinc	14 µg/L
35°36'27"/88°50'11"	1992	Surface	barium	57 µg/L	manganese	6 µg/L	nickel	2 µg/L
35°38'16"/88°47'55"	1989	Surface	zinc	60 µg/L	---a	---a	---a	---a
35°38'16"/88°47'55"	1989	Surface	zinc	60 µg/L	---a	---a	---a	---a
35°40'09"/88°50'03"	1989	Surface	zinc	30 µg/L	barium	14 µg/L	manganese	1 µg/L
35°40'09"/88°50'03"	1989	Surface	zinc	30 µg/L	barium	15 µg/L	---a	---a
35°36'39"/88°50'23"	1992	Surface	manganese	2300 µg/L	barium	76 µg/L	zinc	14 µg/L
35°36'39"/88°50'23"	1992	Surface	barium	51 µg/L	manganese	29 µg/L	zinc	7 µg/L
35°36'39"/88°50'23"	1992	Surface	barium	17 µg/L	zinc	8 µg/L	manganese	6 µg/L
35°36'43"/88°49'01"	1992	Surface	barium	49 µg/L	zinc	6 µg/L	manganese	3 µg/L
35°38'14"/88°48'02"	1989	Ground	zinc	40 µg/L	barium	30 µg/L	manganese	3 µg/L
35°38'15"/88°47'49"	1989	Surface	barium	26 µg/L	copper	20 µg/L	zinc	10 µg/L
35°36'27"/88°50'16"	1992	Surface	manganese	72 µg/L	barium	60 µg/L	zinc	11 µg/L
35°36'27"/88°50'16"	1992	Surface	manganese	80 µg/L	zinc	27 µg/L	barium	25 µg/L
35°36'28"/88°50'05"	1992	Surface	manganese	130 µg/L	barium	61 µg/L	zinc	14 µg/L
35°36'28"/88°50'05"	1992	Surface	manganese	49 µg/L	zinc	45 µg/L	barium	39 µg/L
35°36'34"/88°48'54"	1989	Surface	barium	46 µg/L	zinc	30 µg/L	manganese	1 µg/L

Table 49: USGS water quality data for top three chemicals detected in Madison County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°36'34"/88°48'54"	1989	Surface	barium	46 µg/L	zinc	30 µg/L	lead	10 µg/L
35°36'37"/88°50'22"	1992	Surface	zinc	160 µg/L	manganese	34 µg/L	barium	33 µg/L
35°36'27"/88°50'11"	1992	Surface	barium	74 µg/L	zinc	18 µg/L	manganese	15 µg/L
35°36'27"/88°50'11"	1992	Surface	barium	44 µg/L	zinc	19 µg/L	manganese	3 µg/L
35°36'27"/88°50'11"	1992	Surface	barium	32 µg/L	manganese	31 µg/L	zinc	8 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 50: Top three TRI chemical releases to air, land, and water in Fayettee County, Tennessee

Air Release						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	styrene	41906	cumene hydroperoxide	5080	methylmethacrylate	1139
2001	styrene	57609	cumene hydroperoxide	3935	dicyclopentadiene	1000
2000	styrene	57796	ammonia	4800	cumene hydroperoxide	4535
1999	styrene	65745	ammonia	21740	cumene hydroperoxide	6000
1998	styrene	64317	ammonia	10200	cumene hydroperoxide	7000
1997	styrene	65661	cumene hydroperoxide	6600	decarbromodiphenyloxide	2900
1996	styrene	70881	cumene hydroperoxide	6400	decarbromodiphenyloxide	3400
1995	styrene	54972	cumene hydroperoxide	6900	decarbromodiphenyloxide	1000
1994	styrene	62900	cumene hydroperoxide	15500	decarbromodiphenyloxide	3500
1993	styrene	57100	acetone	42901	cumene hydroperoxide	17500
1992	styrene	26900	acetone	7450	ammonia	2850
1991	xylenes	77000	styrene	61050	acetone	20300
1990	xylenes	66000	styrene	44672	acetone	23977
1989	styrene	52865	acetone	31293	dichloromethane	10184
1988	styrene	62100	acetone	56359	lead	8900
Land Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2000	N-hexane	10	methyl tert butyl ether	10	xylenes	10
1988	lead	48000	antimony	4800	arsenic	4800
Water Release						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2000	N-hexane	5	methyl tert butyl ether	5	xylenes	5

Table 51: USGS water quality data for top three chemicals detected in Fayette County, Tennessee

Latitude/ Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°02'53"/ 89°32'39"	1989	Well	lead	2 µg/L	---	---	---	---
35°02'53"/ 89°32'39"	1990	Well	lead	1 µg/L	---	---	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 52: Top three TRI chemical releases to air in Tipton County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	certain glycol ethers	6013	1,2,4-trimethylbenzene	379	---	---
2001	certain glycol ethers	1576	chlorodifluoromethane	750	1,2,4-trimethylbenzene	552
2000	methanol	12836	certain glycol ethers	1407	1,2,4-trimethylbenzene	978
1999	styrene	3090	chlorodifluoromethane	606	phenol	500
1998	methanol	44164	styrene	2658	chlorodifluoromethane	523
1997	methanol	58418	styrene	2816	chlorodifluoromethane	544
1996	methanol	56752	styrene	3445	certain glycol ethers	1000
1995	methanol	50836	styrene	3726	certain glycol ethers	1000
1994	methanol	37150	styrene	10604	toluene	7968
1993	acetone	207887	toluene	15570	styrene	13676
1992	acetone	216601	toluene	23968	styrene	15497
1991	acetone	288133	toluene	47393	ammonia	35000
1990	acetone	152754	dichloromethane	76310	toluene	51966
1989	acetone	151462	dichloromethane	76690	toluene	63780
1988	acetone	94880	dichloromethane	60415	toluene	39120

^aBlank cells indicate that data not available because less than three chemicals were released

Table 53: Top three TRI chemical releases to land in Tipton County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	copper	191	copper	2	---	---
2001	copper	191	---	---	---	---
2000	copper	191	---	---	---	---
1999	copper	1	---	---	---	---
1998	copper	1	---	---	---	---
1997	copper	1	---	---	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 54: Top three TRI chemical releases to water in Tipton County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
1994	copper	250	antimony	5	phenol	5
1993	copper	250	--- ^a	--- ^a	--- ^a	--- ^a
1991	manganese compounds	94300	phenol	5	--- ^a	--- ^a
1990	manganese compounds	107649	zinc compounds	5	--- ^a	--- ^a
1989	manganese	29741	manganese compounds	29741	--- ^a	--- ^a
1988	sulfuric acid	1519753	sodium hydroxide solution	306435	hydrochloric acid	151233

^aBlank cells indicate that data not available because less than three chemicals were released

Table 55: USGS water quality data for top three chemicals detected in Tipton County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°30'36"/89°58'29"	1990	Well	manganese	1100 µg/L	zinc	100 µg/L	--- ^a	--- ^a
35°30'36"/89°58'29"	1990	Well	manganese	1200 µg/L	zinc	21 µg/L	--- ^a	--- ^a
35°33'44"/89°38'58"	1989	Well	manganese	10 µg/L	zinc	8 µg/L	copper	2 µg/L
35°33'44"/89°38'58"	1990	Well	manganese	10 µg/L	zinc	6 µg/L	copper	1 µg/L
35°36'58"/89°38'52"	1989	Well	manganese	40 µg/L	--- ^a	--- ^a	--- ^a	--- ^a

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 56: Top three TRI chemical releases to air in Haywood County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	di(2-ethylhexyl)phthalate	1428	phthalic anhydride	290	--- ^a	--- ^a
2001	di(2-ethylhexyl)phthalate	1079	phthalic anhydride	380	zinc compounds	95
2000	di(2-ethylhexyl)phthalate	5048	phthalic anhydride	497	zinc compounds	107
1999	di(2-ethylhexyl)phthalate	1056	phthalic anhydride	461	zinc compounds	56
1998	di(2-ethylhexyl)phthalate	1346	phthalic anhydride	315	zinc compounds	212
1997	xylenes	15295	di(2-ethylhexyl)phthalate	1314	phthalic anhydride	438
1996	xylenes	16616	n-butyl alcohol	9991	di(2-ethylhexyl)phthalate	1986
1995	xylenes	32487	n-butyl alcohol	11866	di(2-ethylhexyl)phthalate	2503
1994	xylenes	34033	n-butyl alcohol	11284	di(2-ethylhexyl)phthalate	635
1993	xylenes	33322	n-butyl alcohol	12067	certain glycol ethers	4413
1992	toluene	17970	1,1,1,-trichloroethane	6000	phthalic anhydride	597
1991	toluene	54023	xylenes	29731	1,1,1-trichloroethane	15000
1990	xylenes	164357	toluene	37086	copper	500
1989	xylenes	160238	toluene	12913	phthalic anhydride	2400
1988	xylenes	209079	toluene	9000	phthalic anhydride	4358

^aBlank cells indicate that data not available because less than three chemicals were released

Table 57: Top three TRI chemical releases to land in Haywood County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	216	---	---	---	---
2001	chromium compounds	5	nickel compounds	5	copper compounds	5
2000	chromium compounds	5	copper	5	manganese	5
1993	di(2-ethylhexyl)phtalate	400	---	---	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 58: Top three TRI chemical releases to water in Haywood County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	di(2-ethylhexyl)phthalate	276	zinc compounds	166	antimony compounds	43
2000	di(2-ethylhexyl)phthalate	121	zinc compounds	109	antimony compounds	29
1999	zinc compounds	141	di(2-ethylhexyl)phthalate	42	barium compounds	23
1998	zinc compounds	302	di(2-ethylhexyl)phthalate	137	lead compounds	35
1997	zinc compounds	321	di(2-ethylhexyl)phthalate	50	lead compounds	39
1996	zinc compounds	141	barium compounds	28	n-butyl alcohol	18
1995	zinc compounds	314	di(2-ethylhexyl)phthalate	59	lead compounds	28
1994	di(2-ethylhexyl)phthalate	36	bis(2-ethylhexyl)adipate	22	lead compounds	6
1993	di(2-ethylhexyl)phthalate	20	antimony compounds	10	bis(2-ethylhexyl)adipate	6
1992	di(2-ethylhexyl)phthalate	14	zinc compounds	4	butyl benzyl phthlate	4
1991	di(2-ethylhexyl)phthalate	5	---	---	---	---
1990	bis(2-ethylhexyl)adipate	878	di(2-ethylhexyl)phthalate	15	---	---
1989	bis(2-ethylhexyl)adipate	1900	di(2-ethylhexyl)phthalate	18	---	---
1988	bis(2-ethylhexyl)adipate	1039	di(2-ethylhexyl)phthalate	21	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 59: USGS water quality data for top three chemicals detected in Haywood County, Tennessee

Latitude/ Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°36'23"/89°11'19"	1989	Well	manganese	<10 µg/L	---	---	---	---
35°35'23"/89°15'41"	1989	Well	barium	5 µg/L	copper	2 µg/L	lead	<1 µg/L
35°35'23"/89°15'41"	1990	Well	barium	6 µg/L	lead	3 µg/L	copper	2 µg/L
35°36'52"/89°18'13"	1989	Well	manganese	<10 µg/L	---	---	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 60: Top three TRI chemical releases to air in Knox County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	styrene	557729	methyl methacrylate	70408	---	---
2001	styrene	542175	zinc compounds	47540	methyl methacrylate	45099
2000	styrene	613920	zinc compounds	62894	methyl methacrylate	53816
1999	styrene	404153	zinc compounds	73411	hydrofluoric acid	28390
1998	styrene	465061	toluene	61848	zinc compounds	42322
1997	styrene	402486	methyl ethyl ketone	56038	toluene	49293
1996	styrene	362462	toluene	66141	zinc compounds	46609
1995	styrene	352085	zinc compounds	93918	toluene	73834
1994	styrene	204115	zinc compounds	117386	trichloroethylene	93421
1993	styrene	167035	zinc compounds	156103	toluene	67397
1992	styrene	122220	zinc compounds	151947	trichloroethylene	109000
1991	zinc compounds	148458	1,1,1-trichloroethane	124314	styrene	100120
1990	zinc compounds	131629	acetone	130000	1,1,1-trichloroethane	124365
1989	acetone	296671	trichloroethylene	232000	styrene	186255
1988	acetone	439080	styrene	267788	1,1,1-trichloroethane	130643

^aBlank cells indicate that data not available because less than three chemicals were released

Table 61: Top three TRI chemical releases to land in Knox County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	10000	---a	---a	---a	---a
2001	lead compounds	2347	zinc compounds	1000	lead	61
2000	zinc compounds	1000	nitrate compounds	777	PCBs	23
1999	zinc compounds	15170	---a	---a	---a	---a
1998	zinc compounds	50334	---a	---a	---a	---a
1995	lead compounds	1560	chromium compounds	250	---a	---a
1994	lead compounds	10100	barium compounds	1310	chromium compounds	750
1993	lead compounds	16320	chromium compounds	1470	barium compounds	1210
1992	lead compounds	16190	chromium compounds	1320	---a	---a
1991	lead compounds	5130	chromium compounds	750	---a	---a
1990	manganese compounds	141589	chromium compounds	13998	copper compounds	6208
1989	aluminum oxide (fibrous)	355520	manganese compounds	126040	chromium compounds	12520
1988	aluminum oxide (fibrous)	317545	manganese compounds	112575	chromium compounds	11265

^aBlank cells indicate that data not available because less than three chemicals were released

Table 62: Top three TRI chemical releases to water in Knox County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	nitrate compounds	139000	---	---	---	---
2001	nitrate compounds	223043	zinc compounds	361	copper compounds	258
2000	nitrate compounds	322015	zinc compounds	844	copper compounds	73
1999	nitrate compounds	225963	zinc compounds	1084	manganese compounds	270
1998	nitrate compounds	345956	zinc compounds	1607	manganese compounds	235
1997	nitrate compounds	483986	zinc compounds	284	manganese compounds	214
1996	nitrate compounds	557576	zinc compounds	823	nickel compounds	250
1995	nitrate compounds	582310	zinc compounds	10		
1994	zinc compounds	10	copper compounds	30	manganese compounds	12
1993	zinc compounds	82	copper	18	manganese compounds	15
1992	di (2-ethylhexyl)phthalate	250	copper	250	zinc compounds	79
1991	di (2-ethylhexyl)phthalate	250	zinc compounds	9	---	---
1990	di (2-ethylhexyl)phthalate	250	bis (2-ethylhexyl)adipate	250	N-diethylphthalate	250
1989	di (2-ethylhexyl)phthalate	250	bis (2-ethylhexyl)adipate	250	N-diethylphthalate	250
1988	ammonia	3000	bis (2-ethylhexyl)adipate	250	di (2-ethylhexyl)phthalate	250

^aBlank cells indicate that data not available because less than three chemicals were released

Table 63: Top three TRI chemical releases to air in Sevier County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	styrene	6225	nickel	520	aluminum (fume or dust)	515
2001	styrene	6498	nickel	510	aluminum (fume or dust)	510
2000	styrene	6488	nickel	510	aluminum (fume or dust)	510
1999	styrene	7592	nickel	510	aluminum (fume or dust)	510
1998	styrene	1755	nickel	510	aluminum (fume or dust)	510
1997	styrene	1775	nickel	510	nickel compounds	510
1996	styrene	2230	nickel	510	nickel compounds	510
1995	styrene	2645	nickel	510	nickel compounds	510
1994	methyl ethyl ketone	24534	certain glycol ethers	24247	xylenes	11143
1993	methyl ethyl ketone	26308	certain glycol ethers	20340	xylenes	18350
1992	ethylene glycol	16798	methyl ethyl ketone	15854	xylenes	13062
1991	methyl ethyl ketone	18301	xylenes	15420	styrene	6392
1990	methyl ethyl ketone	12500	xylenes	7500	styrene	6576
1989	methyl ethyl ketone	12100	styrene	6556	nickel compounds	500
1988	methyl ethyl ketone	51107	toluene	20833	xylenes	20173

Table 64: Top three TRI chemical releases to land and water in Sevier County, Tennessee

Land Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	lead	140	---a	---a	---a	---a
Water Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	nickel	10	aluminum (fume or dust)	5	---a	---a
2000	nickel	10	aluminum (fume or dust)	10	---a	---a
1999	nickel	10	aluminum (fume or dust)	10	---a	---a
1998	nickel	10	aluminum (fume or dust)	10	---a	---a
1997	nickel	10	aluminum (fume or dust)	10	nickel compounds	10
1996	nickel	10	aluminum (fume or dust)	10	nickel compounds	10
1995	nickel	10	nickel compounds	10	aluminum (fume or dust)	5
1994	nickel	5	nickel compounds	5	---a	---a
1993	nickel	5	nickel compounds	5	---a	---a
1992	nickel compounds	10	nickel	6	---a	---a
1990	nickel compounds	500	---a	---a	---a	---a
1989	nickel compounds	500	---a	---a	---a	---a
1988	aluminum (fume or dust)	1095	nickel	250	---a	---a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 65: USGS water quality data for top three chemicals detected in Sevier County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°56'40.7"/83°36'55.0"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	xylenes	<0.06 µg/L	toluene	<0.04 µg/L
35°55'20.6"/83°39'58.3"	1997	Surface	manganese	<1 µg/L	xylenes	<0.06 µg/L	toluene	<0.04 µg/L
35°40'14"/83°39'41"	2001	Surface	aluminum	120 µg/L	manganese	22.1 µg/L	---a	---a
35°40'14"/83°39'41"	2001	Surface	aluminum	100 µg/L	manganese	45.1 µg/L	---a	---a
35°44'10"/83°38'06"	1989	Well	manganese	60 µg/L	---a	---a	---a	---a
35°46'06"/83°20'53"	1989	Surface	manganese	630 µg/L	aluminum	60 µg/L	toluene	<0.2 µg/L
35°46'06"/83°20'53"	1990	Surface	manganese	490 µg/L	aluminum	30 µg/L	chromium	2 µg/L
35°47'47"/83°33'38"	1989	Well	manganese	150 µg/L	---a	---a	---a	---a
35°50'21.0"/83°30'50.9"	1998	Well	manganese	2.2 µg/L	methyl ethyl ketone	<1.6 µg/L	xylenes	<0.06 µg/L
35°55'04.3"/83°41'24.0"	1998	Well	manganese	<3 µg/L	xylenes	<0.06 µg/L	toluene	<0.05 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 66: Top three TRI chemical releases to air in Anderson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	hydrochloric acid	4220579	sulfuric acid	322206	hydrofluoric acid	320005
2001	hydrochloric acid	3802237	hydrofluoric acid	330005	sulfuric acid	314226
2000	hydrochloric acid	3434937	sulfuric acid	422922	hydrofluoric acid	290005
1999	hydrochloric acid	2740350	sulfuric acid	403288	hydrofluoric acid	230005
1998	hydrochloric acid	3198556	sulfuric acid	520005	hydrofluoric acid	310005
1997	hydrochloric acid	100350	N-hexane	98805	methanol	78765
1996	N-hexane	93832	methanol	71692	xylene	53674
1995	methanol	84729	xylene	58122	n-butyl alcohol	31384
1994	methanol	92792	xylene	56722	methyl ethyl ketone	35888
1993	methanol	68233	xylene	62660	methyl ethyl ketone	36971
1992	methanol	70400	xylene	45833	methyl ethyl ketone	41276
1991	methyl ethyl ketone	80739	methanol	80596	Freon 113	54023
1990	methanol	128236	methyl ethyl ketone	113700	Freon 113	83061
1989	Freon 113	212545	methyl ethyl ketone	142852	1,1,1-trichloroethane	98060
1988	Freon 113	299220	methyl ethyl ketone	281303	1,1,1-trichloroethane	265961

Table 67: Top three TRI chemical releases to land in Anderson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	lead	1336128	lead compounds	4237	nickel	2287
2001	barium compounds	162005	vanadium compounds	58005	zinc compounds	35600
2000	barium compounds	88000	vanadium compounds	30600	zinc compounds	17200
1999	barium compounds	120000	manganese compounds	35005	zinc compounds	34800
1998	barium compounds	177000	manganese compounds	38000	zinc compounds	35700
1997	lead	710	---a	---a	---a	---a
1996	lead	5	nitrate compounds	1	---a	---a
1995	lead	5	---a	---a	---a	---a
1993	sulfuric acid	250	---a	---a	---a	---a
1990	sulfuric acid	520	---a	---a	---a	---a
1989	sulfuric acid	76	nitric acid	32	hydrochloric acid	10
1988	aluminum oxide (fibrous)	4400160	nitric acid	910	1,1,1-trichloroethane	450

^aBlank cells indicate that data not available because less than three chemicals were released

Table 68: Top three TRI chemical releases to water in Anderson County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	nitrate compounds	73001	barium compounds	5900	manganese compounds	5200
2000	nitrate compounds	250250	manganese compounds	7000	barium compounds	5900
1999	nitrate compounds	103046	barium compounds	5300	ammonia	3600
1998	nitrate compounds	177670	ammonia	24000	manganese compounds	11000
1997	nitrate compounds	274290	ammonia	14000	lead	540
1996	nitrate compounds	150078	ammonia	12900	zinc compounds	386
1995	ammonia	13600	zinc compounds	386	nitrate compounds	175
1994	zinc compounds	401	---	---	---	---
1993	zinc compounds	14	---	---	---	---
1992	zinc compounds	121	---	---	---	---
1991	chlorine	67	zinc compounds	53	Freon 113	8
1990	sulfuric acid	168	zinc compounds	114	Freon 113	74
1989	chlorine	1503	zinc compounds	1067	methanol	210
1988	ethylene glycol	47000	aluminum oxide (fibrous)	12000	methanol	12000

^aBlank cells indicate that data not available because less than three chemicals were released

Table 69: USGS water quality data for top three chemicals detected in Anderson County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36°14'43.7"/84°00'50.4"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	manganese	<1 µg/L	xylenes	<0.06 µg/L
35°59'30"/84°13'11"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	manganese	<1 µg/L	xylenes	<0.06 µg/L
36°05'30.7"/84°12'02.7"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	manganese	<1 µg/L	xylenes	<0.06 µg/L
36°12'26"/84°05'36"	1989	Well	manganese	<10 µg/L	---	---	---	---
36°12'54.9"/83°59'23.3"	1999	Surface	ammonia	0.11 mg/L	methyl ethyl ketone	<1.6 µg/L	xylenes	<0.06 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 70: Top three TRI chemical releases to air in Loudon County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	carbon disulfide	2260000	hydrochloric acid	280275	styrene	155230
2001	carbon disulfide	2236000	hydrochloric acid	292805	acetaldehyde	162200
2000	carbon disulfide	2115000	styrene	169685	acetaldehyde	160200
1999	carbon disulfide	2187000	acetaldehyde	165200	styrene	159698
1998	carbon disulfide	1941000	N-hexane	401529	hydrochloric acid	278170
1997	carbon disulfide	2243000	N-hexane	812336	hydrochloric acid	263005
1996	carbon disulfide	2281000	N-hexane	469924	trichloroethylene	156311
1995	carbon disulfide	2278000	N-hexane	326028	trichloroethylene	179950
1994	carbon disulfide	2274000	copper	159518	trichloroethylene	158931
1993	carbon disulfide	2129000	trichloroethylene	122720	certain glycol ethers	120905
1992	carbon disulfide	2146000	certain glycol ethers	144443	trichloroethylene	866625
1991	carbon disulfide	1832000	trichloroethylene	140794	certain glycol ethers	97389
1990	carbon disulfide	1645000	trichloroethylene	168614	certain glycol ethers	127117
1989	carbon disulfide	2161000	acetone	206638	trichloroethylene	149584
1988	carbon disulfide	2045000	trichloroethylene	168684	acetone	142488

Table 71: Top three TRI chemical releases to land in Loudon County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	nickel compounds	3020	chromium compounds	3020	---	---
2000	nickel compounds	5022	chromium compounds	5022	copper compounds	1333
1999	nickel compounds	6145	chromium compounds	6145	zinc compounds	1536
1998	nickel compounds	5600	chromium compounds	5600	zinc compounds	1560
1997	nickel compounds	4156	chromium compounds	4156	zinc compounds	2076
1996	nickel compounds	3856	zinc compounds	1928	chromium compounds	1928
1995	nickel compounds	5500	---	---	---	---
1994	nickel compounds	5200	---	---	---	---
1993	nickel	750	---	---	---	---
1992	dichloromethane	72	---	---	---	---
1991	ammonia	9700	dichloromethane	378	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 72: Top three TRI chemical releases to water in Loudon County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	nitrate compounds	300	copper	250	nickel compounds	100
2000	nitrate compounds	297	copper	250	nickel compounds	181
1999	nitrate compounds	1454	copper	250	chromium compounds	183
1998	nitrate compounds	1766	chromium compounds	150	nickel compounds	150
1997	nitrate compounds	7196	chloroform	521	chromium compounds	250
1996	nitrate compounds	2000	ammonia	1588	chloroform	678
1995	ammonia	2862	nitrate compounds	1898	copper	1521
1994	chloroform	1290	copper	500	nickel compounds	250
1993	ammonia	13201	copper	250	nickel	250
1992	copper	250	chlorine	5	manganese	5
1991	copper	250	manganese	250	carbon disulfide	25
1990	copper	646	manganese	250	chlorine	250
1989	copper	1227	chlorine	250	---a	---a
1988	copper	967	chlorine	250	manganese	250

^aBlank cells indicate that data not available because less than three chemicals were released

Table 73: USGS water quality data for top three chemicals detected in Loudon County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°38'48.2"/84°23'13.2"	1997	Surface	acetone	<5 µg/L	styrene	0.01 µg/L	---a	---a
35°53'07"/84°18'03"	1988	Surface	aluminum	<10 µg/L	zinc	12 µg/L	---a	---a
35°53'07"/84°18'03"	1988	Surface	aluminum	<10 µg/L	zinc	<3 µg/L	---a	---a
35°53'07"/84°18'03"	1988	Surface	aluminum	<10 µg/L	zinc	5 µg/L	---a	---a
35°53'07"/84°18'03"	1988	Surface	aluminum	10 µg/L	zinc	4 µg/L	copper	1 µg/L
35°53'07"/84°18'03"	1989	Surface	zinc	290 µg/L	aluminum	10 µg/L	copper	1 µg/L
35°53'07"/84°18'03"	1989	Surface	aluminum	20 µg/L	zinc	<3 µg/L	copper	1 µg/L
35°53'07"/84°18'03"	1989	Surface	aluminum	<10 µg/L	copper	5 µg/L	zinc	<3 µg/L
35°53'07"/84°18'03"	1989	Surface	aluminum	<10 µg/L	zinc	3 µg/L	copper	2 µg/L
35°53'07"/84°18'03"	1990	Surface	zinc	11 µg/L	aluminum	<10 µg/L	copper	<10 µg/L
35°53'07"/84°18'03"	1990	Surface	aluminum	20 µg/L	copper	<10 µg/L	zinc	8 µg/L

Table 73: USGS water quality data for top three chemicals detected in Loudon County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°53'07"/84°18'03"	1990	Surface	aluminum	20 µg/L	zinc	7 µg/L	copper	4 µg/L
35°53'07"/84°18'03"	1991	Surface	zinc	42 µg/L	aluminum	<10 µg/L	copper	2 µg/L
35°53'07"/84°18'03"	1991	Surface	aluminum	30 µg/L	zinc	<3 µg/L	copper	2 µg/L
35°53'07"/84°18'03"	1991	Surface	aluminum	<10 µg/L	zinc	<3 µg/L	copper	<1 µg/L
35°53'07"/84°18'03"	1991	Surface	aluminum	10 µg/L	zinc	3 µg/L	copper	1 µg/L
35°43'24"/84°22'54"	1989	Surface	aluminum	<10 µg/L	zinc	<3 µg/L	styrene	<0.2 µg/L
35°43'24"/84°22'54"	1990	Surface	aluminum	20 µg/L	zinc	4 µg/L	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 74: Top three TRI chemical releases to air in Blount County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	hydrochloric acid	4220579	sulfuric acid	322205	hydrofluoric acid	320005
2001	carbonyl sulfide	709900	hydrochloric acid	633000	hydrofluoric acid	146000
2000	carbonyl sulfide	526500	hydrochloric acid	428300	hydrofluoric acid	149000
1999	carbonyl sulfide	536000	hydrochloric acid	448800	hydrofluoric acid	123000
1998	carbonyl sulfide	442300	hydrochloric acid	424300	hydrofluoric acid	109200
1997	hydrochloric acid	459000	carbonyl sulfide	433500	hydrofluoric acid	78000
1996	hydrochloric acid	490000	carbonyl sulfide	396400	hydrofluoric acid	102300
1995	hydrochloric acid	420000	carbonyl sulfide	385800	hydrofluoric acid	87600
1994	carbonyl sulfide	437000	hydrochloric acid	410000	hydrofluoric acid	87600
1993	hydrofluoric acid	410200	hydrochloric acid	122700	styrene	103804
1992	hydrofluoric acid	316000	hydrochloric acid	285000	acetone	129220
1991	hydrofluoric acid	437166	acetone	124210	1,1,1-trichloroethane	96791
1990	hydrofluoric acid	577848	acetone	289193	styrene	121970
1989	hydrofluoric acid	856000	chlorine	86600	aluminum (fume or dust)	18000
1988	aluminum oxide (fibrous)	2352116	hydrofluoric acid	891000	chlorine	160760

Table 75: Top three TRI chemical releases to land and water in Blount County, Tennessee

Land Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
1995	m-xylene	12500	---	---	---	---
1994	m-xylene	1800	---	---	---	---
1993	m-xylene	1700	---	---	---	---
1992	methyl ethyl ketone	10000	m-xylene	1800	---	---
1991	methyl ethyl ketone	11000	manganese	1296	---	---
1989	acetone	24000	---	---	---	---
Water Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2000	manganese	181	lead	89	copper	13
1999	manganese	187	copper	13	---	---
1998	manganese	185	copper compounds	9	copper	5
1997	manganese	177	copper	14	---	---
1996	manganese	164	copper	14	---	---
1995	manganese	169	copper	18	---	---
1994	manganese	190	copper	16	polycyclic aromatics	1
1993	manganese	210	copper	11	lead	5
1992	manganese	145	copper	10	---	---
1991	manganese	145	copper	14	---	---
1988	manganese	193	copper	11	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 76: USGS water quality data for top three chemicals detected in Blount County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°39'52"/83°42'41"	1988	Surface	aluminum	<10 µg/L	lead	<5 µg/L	manganese	3 µg/L
35°39'52"/83°42'41"	1988	Surface	aluminum	20 µg/L	lead	<5 µg/L	manganese	1 µg/L
35°39'52"/83°42'41"	1988	Surface	aluminum	10 µg/L	manganese	5 µg/L	copper	2 µg/L
35°39'52"/83°42'41"	1988	Surface	aluminum	20 µg/L	manganese	7 µg/L	---	---
35°39'52"/83°42'41"	1989	Surface	aluminum	20 µg/L	copper	1 µg/L	---	---
35°39'52"/83°42'41"	1989	Surface	aluminum	20 µg/L	manganese	2 µg/L	copper	1 µg/L
35°39'52"/83°42'41"	1989	Surface	aluminum	10 µg/L	copper	6 µg/L	lead	3 µg/L
35°39'52"/83°42'41"	1989	Surface	aluminum	<10 µg/L	copper	3 µg/L	lead	2 µg/L
35°39'52"/83°42'41"	1990	Surface	aluminum	10 µg/L	lead	<10 µg/L	manganese	<1 µg/L
35°39'52"/83°42'41"	1990	Surface	aluminum	20 µg/L	lead	<10 µg/L	manganese	1 µg/L
35°39'52"/83°42'41"	1990	Surface	aluminum	30 µg/L	lead	14 µg/L	copper	4 µg/L
35°39'52"/83°42'41"	1990	Surface	aluminum	30 µg/L	lead	3 µg/L	manganese	1 µg/L
35°39'52"/83°42'41"	1991	Surface	aluminum	20 µg/L	copper	2 µg/L	lead	1 µg/L
35°39'52"/83°42'41"	1991	Surface	aluminum	20 µg/L	lead	3 µg/L	---	---
35°39'52"/83°42'41"	1991	Surface	aluminum	20 µg/L	manganese	1 µg/L	---	---
35°39'52"/83°42'41"	1992	Surface	aluminum	30 µg/L	manganese	1 µg/L	---	---
35°39'52"/83°42'41"	1992	Surface	aluminum	<10 µg/L	manganese	<1 µg/L	---	---
35°39'52"/83°42'41"	1992	Surface	aluminum	20 µg/L	manganese	1 µg/L	---	---
35°39'52"/83°42'41"	1992	Surface	aluminum	<10 µg/L	manganese	1 µg/L	---	---
35°39'52"/83°42'41"	1993	Surface	aluminum	<10 µg/L	manganese	1 µg/L	---	---

Table 76: USGS water quality data for top three chemicals detected in Blount County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°39'52"/83°42'41"	1993	Surface	aluminum	20 µg/L	manganese	<1 µg/L	---	---
35°39'52"/83°42'41"	1993	Surface	aluminum	40 µg/L	manganese	2 µg/L	---	---
35°39'52"/83°42'41"	1993	Surface	aluminum	10 µg/L	manganese	2 µg/L	---	---
35°39'52"/83°42'41"	1995	Surface	aluminum	10 µg/L	manganese	2 µg/L	---	---
35°39'52"/83°42'41"	1995	Surface	aluminum	60 µg/L	manganese	<1 µg/L	---	---
35°39'52"/83°42'41"	1996	Surface	aluminum	20 µg/L	manganese	<1 µg/L	---	---
35°43'18"/83°59'05"	1997	Surface	acetone	<5 µg/L	methyl ethyl ketone	<1.6 µg/L	1,1,1-trichloroethane	0.08 µg/L
35°43'43"/84°06'09"	1989	Surface	manganese	4 µg/L	copper	1 µg/L	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 77: Top three TRI chemical releases to air in Hamilton County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	methanol	1392323	dichloromethane	375469	ammonia	96111
2000	methanol	1475348	dichloromethane	553316	ammonia	88126
1999	methanol	1412539	dichloromethane	457960	ammonia	86552
1998	methanol	1353289	dichloromethane	414399	ammonia	135002
1997	methanol	1271387	dichloromethane	795874	ammonia	115108
1996	methanol	1373839	dichloromethane	953948	ammonia	125283
1995	methanol	1813579	dichloromethane	688771	triethylamine	102000
1994	methanol	1999584	dichloromethane	502766	ammonia	117482
1993	methanol	2515266	1,1,1-trichloroethane	162412	ammonia	128725
1992	methanol	2604598	dichloromethane	911000	1,1,1-trichloroethane	399827
1991	methanol	3216953	dichloromethane	731822	1,1,1-trichloroethane	377832
1990	methanol	2930670	dichloromethane	479362	1,1,1-trichloroethane	383858
1989	methanol	2732211	dichloromethane	959084	1,1,1-trichloroethane	643691
1988	methanol	2650655	1,1,1-trichloroethane	604110	dichloromethane	568080

Table 78: Top three TRI chemical releases to land in Hamilton County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	84073	manganese compounds	76848	---	---
2001	manganese compounds	92249	zinc compounds	85822	lead compounds	1906
2000	manganese compounds	110200	zinc compounds	100022	copper compounds	2762
1999	manganese compounds	89450	zinc compounds	83313	xylenes	9300
1998	manganese compounds	86297	zinc compounds	80376	copper compounds	2845
1997	manganese compounds	67600	zinc compounds	62962	copper compounds	2963
1996	manganese compounds	82642	zinc compounds	76971	copper compounds	3151
1995	manganese compounds	88289	zinc compounds	82231	lead compounds	14748
1994	manganese compounds	86028	zinc compounds	75682	lead compounds	13573
1993	manganese compounds	82253	zinc compounds	72364	lead compounds	12978
1992	manganese compounds	89279	zinc compounds	76214	manganese	45117
1991	manganese compounds	145881	zinc compounds	128341	manganese	28515
1990	manganese	172690	zinc (fume or dust)	124878	lead	12363
1989	nickel	1212907	manganese	349323	lead	322859

^aBlank cells indicate that data not available because less than three chemicals were released

Table 79: Top three TRI chemical releases to water in Hamilton County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	copper	250	manganese compounds	18	zinc compounds	15
2000	copper	250	zinc compounds	181	manganese compounds	33
1999	copper	250	zinc compounds	123	manganese compounds	44
1998	nitrate compounds	40557	sodium nitrite	3471	copper	250
1997	nitrate compounds	169074	sodium nitrite	13533	copper	280
1996	nitrate compounds	247951	sodium nitrite	15317	zinc compounds	179
1995	nitrate compounds	156220	sodium nitrite	16263	zinc compounds	134
1994	zinc compounds	169	ammonia	101	bis (2-ethylhexyl)adipate	100
1993	ammonia	45317	chlorine	250	bis (2-ethylhexyl)adipate	238
1992	ammonia	32171	zinc compounds	88	bis (2-ethylhexyl)adipate	72
1991	manganese	375	zinc compounds	135	bis (2-ethylhexyl)adipate	40
1990	manganese	620	copper compounds	250	manganese compounds	250
1989	chlorine	13356	nickel	250	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 80: USGS water quality data for top three chemicals detected in Hamilton County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 11'06"/85° 08'12"	1988	Surface	manganese	9 µg/L	nickel	7 µg/L	lead	<5 µg/L
35° 11'06"/85° 08'12"	1988	Surface	manganese	2 µg/L	--- ^a	--- ^a	--- ^a	--- ^a
35° 07'50.9"/85° 0'59.4"	1997	Surface	manganese	144 µg/L	xylenes	0.06 µg/L	1,1,1-trichloroethane	0.01 µg/L
35° 14'07"/85° 11'47"	1991	Surface	manganese	4 µg/L	--- ^a	--- ^a	--- ^a	--- ^a
35° 14'07"/85° 11'47"	1991	Surface	manganese	10 µg/L	--- ^a	--- ^a	--- ^a	--- ^a
35° 14'24"/85° 00'39"	1990	Surface	copper	20 µg/L	zinc	11 µg/L	lead	10 µg/L
35° 14'24"/85° 00'39"	1990	Surface	zinc	6 µg/L	copper	1 µg/L	chromium	1 µg/L
35° 07'50"/85° 04'41"	1989	Surface	zinc	170 µg/L	lead	1 µg/L	chromium	1 µg/L
35° 06'56"/85° 04'13"	1989	Surface	zinc	19 µg/L	copper	3 µg/L	manganese	2 µg/L
35° 06'56"/85° 05'18"	1989	Surface	zinc	10 µg/L	manganese	6 µg/L	nickel	5 µg/L
35° 07'36"/85° 05'28"	1989	Surface	zinc	14 µg/L	manganese	5 µg/L	nickel	1 µg/L
35° 05'59"/85° 05'16"	1989	Surface	zinc	670 µg/L	manganese	5 µg/L	copper	3 µg/L
35° 06'14"/85° 03'55"	1989	Surface	zinc	31 µg/L	nickel	4 µg/L	lead	1 µg/L
35° 06'52"/85° 04'54"	1989	Surface	zinc	270 µg/L	copper	3 µg/L	nickel	3 µg/L
35° 01'02"/85° 14'59"	1993	Surface	zinc	50 µg/L	lead	16 µg/L	chromium	11 µg/L
35° 01'02"/85° 14'59"	1993	Surface	zinc	80 µg/L	lead	15 µg/L	copper	14 µg/L
35° 03'04"/85° 10'51"	1992	Surface	copper	11 µg/L	lead	6 µg/L	nickel	2 µg/L
35° 03'04"/85° 10'51"	1992	Surface	lead	4 µg/L	copper	3 µg/L	nickel	2 µg/L
35° 03'04"/85° 10'51"	1993	Surface	lead	6 µg/L	copper	2 µg/L	nickel	2 µg/L
35° 04'17"/85° 15'50"	1992	Surface	zinc	150 µg/L	copper	16 µg/L	lead	15 µg/L
35° 04'17"/85° 15'50"	1992	Surface	zinc	100 µg/L	lead	11 µg/L	copper	11 µg/L
35° 04'17"/85° 15'50"	1993	Surface	zinc	100 µg/L	lead	4 µg/L	copper	4 µg/L
35° 07'55"/85° 14'10"	1992	Surface	zinc	220 µg/L	lead	41 µg/L	copper	13 µg/L

Table 80: USGS water quality data for top three chemicals detected in Hamilton County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 07'55"/85° 14'10"	1992	Surface	zinc	100 µg/L	lead	21 µg/L	copper	7 µg/L
35° 07'55"/85° 14'10"	1993	Surface	zinc	140 µg/L	lead	39 µg/L	copper	12 µg/L
35° 11'48"/85° 14'54"	1988	Surface	zinc	4 µg/L	manganese	4 µg/L	nickel	3 µg/L
35° 13'20"/85° 13'16"	1988	Surface	manganese	60 µg/L	zinc	18 µg/L	nickel	11 µg/L
35° 12'48"/85° 12'52"	1988	Surface	zinc	10 µg/L	nickel	5 µg/L	--- ^a	--- ^a

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 81: Top three TRI chemical releases to air in McMinn County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	methanol	428196	formaldehyde	209105	ammonia	146449
2001	methanol	534901	formaldehyde	195987	sulfuric acid	151577
2000	methanol	641169	formaldehyde	245100	ammonia	170741
1999	methanol	677849	formaldehyde	305778	ammonia	212997
1998	methanol	696029	formaldehyde	280985	sulfuric acid	187448
1997	methanol	620490	formaldehyde	243312	sulfuric acid	109662
1996	methanol	679091	formaldehyde	236492	zinc compounds	152726
1995	methanol	753464	formaldehyde	230814	toluene	198447
1994	methanol	755564	toluene	287093	formaldehyde	209390
1993	methanol	349474	toluene	272872	methyl ethyl ketone	177241
1992	methanol	336531	toluene	305639	methyl ethyl ketone	187111
1991	methanol	505949	hydrochloric acid	253817	formaldehyde	227680
1990	methanol	391451	formaldehyde	326806	chloroform	225985
1989	hydrochloric acid	820505	chloroform	327798	formaldehyde	298438
1988	chlorine	640018	chloroform	340000	methanol	138701

Table 82: Top three TRI chemical releases to land in McMinn County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	655490	manganese compounds	450000	---	---
2001	manganese compounds	33156	barium compounds	30347	vanadium compounds	27932
2000	manganese compounds	48496	barium compounds	23478	copper compounds	19874
1999	manganese compounds	213042	zinc compounds	82859	barium compounds	43289
1998	barium compounds	467533	manganese compounds	86707	zinc compounds	31868
1997	manganese compounds	62450	barium compounds	22400	zinc compounds	5813
1996	manganese compounds	11354	barium compounds	5489	nickel compounds	5240
1995	methanol	3225	acetaldehyde	724	cresol	255
1994	methanol	3476	acetaldehyde	621	chloroform	133
1993	methanol	8092	acetone	8064	chloroform	160
1992	methanol	9988	acetone	7897	chloroform	175
1991	methanol	8722	acetone	8230	chloroform	58
1990	acetone	8892	methanol	2824	---	---
1989	phenol	112	acetone	80	dichloromethane	39
1988	methanol	1100000	acetone	8100	chloroform	3900

^aBlank cells indicate that data are not available because less than three chemicals were released

Table 83: Top three TRI chemical releases to water in McMinn County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	manganese compounds	24949	formaldehyde	4238	acetaldehyde	3072
2000	manganese compounds	24950	zinc compounds	4766	formic acid	3762
1999	ammonia	10681	formaldehyde	2815	acetaldehyde	2268
1998	methanol	42599	ammonia	10390	acetaldehyde	1283
1997	methanol	66625	zinc compounds	21891	chloroform	4628
1996	manganese compounds	138335	barium compounds	18250	ammonia	5351
1995	ethylene glycol	14166	ammonia	5351	chloroform	4803
1994	ammonia	11940	ethylene glycol	6336	chloroform	4628
1993	ammonia	17306	chloroform	7441	acetone	5019
1992	ammonia	13661	chloroform	6527	acetone	3873
1991	ammonia	59150	chloroform	6052	acetone	4048
1990	ammonia	64850	chloroform	19455	acetone	3985
1989	chloroform	16300	phenol	5314	acetone	3881
1988	acetone	4000	chloroform	1700	chlorine	175

Table 84: USGS water quality data for top three chemicals detected in McMinn County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 30'06.3"/84° 30'18.8"	1997	Surface	acetone	<5 µg/L	methyl ethyl ketone	<1.6 µg/L	manganese	<1 µg/L
35° 20'49"/84° 43'36"	1989	Surface	manganese	<10 µg/L	---	---	---	---
35° 28'55.6"/84° 29'50.1"	1999	Surface	manganese	5 µg/L	acetone	<5 µg/L	methyl ethyl ketone	<1.6 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 85: Top three TRI chemical releases to air, land and water in Rhea County, Tennessee

Air Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	methanol	32439	certain glycol ethers	16085	acetaldehyde	12883
2001	methanol	41477	xylenes	15635	certain glycol ethers	10957
2000	methanol	43397	N-hexane	15300	xylenes	15088
1999	methanol	57900	xylenes	22410	certain glycol ethers	10500
1998	methanol	30300	toluene	17220	xylenes	16760
1997	toluene	49043	methanol	43808	certain glycol ethers	13200
1996	methanol	29712	toluene	20457	certain glycol ethers	12700
1995	toluene	21289	methanol	14032	certain glycol ethers	13000
1994	methanol	41493	methyl ethyl ketone	17886	certain glycol ethers	12980
1993	methanol	78706	acetone	44000	toluene	39591
1992	1,1,1-trichloroethane	136000	methanol	54440	acetone	53723
1991	methanol	137972	1,1,1-trichloroethane	103600	acetone	50820
1990	methanol	124749	1,1,1-trichloroethane	122000	toluene	37150
1989	1,1,1-trichloroethane	284000	toluene	38810	acetone	36480
1988	1,1,1-trichloroethane	315000	methanol	12650	acetone	9050
Land Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	lead	1	---a	---a	---a	---a
2001	lead	530	---a	---a	---a	---a
Water Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	zinc compounds	12000	manganese	4100	chromium	250
2000	zinc compounds	12900	---a	---a	---a	---a
1999	zinc compounds	9500	---a	---a	---a	---a
1998	zinc compounds	10000	---a	---a	---a	---a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 86: USGS water quality data for top three chemicals detected in Rhea County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 42'55"/82° 52'51"	1996	Surface	manganese	6 µg/L	---	---	---	
35° 36'44.0"/84° 50'01.5"	1997	Surface	acetone	<5 µg/L	manganese	<1 µg/L	xylenes	<0.06 µg/L
35° 25'50.1"/85° 02'46.7"	1999	Surface	acetone	<5 µg/L	manganese	4.6 µg/L	xylenes	<0.06 µg/L
35° 26'43"/85° 04'43"	1990	Surface	lead	<10 µg/L	zinc	7 µg/L	chromium	<5 µg/L
35° 26'43"/85° 04'43"	1991	Surface	zinc	18 µg/L	lead	3 µg/L	chromium	2 µg/L
35° 26'40"/84° 52'43"	1990	Surface	manganese	30 µg/L	---	---	---	
35° 39'21.3"/84° 53'20.1"	1999	Well	manganese	8 µg/L	benzene	<0.1 µg/L	xylenes	<0.06 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 87: Top three TRI chemical releases to air, land and water in Marion County, Tennessee

Air Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	sulfuric acid	3461	zinc compounds	103	manganese	33
2001	sulfuric acid	4204	zinc compounds	413	manganese	25
2000	sulfuric acid	4914	zinc compounds	96	lead compounds	6
1999	sulfuric acid	2972	zinc compounds	986	lead compounds	7
1998	sulfuric acid	322	zinc compounds	322	---a	---a
1997	zinc compounds	377	sulfuric acid	340	dicabromodiphenyl oxide	5
1996	sulfuric acid	1355	zinc compounds	437	hydrochloric acid	103
1995	zinc compounds	1034	hydrochloric acid	525	manganese compounds	255
1994	manganese compounds	255	chromium compounds	255	antimony compounds	255
1993	antimony compounds	255	chromium compounds	255	sulfuric acid	5
Land Release						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	lead	190	---a	---a	---a	---a
Water Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
1995	manganese compounds	20	antimony compounds	20	chromium compounds	8
1994	manganese compounds	20	antimony compounds	20	chromium compounds	8
1993	antimony compounds	10	---a	---a	---a	---a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 88: USGS water quality data for top three chemicals detected in Marion County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 12'23.42"/85° 29'49.68"	1988	Surface	manganese	130 µg/L	zinc	<10 µg/L	chromium	3 µg/L
35° 12'23.42"/85° 29'49.68"	1988	Surface	manganese	30 µg/L	zinc	<10 µg/L	chromium	<1 µg/L
35° 12'23.42"/85° 29'49.68"	1988	Surface	manganese	30 µg/L	zinc	<10 µg/L	chromium	<1 µg/L
35° 12'23.42"/85° 29'49.68"	1988	Surface	manganese	70 µg/L	zinc	<10 µg/L	chromium	<1 µg/L
35° 03'04"/85° 35'37"	1990	Well	manganese	700 µg/L	---a	---a	---a	---a
35° 03'14"/85° 44'22"	1990	Well	manganese	10 µg/L	---a	---a	---a	---a
35° 07'15"/85° 35'39"	1990	Surface	zinc	11 µg/L	lead	<10 µg/L	---a	---a
35° 07'15"/85° 35'39"	1990	Surface	zinc	3 µg/L	lead	<1 µg/L	---a	---a
35° 09'24"/85° 24'53"	1991	Well	manganese	310 µg/L	---a	---a	---a	---a
35° 09'33"/85° 24'59"	1991	Well	manganese	330 µg/L	---a	---a	---a	---a

Table 88: USGS water quality data for top three chemicals detected in Marion County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 11'08"/85° 26'10"	1991	Well	manganese	52 µg/L	---	---	---	---
35° 11'16"/85° 26'10"	1991	Well	manganese	20 µg/L	---	---	---	---
35° 10'16"/85° 25'02"	1991	Well	manganese	590 µg/L	---	---	---	---
35° 10'54"/85° 26'12"	1990	Well	manganese	460 µg/L	zinc	110 µg/L	lead	1 µg/L
35° 10'54"/85° 26'12"	1991	Well	manganese	510 µg/L	---	---	---	---
35° 10'57"/85° 26'12"	1990	Well	manganese	670 µg/L	zinc	120 µg/L	---	---
35° 10'57"/85° 26'12"	1991	Well	manganese	830 µg/L	---	---	---	---
35° 11'03"/85° 26'17"	1991	Well	manganese	12 µg/L	---	---	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 89: Top three TRI chemical releases to air in Bradley County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	ammonia	127762	chlorine	91402	toluene	41592
2001	chlorine	72802	ammonia	55337	toluene	41293
2000	ammonia	141668	chlorine	93020	toluene	50987
1999	ammonia	164022	chlorine	98475	toluene	52367
1998	ammonia	212563	chlorine	82632	toluene	61743
1997	ammonia	185711	chlorine	97067	toluene	51625
1996	ammonia	1005190	chlorine	107291	phenol	98506
1995	toluene	142704	chlorine	128291	phenol	107305
1994	toluene	152436	chlorine	132324	1,1,1-trichloroethane	36189
1993	chlorine	139095	1,1,1-trichloroethane	116852	toluene	88200
1992	chlorine	169795	toluene	167590	1,1,1-trichloroethane	137363
1991	1,1,1-trichloroethane	216058	chlorine	190734	methyl ethyl ketone	85777
1990	1,1,1-trichloroethane	265412	chlorine	166033	toluene	93268
1989	1,1,1-trichloroethane	345007	chlorine	166693	toluene	95903
1988	1,1,1-trichloroethane	286668	toluene	216550	chlorine	162902

Table 90: Top three TRI chemical releases to land in Bradley County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	33331	nickel compounds	7557	---a	---a
2001	mercury	988	ammonia	113	zinc compounds	5
2000	manganese compounds	764	---a	---a	---a	---a
1999	mercury	998	zinc compounds	5	---a	---a
1998	disocynates	23400	mercury	1964	zinc compounds	5
1997	mercury	661	---a	---a	---a	---a
1996	mercury	534	---a	---a	---a	---a
1995	maleic anhydride	250	sodium nitrite	250	mercury	143
1994	maleic anhydride	250	mercury	142	hydrochloric acid	51
1993	nickel	20000	barium compounds	7100	manganese compounds	3300
1992	mercury	3111	hydrochloric acid	250	sulfuric acid	119
1991	mercury	2335	sulfuric acid	325	---a	---a
1990	mercury	3926	maleic anhydride	250	hydrochloric acid	113
1989	aluminum oxide (fibrous)	197000	mercury	4431	maleic anhydride	250
1988	aluminum oxide (fibrous)	134000	mercury	3067	---a	---a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 91: Top three TRI chemical releases to water in Bradley County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	manganese compounds	250	zinc compounds	250	mercury	8
2000	zinc compounds	250	manganese compounds	250	mercury	7
1999	manganese compounds	250	zinc compounds	250	mercury	13
1998	manganese compounds	250	zinc compounds	250	mercury	15
1997	manganese compounds	2251	zinc compounds	250	barium compounds	45
1996	manganese compounds	255	zinc compounds	250	mercury	40
1995	mercury	43	---	---	---	---
1994	mercury	53	---	---	---	---
1993	mercury	26	---	---	---	---
1992	mercury	17	---	---	---	---
1991	mercury	22	sulfuric acid	10	---	---
1990	mercury	25	sulfuric acid	10	---	---
1989	manganese compounds	250	barium compounds	250	mercury	25
1988	sodium hydroxide solution	610	sulfuric acid	500	hydrochloric acid	250

^aBlank cells indicate that data not available because less than three chemicals were released

Table 92: USGS water quality data for top three chemicals detected in Bradley County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 07'26"/84° 51'05"	1989	Surface	chloride	3.6 mg/L	barium	32 µg/L	zinc	5 µg/L
35° 07'26"/84° 51'05"	1990	Surface	chloride	4.8 mg/L	barium	36 µg/L	zinc	3 µg/L
35° 12'28.2"/84° 47'08.4"	1997	Surface	chloride	2.11 mg/L	methyl ethyl ketone	<1.6 µg/L	toluene	0.1 µg/L
35° 17'42.27"/84° 45'36.05"	1988	Surface	manganese	510 µg/L	zinc	50 µg/L	copper	<10 µg/L
35° 17'42.27"/84° 45'36.05"	1988	Surface	manganese	70 µg/L	zinc	40 µg/L	copper	<10 µg/L
35° 17'42.27"/84° 45'36.05"	1988	Surface	manganese	50 µg/L	copper	40 µg/L	zinc	20 µg/L
35° 17'42.27"/84° 45'36.05"	1988	Surface	manganese	80 µg/L	copper	<10 µg/L	zinc	<10 µg/L
35° 17'42.27"/84° 45'36.05"	1988	Surface	manganese	50 µg/L	zinc	40 µg/L	copper	<10 µg/L
35° 01'59"/84° 53'31"	1990	Well	chloride	8.7 mg/L	manganese	<10 µg/L	---a	---a
35° 02'14"/84° 49'21"	1989	Well	chloride	1.0 mg/L	manganese	40 µg/L	---a	---a
35° 06'11"/84° 52'03"	1989	Surface	chloride	1.7 mg/L	barium	75 µg/L	zinc	8 µg/L
35° 06'11"/84° 52'03"	1990	Surface	chloride	2.60 mg/L	barium	74 µg/L	zinc	29 µg/L
35° 15'16.5"/84° 42'05.0"	1999	Well	chloride	1.88 mg/L	manganese	<3 µg/L	methyl ethyl ketone	<1.6 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 93: Top three TRI chemical releases to air in Sullivan County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	methanol	712098	hydrochloric acid	616891	sulfuric acid	485779
2001	hydrochloric acid	1685494	methanol	933374	hydrofluoric acid	216374
2000	hydrochloric acid	1681980	methanol	1084747	sulfuric acid	506000
1999	hydrochloric acid	1740980	methanol	1076803	sulfuric acid	494000
1998	hydrochloric acid	1790000	methanol	1099100	toluene	262100
1997	hydrochloric acid	1920015	methanol	971000	sulfuric acid	771800
1996	hydrochloric acid	2140076	methanol	1501000	sulfuric acid	748660
1995	hydrochloric acid	3580240	methanol	1541100	sulfuric acid	770800
1994	hydrochloric acid	2880068	methanol	1511100	toluene	240000
1993	acetone	22364321	hydrochloric acid	2620820	methanol	2081794
1992	acetone	25624617	hydrochloric acid	2530000	methanol	2131342
1991	acetone	32094237	hydrochloric acid	2833500	methanol	2579515
1990	acetone	33423250	hydrochloric acid	2644000	methanol	2048464
1989	acetone	36007189	methanol	3021764	hydrochloric acid	2784000
1988	acetone	34022154	methanol	3049363	hydrochloric acid	2581700

Table 94: Top three TRI chemical releases to land in Sullivan County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	manganese compounds	60505	zinc compounds	43708	barium compounds	42084
2001	barium compounds	417033	vanadium compounds	103885	zinc compounds	99207
2000	barium compounds	397300	manganese compounds	126063	copper compounds	123000
1999	barium compounds	299800	zinc compounds	126000	vanadium compounds	94000
1998	barium compounds	351000	copper compounds	141000	vanadium compounds	120000
1997	barium compounds	280290	vanadium compounds	110000	copper compounds	91600
1996	barium compounds	280340	copper compounds	102400	vanadium compounds	110000
1995	vanadium compounds	110000	manganese compounds	47000	zinc compounds	38000
1994	manganese compounds	20000	antimony compounds	12000	chromium compounds	7000
1993	zinc compounds	30000	copper compounds	28000	manganese compounds	15000
1992	copper compounds	64000	zinc compounds	42000	chromium compounds	29000
1991	chromium compounds	30000	manganese compounds	20000	zinc compounds	13000
1990	barium compounds	230000	chromium compounds	140000	zinc compounds	25000
1989	manganese compounds	85000	zinc compounds	32000	chromium compounds	26000
1988	zinc compounds	25000	antimony compounds	22000	aluminum oxide (fibrous)	20000

Table 95: Top three TRI chemical releases to water in Sullivan County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	ethylene glycol	137705	nitrate compounds	129749	formic acid	64570
2000	nitrate compounds	130000	ethylene glycol	75000	formic acid	67000
1999	nitrate compounds	130000	formic acid	63000	manganese compounds	35000
1998	nitrate compounds	110000	formic acid	63000	1,4-dioxane	44000
1997	ethylene glycol	80000	formic acid	61000	1,4-dioxane	43000
1996	1,4-dioxane	95000	ethylene glycol	85000	n-butyl alcohol	26000
1995	ethylene glycol	190000	1,4-dioxane	65000	ammonia	28490
1994	ethylene glycol	270000	n-butyl alcohol	21000	methanol	17000
1993	1,4-dioxane	80000	ethylene glycol	75000	2-methoxyethanol	22000
1992	1,4-dioxane	87000	2-methoxyethanol	80000	ethylene glycol	67000
1991	ethylene glycol	180000	2-methoxyethanol	78000	methanol	31050
1990	ammonium sulfate	2100000	ethylene glycol	220000	2,4-dinitrophenol	87000
1989	ammonium sulfate	2500000	ethylene glycol	210000	2,4-dinitrophenol	160000
1988	ammonium sulfate	820000	ethylene glycol	300000	2-methoxyethanol	120000

Table 96: USGS water quality data for top three chemicals detected in Sullivan County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 32'04"/82° 14'27"	1998	Surface	manganese	6.2 µg/L	---	---	---	---
36° 32'44"/82° 11'35"	1992	Surface	zinc	150 µg/L	manganese	90 µg/L	vanadium	<10 µg/L
36° 32'44"/82° 11'35"	1992	Surface	zinc	140 µg/L	---	---	---	---
36° 32'44"/82° 11'35"	1992	Surface	zinc	150 µg/L	---	---	---	---
36° 32'44"/82° 11'35"	1993	Surface	zinc	100 µg/L	manganese	20 µg/L	chromium	10 µg/L
36° 30'35"/82° 34'02"	1998	Surface	manganese	38.1 µg/L	---	---	---	---
36° 34'57.3"/82° 19'30.1"	1997	Surface	manganese	1.7 µg/L	toluene	<0.04 µg/L	---	---
36° 33'14"/82° 33'00"	1998	Surface	manganese	14.9 µg/L	---	---	---	---
36° 25'30"/82° 36'28"	1995	Surface	manganese	10 µg/L	---	---	---	---
36° 25'30"/82° 36'28"	1998	Surface	manganese	7.7 µg/L	---	---	---	---
36° 24'14.4"/82° 20'35.9"	1997	Well	acetone	<5 µg/L	manganese	1.1 µg/L	toluene	<0.04 µg/L
36° 27'25"/82° 10'15"	1990	Well	manganese	4800 µg/L	---	---	---	---
36° 34'44.8"/82° 24'40.8"	1997	Surface	manganese	228 µg/L	acetone	<5 µg/L	toluene	0.01 µg/L
36° 35'39"/82° 17'51"	1990	Surface	manganese	10 µg/L	---	---	---	---
36° 32'42.6"/82° 22'03.2"	1997	Well	manganese	812 µg/L	acetone	<10 µg/L	toluene	<0.08 µg/L
36° 33'34.5"/82° 04'43.1"	1998	Well	acetone	<5 µg/L	manganese	<3 µg/L	toluene	0.04 µg/L
36° 33'05"/82° 16'04"	1990	Ground	barium	170 µg/L	copper	<10 µg/L	zinc	4 µg/L
36° 33'05"/82° 16'04"	1990	Surface	barium	200 µg/L	copper	<10 µg/L	manganese	6 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 97: USGS water quality data for top three chemicals detected in Humphreys County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 55'48"/87° 44'35"	1988	Surface	manganese	30 µg/L	zinc	<10 µg/L	chromium	3 µg/L
35° 55'48"/87° 44'35"	1988	Surface	manganese	50 µg/L	zinc	<10 µg/L	chromium	<1 µg/L
35° 55'48"/87° 44'35"	1988	Surface	manganese	40 µg/L	zinc	10 µg/L	chromium	<1 µg/L
35° 55'48"/87° 44'35"	1988	Surface	manganese	60 µg/L	zinc	<10 µg/L	chromium	3 µg/L
35° 55'48"/87° 44'35"	1988	Surface	manganese	50 µg/L	zinc	<10 µg/L	chromium	2 µg/L
35° 55'48"/87° 44'35"	1988	Surface	manganese	30 µg/L	zinc	<10 µg/L	chromium	1 µg/L
36° 09'13"/87° 46'47"	2001	Surface	manganese	4.7 µg/L	---a	---a	---a	---a
36° 09'13"/87° 46'47"	2001	Surface	manganese	1.7 µg/L	---a	---a	---a	---a
36° 12'33"/87° 43'24"	2000	Surface	manganese	3.2 µg/L	---a	---a	---a	---a
36° 12'33"/87° 43'24"	2000	Surface	manganese	5.6 µg/L	---a	---a	---a	---a
35° 58'12"/87° 47'49"	1989	Surface	manganese	210 µg/L	---a	---a	---a	---a
36° 02'56"/87° 52'17"	1988	Well	barium	3500 µg/L	manganese	2100 µg/L	zinc	50 µg/L
36° 08'11"/87° 49'54"	1988	Ground	chloride	2.2 mg/L	zinc	280 µg/L	barium	<100 µg/L

Table 97: USGS water quality data for top three chemicals detected in Humphreys County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 07'48"/87° 49'46"	1989	Ground	chloride	1400 mg/L	---	---	---	---
36° 07'48"/87° 49'46"	1989	Ground	chloride	2900 mg/l	---	---	---	---
36° 07'48"/87° 49'46"	1989	Ground	chloride	1500 mg/L	barium	300 µg/L	vanadium	34 µg/L
36° 07'48"/87° 49'46"	1989	Ground	chloride	870 mg/L	barium	200 µg/L	vanadium	16 µg/L
36° 07'48"/87° 49'46"	1989	Ground	chloride	160 mg/L	barium	98 µg/L	manganese	81 µg/L
36° 07'48"/87° 49'46"	1990	Ground	chloride	110 mg/L	manganese	100 µg/L	barium	85 µg/L
36° 07'48"/87° 49'46"	1990	Ground	chloride	2100 mg/L	barium	800 µg/L	zinc	110 µg/L
36° 07'48"/87° 49'46"	1990	Ground	chloride	690 mg/L	barium	400 µg/L	vanadium	16 µg/L
36° 07'48"/87° 49'46"	1990	Ground	chloride	260 mg/L	barium	<100 µg/L	zinc	20 µg/L
36° 07'48"/87° 49'46"	1990	Ground	chloride	130 mg/L	barium	58 µg/L	manganese	53 µg/L
36° 07'48"/87° 49'46"	1990	Ground	chloride	550 mg/L	barium	200 µg/L	manganese	40 µg/L
36° 07'48"/87° 49'46"	1991	Ground	chloride	210 mg/L	barium	110 µg/L	manganese	32 µg/L
36° 07'48"/87° 49'46"	1991	Ground	chloride	910 mg/L	barium	100 µg/L	lead	67 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 98: Top three TRI chemical releases to air in Hamblen County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
					--- ^a	--- ^a
2002	carbon disulfide	17711980	hydrochloric acid	363987		
2001	carbon disulfide	2256917	dichloromethane	447130	hydrochloric acid	331267
2000	carbon disulfide	16959784	dichloromethane	791526	toluene	406142
1999	carbon disulfide	13364000	dichloromethane	841392	hydrochloric acid	298600
1998	carbon disulfide	17365000	dichloromethane	850354	toluene	287264
1997	carbon disulfide	16800000	dichloromethane	864559	toluene	329840
1996	carbon disulfide	18100000	dichloromethane	741800	toluene	352805
1995	carbon disulfide	23200000	dichloromethane	707271	toluene	409380
1994	carbon disulfide	21400000	dichloromethane	802928	toluene	577665
1993	carbon disulfide	22250000	toluene	546387	dichloromethane	410471
1992	carbon disulfide	20400000	toluene	579822	dichloromethane	318278
1991	carbon disulfide	19500000	toluene	573375	dichloromethane	413823
1990	carbon disulfide	22500000	toluene	685162	dichloromethane	527803
1989	carbon disulfide	23700000	toluene	697894	dichloromethane	520360
1988	carbon disulfide	15300000	toluene	777071	methanol	446643

^aBlank cells indicate that data not available because less than three chemicals were released

Table 99: Top three TRI chemical releases to land in Hamblen County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	335918	manganese compounds	674	---a	---a
2001	zinc compounds	314528	ethylene glycol	94700	manganese compounds	9356
2000	zinc compounds	216000	ethylene glycol	115620	manganese compounds	8900
1999	ethylene glycol	223080	zinc compounds	136500	manganese compounds	7460
1998	zinc compounds	252000	ethylene glycol	202800	manganese compounds	8100
1997	zinc compounds	309000	ethylene glycol	260000	manganese compounds	5800
1996	zinc compounds	313000	ethylene glycol	260000	biphenyl	13392
1995	ethylene glycol	260000	antimony compounds	6200	---a	---a
1994	ethylene glycol	130000	antimony compounds	6600	---a	---a
1993	ethylene glycol	225000	antimony compounds	7500	methanol	5000
1992	ethylene glycol	133000	antimony compounds	6200	---a	---a
1991	zinc compounds	1500000	ethylene glycol	31000	antimony compounds	1600
1990	zinc compounds	2300000	ethylene glycol	94000	antimony compounds	4300
1989	zinc compounds	1600000	ethylene glycol	130000	antimony compounds	6100
1988	zinc compounds	1600000	ethylene glycol	130000	methyl ethyl ketone	18425

^aBlank cells indicate that data not available because less than three chemicals were released

Table 100: Top three TRI chemical releases to water in Hamblen County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	ammonia	12572	zinc compounds	2700	chlorine	250
2000	ammonia	12230	zinc compounds	3111	carbon disulfide	750
1999	ammonia	11600	zinc compounds	3468	manganese compounds	251
1998	ammonia	13000	zinc compounds	4710	manganese compounds	2001
1997	zinc compounds	4100	manganese compounds	2000	copper compounds	250
1996	ammonia	18700	zinc compounds	4900	manganese compounds	2000
1995	ammonia	21000	zinc compounds	8100	manganese compounds	2000
1994	ammonia	13500	zinc compounds	4800	manganese compounds	1300
1993	ammonia	14000	zinc compounds	7000	manganese compounds	750
1992	ammonia	22000	zinc compounds	5500	methyl ethyl ketone	17
1991	ammonia	22000	zinc compounds	7000	certain glycol ethers	1900
1990	zinc compounds	10000	ammonia	4000	certain glycol ethers	1900
1989	zinc compounds	10000	ammonia	4000	certain glycol ethers	1400
1988	zinc compounds	10000	certain glycol ethers	1400	---a	---a

^aBlank cells indicate that data not available because less than three chemicals were released

Table 101: USGS water quality data for top three chemicals detected in Hamblen County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 10'18.9"/83° 13'35.7"	1998	Well	acetone	<5 µg/L	manganese	<4 µg/L	methyl ethyl ketone	<1.6 µg/L
36° 11'07.3"/83° 09'46.4"	1997	Well	manganese	181 µg/L	acetone	<5 µg/L	methyl ethyl ketone	<5 µg/L
36° 11'35.0"/83° 12'12.5"	1997	Well	manganese	43.5 µg/L	acetone	<20 µg/L	dichloromethane	<1.5 µg/L
36° 17'24"/83° 11'39"	1989	Well	manganese	<10 µg/L	---	---	---	---
36° 11'54"/83° 09'19"	1997	Surface	manganese	8.1 µg/L	---	---	---	---
36° 08'17"/83° 14'47"	1997	Surface	manganese	8.5 µg/L	---	---	---	---
36° 15'58.9"/83° 13'26"	1997	Surface	manganese	<1 µg/L	dichloromethane	<0.4 µg/L	toluene	<0.04 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 102: Top three TRI chemical releases to air in Montgomery County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	15442408	---	---	---	
2001	sulfuric acid	113793	chlorodifluoromethane	113808	zinc compounds	70017
2000	sulfuric acid	141040	chlorodifluoromethane	91423	zinc compounds	74933
1999	sulfuric acid	141421	chlorodifluoromethane	87000	zinc compounds	66933
1998	sulfuric acid	122435	chlorodifluoromethane	110000	zinc compounds	69420
1997	chlorodifluoromethane	40000	zinc compounds	30597	certain glycol ethers	20853
1996	chlorodifluoromethane	84000	zinc compounds	27097	methanol	15429
1995	chlorodifluoromethane	160000	zinc compounds	30000	toluene	20000
1994	chlorodifluoromethane	150000	xylenes	43200	toluene	35900
1993	xylenes	37900	toluene	34200	zinc compounds	26303
1992	toluene	51587	xylenes	31600	zinc compounds	22002
1991	zinc compounds	125522	sulfuric acid	82000	toluene	61500
1990	zinc (fume or dust)	132998	sulfuric acid	108686	xylenes	58500
1989	zinc (fume or dust)	128500	sulfuric acid	106035	trichloroethylene	52700
1988	zinc (fume or dust)	124200	trichloroethylene	111000	sulfuric acid	102600

^aBlank cells indicate that data not available because less than three chemicals were released

Table 103: Top three TRI chemical releases to land in Montgomery County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	copper compounds	517525	lead compounds	489436	---a	---a
2001	copper compounds	10473784	zinc compounds	7883743	lead compounds	5362071
2000	zinc compounds	13406880	copper compounds	1049730	lead compounds	584285
1999	zinc compounds	8200478	copper compounds	551880	lead compounds	3356584
1998	zinc compounds	4656675	copper compounds	453799	lead compounds	266727
1997	zinc compounds	2252	---a	---a	---a	---a
1996	chloroprene	8640	zinc compounds	2815	---a	---a
1995	zinc compounds	9538	chloroprene	5104	---a	---a
1994	zinc compounds	8312	chloroprene	3997	---a	---a
1993	acrylonitrile	6332	chloroprene	3018	zinc compounds	3018
1992	acrylonitrile	7654	chloroprene	1811	zinc compounds	1463
1991	acrylonitrile	4161	chloroprene	2011	zinc compounds	2000
1990	zinc (fume or dust)	2244157	copper	224939	lead	145179
1989	zinc (fume or dust)	2168270	copper	217331	lead	140269
1988	zinc (fume or dust)	2099000	copper	210390	lead	135787

^aBlank cells indicate that data not available because less than three chemicals were released

Table 104: Top three TRI chemical releases to water in Montgomery County, Tennessee

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	manganese compounds	64348	zinc compounds	3927	cadmium compounds	301
2000	manganese compounds	73599	zinc compounds	4863	cadmium compounds	273
1999	zinc compounds	5868	cadmium compounds	414	lead compounds	216
1998	zinc compounds	7658	cadmium compounds	376	lead compounds	184
1997	zinc compounds	250	copper	1	---	---
1996	zinc compounds	250	copper	21	chloroprene	5
1995	copper	1	---	---	---	---
1994	copper	5	---	---	---	---
1993	copper	3	---	---	---	---
1992	copper	4	---	---	---	---
1991	zinc compounds	11000	cadmium compounds	1700	lead compounds	222
1990	manganese	18390	zinc (fume or dust)	2780	copper	753
1989	manganese	17770	zinc (fume or dust)	2690	copper	763
1988	manganese	17200	zinc (fume or dust)	2600	copper	750

^aBlank cells indicate that data not available because less than three chemicals were released

Table 105: USGS water quality data for top three chemicals detected in Montgomery County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 21'30"/87° 22'44"	1990	Surface	cadmium	2 µg/L	manganese	2 µg/L	lead	<1 µg/L
36° 21'30"/87° 22'44"	1990	Surface	manganese	18 µg/L	cadmium	<1 µg/L	lead	<1 µg/L
36° 31'40"/87° 18'08"	1988	Surface	manganese	29 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	48 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	340 µg/L	copper	40 µg/L	lead	10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	89 µg/L	lead	50 µg/L	copper	40 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	41 µg/L	copper	30 µg/L	lead	20 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	30 µg/L	copper	20 µg/L	lead	<10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	20 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	63 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	59 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 30'56"/87° 18'43"	1988	Surface	manganese	41 µg/L	lead	<10 µg/L	copper	<10 µg/L

Table 105: USGS water quality data for top three chemicals detected in Montgomery County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 30'59"/87° 19'07"	1988	Surface	manganese	80 µg/L	copper	<10 µg/L	lead	<10 µg/L
36° 30'59"/87° 19'07"	1988	Surface	manganese	100 µg/L	copper	<10 µg/L	lead	<10 µg/L
36° 30'59"/87° 19'07"	1988	Surface	manganese	700 µg/L	copper	<10 µg/L	---a	---a
36° 30'59"/87° 19'07"	1988	Surface	manganese	220 µg/L	copper	<10 µg/L	cadmium	<1 µg/L
36° 30'59"/87° 19'07"	1988	Surface	manganese	110 µg/L	copper	<10 µg/L	lead	<10 µg/L
36° 38'01"/87° 32'17"	1994	Surface	manganese	17 µg/L	copper	<10 µg/L	lead	<10 µg/L
36° 38'18"/87° 33'07"	1995	Surface	manganese	2 µg/L	---a	---a	---a	---a
36° 38'18"/87° 33'07"	1995	Surface	manganese	8 µg/L	---a	---a	---a	---a
36° 38'18"/87° 33'07"	1995	Surface	manganese	2 µg/L	---a	---a	---a	---a
36° 38'18"/87° 33'07"	1995	Surface	manganese	5 µg/L	---a	---a	---a	---a
36° 38'18"/87° 33'07"	1995	Surface	manganese	2 µg/L	---a	---a	---a	---a
36° 38'18"/87° 33'07"	1995	Surface	manganese	6 µg/L	---a	---a	---a	---a

Table 105: USGS water quality data top three chemical releases in Montgomery County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36° 37'11"/87° 30'18"	1994	Surface	manganese	200 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 37'10"/87° 31'38"	1995	Ground	manganese	48 µg/L	---a	---a	---a	---a
36° 37'10"/87° 31'38"	1995	Ground	manganese	40 µg/L	---a	---a	---a	---a
36° 37'10"/87° 31'38"	1995	Ground	manganese	54 µg/L	---a	---a	---a	---a
36° 37'10"/87° 31'38"	1995	Ground	manganese	16 µg/L	---a	---a	---a	---a
36° 37'10"/87° 31'38"	1995	Ground	manganese	10 µg/L	---a	---a	---a	---a
36° 37'10"/87° 31'38"	1995	Ground	manganese	28 µg/L	---a	---a	---a	---a
36° 30'54"/87° 18'28"	1988	Well	manganese	70 µg/L	copper	20 µg/L	lead	<10 µg/L
36° 30'57"/87° 18'55"	1988	Well	manganese	18 µg/L	copper	<10 µg/L	---a	---a
36° 30'57"/87° 18'55"	1988	Well	manganese	18 µg/L	lead	<10 µg/L	copper	<10 µg/L
36° 31'37"/87° 20'03"	1988	Surface	manganese	42 µg/L	lead	20 µg/L	copper	<10 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 106: Top three TRI chemical releases to air in Los Angeles County, California

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	ammonia	3261037	nitrate compounds	1240733	styrene	531572
2001	ammonia	2641089	styrene	521832	methanol	389163
2000	ammonia	3020016	methanol	6617774	1-chloro-1,1-difluoroethane	391031
1999	ammonia	3113102	methanol	1099225	styrene	675670
1998	ammonia	2051745	methanol	1188160	certain glycol ethers	642918
1997	ammonia	2386243	formic acid	1200000	methanol	905117
1996	ammonia	2736575	formic acid	1460000	methanol	1357568
1995	1,1,1-trichloroethane	2838936	ammonia	2356027	tetrachloroethylene	905319
1994	1,1,1-trichloroethane	4833058	ammonia	2551402	styrene	611500
1993	1,1,1-trichloroethane	7243476	ammonia	2515728	certain glycol ethers	820849
1992	1,1,1-trichloroethane	9457150	ammonia	2391041	dichloromethane	1610487
1991	1,1,1-trichloroethane	12091184	ammonia	2588965	dichloromethane	2254152
1990	1,1,1-trichloroethane	14276469	dichloromethane	3066098	ammonia	2230329
1989	1,1,1-trichloroethane	14678958	dichloromethane	3692727	Freon 113	2518988
1988	1,1,1-trichloroethane	14791588	dichloromethane	3910785	tetrachloroethylene	2727402

Table 107: Top three TRI chemical releases to land in Los Angeles County, California

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	lead compounds	52876	copper	14785	aluminum (fume or dust)	10905
2000	diethanol amine	66152	nitric acid	44528	polycyclic aromatics	11213
1999	nitric acid	64733	diethanol amine	6423	methyl tert butyl ether	2779
1998	nitric acid	68210	sodium nitrite	2983	zinc (fume or dust)	1476
1997	lead	75776	phosphoric acid	73205	nitric acid	65957
1996	phosphoric acid	38125	nitric acid	34130	lead	19253
1995	naphthalene	3075	zinc compounds	2274	sodium nitrite	2136
1994	toluene	740	m-xylene	570	nickel	500
1993	sulfuric acid	54450	1,1,1-trichloroethane	12376	ammonia	2250
1992	1,1,1-trichloroethane	14210	acetone	2442	nickel	700
1991	sulfuric acid	59410	1,1,1-trichloroethane	18250	zinc (fume or dust)	2500
1990	xylenes	59020	1,1,1-trichloroethane	13595	dichloromethane	3554
1989	1,1,1-trichloroethane	14300	asbestos (friable)	10750	barium	3800
1988	sodium hydroxide solution	92007	copper	99516	asbestos (friable)	14000

Table 108: Top three TRI chemical releases to water in Los Angeles County, California

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	nitrate compounds	1502718	zinc compounds	2394	ammonia	1967
2000	nitrate compounds	1763621	diethanol amine	38821	methyl tert butyl ether	29201
1999	nitrate compounds	2100000	methyl tert butyl ether	30249	propylene oxide	9852
1998	nitrate compounds	450000	ammonia	10861	methyl tert butyl ether	10552
1997	nitrate compounds	260000	ammonia	9480	methyl tert butyl ether	9400
1996	nitrate compounds	270000	manganese	13250	ammonia	10020
1995	nitrate compounds	180000	manganese	15005	ammonia	12339
1994	ammonia	173135	manganese	15000	methyl tert butyl ether	8600
1993	ammonia	165612	manganese	15000	methyl tert butyl ether	8800
1992	ammonia	99744	sulfuric acid	26400	manganese	15000
1991	ammonia	85797	manganese	14000	methyl tert butyl ether	8100
1990	ammonia	190254	manganese	13689	sulfuric acid	5080
1989	ammonia	138370	manganese	14010	phosphoric acid	9200
1988	sodium hydroxide solution	336907	ammonia	106560	nitric acid	16250

Table 109: USGS water quality data for top three chemicals detected in Los Angeles County, California

Latitude and Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
33° 59'43"/118° 04'22"	1994	Ground	zinc	48 µg/L	manganese	23 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	42 µg/L	manganese	22 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	42 µg/L	manganese	18 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	42 µg/L	manganese	16 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	43 µg/L	manganese	14 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	41 µg/L	manganese	15 µg/L	lead	10 µg/L
33° 59'43"/118° 04'22"	1994	Ground	zinc	58 µg/L	lead	20 µg/L	manganese	10 µg/L
33° 59'43"/118° 04'22"	1994	Ground	zinc	59 µg/L	manganese	12 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	56 µg/L	manganese	15 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	57 µg/L	manganese	15 µg/L	---	---
33° 59'43"/118° 04'22"	1994	Ground	zinc	44 µg/L	manganese	13 µg/L	---	---

Table 109: USGS water quality data for top three chemicals detected in Los Angeles County, California

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 49'02"/118° 12'20"	1990	Surface	zinc	35 µg/L	manganese	16 µg/L	copper	6 µg/L
35° 49'02"/118° 12'20"	1991	Surface	manganese	47 µg/L	zinc	14 µg/L	copper	4 µg/L
35° 49'02"/118° 12'20"	1991	Surface	zinc	40 µg/L	manganese	10 µg/L	copper	<1 µg/L
35° 49'02"/118° 12'20"	1991	Surface	zinc	38 µg/L	manganese	4 µg/L	lead	2 µg/L
33° 59'43"/118° 04'22"	1994	Ground	manganese	2000 µg/L	lead	10 µg/L	zinc	7 µg/L
33° 59'43"/118° 04'22"	1994	Ground	manganese	1900 µg/L	copper	10 µg/L	zinc	8 µg/L
33° 59'43"/118° 04'22"	1994	Ground	manganese	1700 µg/L	copper	20 µg/L	lead	10 µg/L
33° 59'43"/118° 04'22"	1994	Ground	manganese	1600 µg/L	zinc	14 µg/L	---a	---a
33° 59'43"/118° 04'22"	1993	Ground	zinc	38 µg/L	lead	20 µg/L	manganese	2 µg/L
33° 59'43"/118° 04'22"	1993	Ground	zinc	32 µg/L	manganese	4 µg/L	---a	---a
33° 59'43"/118° 04'22"	1993	Ground	zinc	31 µg/L	lead	10 µg/L	manganese	2 µg/L

Table 109: USGS water quality data for top three chemicals detected in Los Angeles County, California

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35° 49'02"/118° 12'20"	1988	Surface	lead	16 µg/L	copper	8 µg/L	manganese	<1 µg/L
35° 49'02"/118° 12'20"	1988	Surface	zinc	7 µg/L	copper	5 µg/L	lead	<5 µg/L
35° 49'02"/118° 12'20"	1988	Surface	zinc	7 µg/L	lead	<5 µg/L	copper	2 µg/L
35° 49'02"/118° 12'20"	1988	Surface	zinc	36 µg/L	manganese	30 µg/L	copper	7 µg/L
35° 49'02"/118° 12'20"	1989	Surface	copper	10 µg/L	zinc	7 µg/L	lead	<5 µg/L
35° 49'02"/118° 12'20"	1989	Surface	copper	6 µg/L	zinc	5 µg/L	lead	<1 µg/L
35° 49'02"/118° 12'20"	1989	Surface	zinc	22 µg/L	copper	9 µg/L	lead	1 µg/L
35° 49'02"/118° 12'20"	1989	Surface	zinc	29 µg/L	copper	8 µg/L	manganese	3 µg/L
35° 49'02"/118° 12'20"	1990	Surface	zinc	18 µg/L	copper	<10 µg/L	lead	<10 µg/L
35° 49'02"/118° 12'20"	1990	Surface	zinc	17 µg/L	copper	9 µg/L	lead	<1 µg/L
35° 49'02"/118° 12'20"	1990	Surface	zinc	20 µg/L	copper	5 µg/L	manganese	3 µg/L

Table 109: USGS water quality data for top three chemicals detected in Los Angeles County, California

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
33° 59'43"/118° 04'22"	1994	Ground	zinc	51 µg/L	lead	40 µg/L	manganese	16 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 110: Top three TRI chemical releases to air in District of Columbia, Washington

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	sulfuric acid	59546	chlorine	3430	---	---
2001	sulfuric acid	40732	---	---	---	---
2000	sulfuric acid	53000	---	---	---	---
1999	sulfuric acid	79000	---	---	---	---
1998	sulfuric acid	66250	chlorine	2700	---	---
1997	chlorine	3310	---	---	---	---
1996	chlorine	3910	---	---	---	---
1995	certain glycol ethers	7350	chlorine	3110	---	---
1994	certain glycol ethers	6250	chlorine	3410	---	---
1988	copper	250	---	---	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 111: Top three TRI chemical releases to land and water in District of Columbia, Washington

Land Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	copper compounds	1350	---	---	---	---
2001	copper compounds	4600	nitrate compounds	327	---	---
2000	manganese compounds	9961	copper compounds	3017	---	---
1998	copper compounds	8800	---	---	---	---
1997	copper compounds	3300	---	---	---	---
1996	copper compounds	5000	---	---	---	---
1995	copper compounds	19000	---	---	---	---
1994	copper compounds	17300	---	---	---	---
Water Releases						
Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	manganese compounds	12800	nitrate compounds	656	---	---
2000	nitrate compounds	195	manganese compounds	74	---	---
1999	manganese compounds	40	copper compounds	4	---	---
1998	chlorine	6	---	---	---	---
1996	chlorine	300	---	---	---	---
1995	chlorine	255	---	---	---	---
1994	chlorine	1600	---	---	---	---
1989	copper compounds	250	---	---	---	---
1988	copper compounds	250	---	---	---	---

^aBlank cells indicate that data not available because less than three chemicals were released

Table 112: USGS water quality data for top three chemicals detected in District of Columbia, Washington

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
38° 55'17"/77° 05'53"	1994	Surface	manganese	51 µg/L	---	---	---	---
38° 58'34.7"/77° 03'07.3"	1999	Surface	manganese	55.7 µg/L	---	---	---	---
38° 58'58.4"/77° 02'24.9"	1999	Surface	manganese	104 µg/L	---	---	---	---
38° 58'00.3"/77° 02'46.3"	1999	Surface	manganese	2.2 µg/L	---	---	---	---
38° 57'36.6"/77° 02'31.4"	1999	Surface	manganese	104 µg/L	---	---	---	---
38° 54'41.8"/77° 03'07.2"	1999	Surface	manganese	53.2 µg/L	---	---	---	---
38° 57'05"/77° 03'11"	1994	Surface	manganese	3 µg/L	---	---	---	---
38° 54'44"/76° 57'55"	1994	Surface	chloride	55 mg/L	manganese	110 µg/L	---	---
38° 55'03.6"/76° 56'37.7"	2002	Surface	manganese	2300 µg/L	copper	<2 µg/L	lead	<1 µg/L
38° 55'03.6"/76° 56'37.7"	2002	Surface	manganese	1800 µg/L	---	---	---	---
38° 54'43.5"/76° 56'28.4"	2002	Surface	manganese	120 µg/L	lead	<1 µg/L	---	---
38° 54'43.5"/76° 56'28.4"	2002	Surface	manganese	220 µg/L	copper	<2 µg/L	lead	<1 µg/L
38° 53'52"/76° 56'00"	1994	Surface	chloride	37 mg/L	manganese	150 µg/L	---	---
38° 52'24"/76° 57'30"	1994	Surface	chloride	42 mg/L	manganese	100 µg/L	---	---
38° 54'24"/76° 56'57"	1994	Surface	chloride	34 mg/L	manganese	47 µg/L	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 113: Top three TRI chemical releases to air in Bartow County, Georgia

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	hydrochloric acid	17796865	sulfuric acid	1761343	---	---
2001	hydrochloric acid	14063797	sulfuric acid	1579001	hydrofluoric acid	745347
2000	hydrochloric acid	15289454	sulfuric acid	1618107	hydrofluoric acid	838329
1999	hydrochloric acid	16685599	sulfuric acid	1267727	hydrofluoric acid	1048105
1998	hydrochloric acid	15498275	sulfuric acid	1313786	hydrofluoric acid	1186921
1997	xylene	56760	zinc compounds	24087	barium compounds	6342
1996	N-methyl-2-pyrrolidine	36481	dichloromethane	19265	zinc compounds	17600
1995	ammonia	62037	zinc compounds	21100	dichloromethane	13876
1994	ammonia	24452	zinc compounds	20600	methanol	13800
1993	ammonia	32837	acetone	31543	zinc compounds	18500
1992	acetone	23306	methanol	22300	zinc compounds	18100
1991	acetone	43162	toluene	26600	methanol	25550
1990	acetone	34205	xylene	30340	zinc compounds	19640
1989	xylene	70435	zinc compounds	50388	methyl isobutyl ketone	34478
1988	zinc (fume or dust)	56419	methanol	28231	xylene	24674

^aBlank cells indicate that data not available because less than three chemicals were released

Table 114: Top three TRI chemical releases to land in Bartow County, Georgia

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	barium compounds	732501	---	---	---	
2001	barium compounds	501895	vanadium compounds	184493	copper compounds	121843
2000	barium compounds	654956	vanadium compounds	200668	copper compounds	129917
1999	barium compounds	496695	copper compounds	88296	chromium compounds	77717
1998	barium compounds	712843	copper compounds	125663	manganese compounds	118157
1988	sodium hydroxide solution	250	---	---	---	

^aBlank cells indicate that data not available because less than three chemicals were released

Table 115: Top three TRI chemical releases to water in Bartow County, Georgia

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	nitrate compounds	25499	copper compounds	11744	barium compounds	9664
2000	copper compounds	11734	barium compounds	10896	nitrate compounds	9397
1999	copper compounds	11719	barium compounds	6883	nitrate compounds	6418
1998	copper compounds	11719	nitrate compounds	9649	barium compounds	9637
1997	nitrate compounds	16616	barium compounds	7190	ammonia	66
1996	nitrate compounds	29230	barium compounds	6546	zinc compounds	93
1995	nitrate compounds	27194	barium compounds	5216	zinc compounds	86
1994	barium compounds	5346	ammonia	518	zinc compounds	86
1993	barium compounds	3995	ammonia	750	---	---
1992	barium compounds	11000	ammonia	750	---	---
1991	barium compounds	13000	ammonia	750	---	---
1990	barium compounds	17000	ammonia	750	---	---
1989	barium compounds	12250	ammonia	750	---	---
1988	barium compounds	14000	sodium hydroxide solution	4200	ammonia	750

^aBlank cells indicate that data not available because less than three chemicals were released

Table 116: USGS water quality data for top three chemicals detected in Bartow County, Georgia

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
34° 12'58"/84° 41'10"	2001	Surface	zinc	6 µg/L	copper	<2 µg/L	chromium	<1 µg/L
34° 09'47"/84° 44'28"	1988	Surface	manganese	40 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1988	Surface	manganese	30 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1988	Surface	manganese	190 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1988	Surface	manganese	40 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	20 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	20 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	50 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	50 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	50 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	20 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	30 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1989	Surface	manganese	300 µg/L	---	---	---	---

Table 116: USGS water quality data for top three chemicals detected in Bartow County, Georgia

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
34° 06'31"/84° 57'02"	2001	Surface	zinc	<2 µg/L	copper	<2 µg/L	chromium	<1 µg/L
34° 06'31"/84° 57'02"	2001	Surface	zinc	6 µg/L	copper	<2 µg/L	chromium	<1 µg/L
34° 06'53"/84° 47'24"	2001	Surface	zinc	<2 µg/L	copper	<2 µg/L	chromium	<1 µg/L
34° 06'53"/84° 47'24"	2001	Surface	zinc	22 µg/L	copper	7 µg/L	chromium	6 µg/L
34° 06'54"/84° 53'24"	2001	Surface	zinc	<2 µg/L	copper	<2 µg/L	chromium	<1 µg/L
34° 09'47"/84° 44'28"	1993	Surface	manganese	550 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1993	Surface	manganese	10 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1993	Surface	manganese	110 µg/L	---	---	---	---
34° 09'47"/84° 44'28"	1994	Surface	manganese	20 µg/L	---	---	---	---
34° 09'12"/84° 46'16"	2001	Surface	zinc	3 µg/L	copper	<2 µg/L	antimony	<1 µg/L
34° 09'12"/84° 46'16"	2001	Surface	zinc	3 µg/L	copper	<2 µg/L	antimony	<1 µg/L
34° 08'34"/84° 50'20"	2001	Surface	zinc	5 µg/L	copper	<2 µg/L	chromium	<1 µg/L
34° 08'34"/84° 50'20"	2001	Surface	zinc	21 µg/L	copper	7 µg/L	chromium	7 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 117: Top three TRI chemical releases to air in Suffolk County, New York

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	sulfuric acid	724010	hydrochloric acid	92000	toluene	30593
2001	sulfuric acid	656305	hydrochloric acid	95400	toluene	42106
2000	sulfuric acid	711260	hydrochloric acid	124100	toluene	58838
1999	sulfuric acid	494265	hydrochloric acid	66500	trichloroethylene	44189
1998	sulfuric acid	575265	toluene	75647	hydrochloric acid	71000
1997	xylenes	155123	methyl ethyl ketone	131398	toluene	112909
1996	methyl ethyl ketone	101918	xylenes	100935	toluene	83374
1995	methyl ethyl ketone	78162	dichloromethane	67635	toluene	63362
1994	dichloromethane	82460	chlorodifluoromethane	71821	methyl ethyl ketone	69353
1993	1,1,1-trichloroethane	140081	Freon 113	87305	dichloromethane	87177
1992	1,1,1-trichloroethane	775414	Freon 113	131137	dichloromethane	114222
1991	1,1,1-trichloroethane	756319	Freon 113	160912	dichloromethane	152670
1990	1,1,1-trichloroethane	603769	Freon 113	238892	dichloromethane	167380
1989	1,1,1-trichloroethane	754280	Freon 113	271530	dichloromethane	236754
1988	1,1,1-trichloroethane	803682	Freon 113	371128	dichloromethane	280917

Table 118: Top three TRI chemical releases to land in Suffolk County, New York

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2000	sulfuric acid	250	---	---	---	
1999	sulfuric acid	250	---	---	---	
1998	sulfuric acid	250	---	---	---	
1997	sulfuric acid	250	phosphoric acid	250	---	---
1996	copper	386	manganese compounds	61	---	---
1995	toluene	252	---	---	---	
1994	toluene	275	---	---	---	
1993	toluene	300	---	---	---	
1992	toluene	250	---	---	---	
1991	toluene	28	---	---	---	
1990	toluene	21	---	---	---	
1989	trichloroethylene	500	toluene	343	---	---
1988	sodium hydroxide solution	26000	toluene	2936	dichloromethane	250

^aBlank cells indicate that data not available because less than three chemicals were released

Table 119: Top three TRI chemical releases to water in Suffolk County, New York

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2001	methanol	5835	vanadium compounds	4900	nickel compounds	1500
2000	methanol	5489	vanadium compounds	4135	t-butyl alcohol	1388
1999	t-butyl alcohol	4781	methanol	4539	xylene	126
1998	t-butyl alcohol	5414	methanol	2730	methyl tert butyl ether	25
1997	copper compounds	30	---a	---a	---a	---a
1996	certain glycol ethers	1397	copper compounds	56	---a	---a
1995	certain glycol ethers	3673	copper compounds	82	---a	---a
1994	certain glycol ethers	8453	copper compounds	117	---a	---a
1993	certain glycol ethers	3620	copper compounds	94	---a	---a
1992	certain glycol ethers	5852	copper compounds	74	---a	---a
1991	certain glycol ethers	3622	copper compounds	58	---a	---a
1990	certain glycol ethers	2800	sulfuric acid	1368	copper compounds	107
1989	certain glycol ethers	632	chromium compounds	267	xylene	250
1988	certain glycol ethers	5111	sodium hydroxide solution	1600	hydrochloric acid	680

^aBlank cells indicate that data not available because less than three chemicals were released

Table 120: USGS water quality data for top three chemicals detected in Suffolk County, New York

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
40° 57'38"/73° 08'28"	1990	Surface	vanadium	1 µg/L	lead	1 µg/L	nickel	<1 µg/L
40° 57'38"/73° 08'28"	1990	Surface	vanadium	1 µg/L	lead	1 µg/L	nickel	<1 µg/L
40° 51'43"/73° 15'54"	1988	Surface	chromium	<10 µg/L	lead	<10 µg/L	toluene	<5 µg/L
40° 51'38"/73° 19'05"	1988	Surface	chromium	<10 µg/L	lead	<10 µg/L	toluene	<5 µg/L
40° 50'47"/73° 16'15"	1988	Surface	iron	<50 µg/L	chromium	<10 µg/L	toluene	<5 µg/L
40° 51'00"/73° 15'26"	1988	Surface	lead	<10 µg/L	xylenes	<5 µg/L	1,1,1-trichloroethane	3 µg/L
40° 51'00"/73° 15'26"	1988	Surface	lead	<10 µg/L	xylenes	<6 µg/L	1,1,1-trichloroethane	6 µg/L
40° 51'00"/73° 15'26"	1988	Surface	lead	<10 µg/L	xylenes	<8 µg/L	1,1,1-trichloroethane	6 µg/L
40° 51'00"/73° 15'26"	1988	Surface	lead	<10 µg/L	xylenes	<8 µg/L	1,1,1-trichloroethane	5 µg/L
40° 51'00"/73° 15'26"	1988	Surface	lead	<10 µg/L	xylenes	<9 µg/L	1,1,1-trichloroethane	4 µg/L
40° 51'00"/73° 15'26"	1988	Surface	lead	<10 µg/L	xylenes	<5 µg/L	1,1,1-trichloroethane	4 µg/L
40° 49'21"/73° 12'24"	2002	Surface	vanadium	<8 µg/L	nickel	<2 µg/L	chromium	0.5 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	1 µg/L	methyl tert butyl ether	0.1 µg/L	dichloromethane	<0.1 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	<5 µg/L	methyl tert butyl ether	0.1 µg/L	dichloromethane	<0.1 µg/L

Table 120: USGS water quality data for top three chemicals detected in Suffolk County, New York

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	4.2 µg/L	dichloromethane	<0.8 µg/L	methyl tert butyl ether	0.1 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	<3.3 µg/L	dichloromethane	<0.8 µg/L	methyl tert butyl ether	0.1 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	dichloromethane	<0.4 µg/L	methyl tert butyl ether	0.1 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	0.9 µg/L	dichloromethane	<0.4 µg/L	methyl tert butyl ether	0.1 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	dichloromethane	<0.4 µg/L	methyl tert butyl ether	0.1 µg/L
40° 49'36"/73° 03'26"	1997	Surface	methyl ethyl ketone	<1.6 µg/L	dichloromethane	<0.4 µg/L	toluene	<0.04 µg/L
40° 49'36"/73° 03'26"	1998	Surface	methyl ethyl ketone	<1.6 µg/L	dichloromethane	<0.4 µg/L	methyl tert butyl ether	0.3 µg/L
40° 49'36"/73° 03'26"	1998	Surface	methyl ethyl ketone	<1.6 µg/L	dichloromethane	<0.4 µg/L	methyl tert butyl ether	<0.1 µg/L
40° 47'08"/73° 19'02"	1988	Surface	chromium	<10 µg/L	toluene	<6 µg/L	xylenes	<4 µg/L
40° 49'20"/73° 14'28"	1988	Surface	lead	<10 µg/L	toluene	<5 µg/L	1,1,1-trichloroethane	3 µg/L
40° 43'39"/73° 13'51"	1993	Surface	methyl tert butyl ether	1 µg/L	xylenes	<0.5 µg/L	1,1,1-trichloroethane	<0.5 µg/L
40° 43'39"/73° 13'51"	1995	Surface	methyl tert butyl ether	8 µg/L	xylenes	<0.5 µg/L	1,1,1-trichloroethane	<0.5 µg/L
40° 43'34"/73° 14'41"	1993	Surface	methyl tert butyl ether	0.6 µg/L	--- ^a	--- ^a	--- ^a	--- ^a
40° 43'34"/73° 14'41"	1994	Surface	methyl tert butyl ether	0.8 µg/L	--- ^a	--- ^a	--- ^a	--- ^a

Table 120: USGS water quality data for top three chemicals detected in Suffolk County, New York

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
40° 55'19"/72° 25'18"	2001	Surface	methyl ethyl ketone	<1.6 µg/L	methyl tert butyl ether	<0.2 µg/L	xylene	<0.06 µg/L
40° 55'19"/72° 25'18"	2002	Surface	methyl ethyl ketone	<5 µg/L	methyl tert butyl ether	0.2 µg/L	xylene	<0.07 µg/L
40° 52'56"/73° 25'17"	1993	Surface	methyl tert butyl ether	2 µg/L	---a	---a	---a	---a
40° 52'56"/73° 25'17"	1994	Surface	methyl tert butyl ether	2 µg/L	---a	---a	---a	---a
40° 52'56"/73° 25'17"	1995	Surface	methyl tert butyl ether	2 µg/L	---a	---a	---a	---a
40° 50'58"/73° 13'29"	1995	Surface	methyl tert butyl ether	0.8 µg/L	---a	---a	---a	---a
40° 50'58"/73° 13'29"	1995	Surface	methyl tert butyl ether	6 µg/L	---a	---a	---a	---a
40° 50'58"/73° 13'29"	1996	Surface	methyl tert butyl ether	3 µg/L	---a	---a	---a	---a
40° 58'20"/72° 17'39"	2001	Surface	methyl ethyl ketone	<1.6 µg/L	dichloromethane	<0.2 µg/L	toluene	0.18 µg/L
40° 58'20"/72° 17'39"	2002	Surface	methyl ethyl ketone	<5 µg/L	dichloromethane	<0.2 µg/L	methyl tert butyl ether	<0.2 µg/L
40° 59'21"/72° 18'12"	1993	Surface	methyl tert butyl ether	0.8 µg/L	---a	---a	---a	---a
40° 57'34"/72° 10'42"	1993	Surface	methyl tert butyl ether	<0.5 µg/L	xylene	<0.5 µg/L	1,1,1-trichloroethane	<0.5 µg/L
40° 57'18"/72° 10'42"	2002	Surface	methyl tert butyl ether	0.2 µg/L	dichloromethane	<0.2 µg/L	toluene	0.08 µg/L
40° 57'01"/72° 14'20"	1993	Surface	methyl tert butyl ether	3 µg/L	xylene	<0.5 µg/L	1,1,1-trichloroethane	<0.5 µg/L
40° 57'01"/72° 14'20"	1995	Surface	1,1,1-trichloroethane	1 µg/L	methyl tert butyl ether	<0.5 µg/L	---a	---a

Table 120: USGS water quality data top three chemical releases in Suffolk County, New York

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
40° 41'30"/73° 21'20"	1996	Surface	methyl tert butyl ether	10 µg/L	---	---	---	---
40° 41'30"/73° 21'20"	1997	Surface	methyl tert butyl ether	4.1 µg/L	1,1,1-trichloroethane	2.30 µg/L	---	---
40° 40'13"/73° 24'51"	1993	Surface	1,1,1-trichloroethane	2 µg/L	methyl tert butyl ether	0.9 µg/L	---	---
40° 40'13"/73° 24'51"	1994	Surface	methyl tert butyl ether	1 µg/L	---	---	---	---
40° 40'13"/73° 24'51"	1995	Surface	methyl tert butyl ether	0.9 µg/L	---	---	---	---

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 121: Top three TRI chemical releases to air in Harris County, Texas

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	ethylene	3079019	nitrate compounds	2972526	--- ^a	--- ^a
2001	ethylene	3448352	propylene	2996818	sulfuric acid	1239108
2000	ethylene	3656276	propylene	3345541	ammonia	1680037
1999	ethylene	4512484	ammonia	2643508	methanol	1983741
1998	ethylene	4301034	propylene	3087925	methanol	2686207
1997	ethylene	4450536	methanol	3175650	ammonia	2002960
1996	ethylene	4719093	propylene	3552679	methanol	3241568
1995	ethylene	4111088	methanol	3352791	propylene	3347314
1994	ethylene	4328047	methanol	4019185	ethylene glycol	2692543
1993	ethylene	6083349	methanol	4047903	propylene	4009453
1992	ethylene	5782120	methanol	4303490	propylene	3039723
1991	ethylene	5240393	methanol	4555220	ammonia	3340273
1990	ethylene	5563443	toluene	3428849	ammonia	3412519
1989	ethylene	6628601	methanol	4582641	toluene	3393529
1988	ethylene	6487739	methanol	5014526	toluene	3582213

Table 122: Top three TRI chemical releases to land in Harris County, Texas

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	zinc compounds	1788556	--- ^a	--- ^a	--- ^a	--- ^a
2001	zinc compounds	321590	copper	67092	nickel	31333
2000	zinc compounds	392028	methanol	180231	barium compounds	63184
1999	zinc compounds	435199	methanol	198916	barium compounds	47283
1998	zinc compounds	477581	4,4'-isopropylidene phenol	60000	manganese compounds	46515
1997	zinc compounds	529586	manganese compounds	50606	barium compounds	29976
1996	4,4'-isopropylidene phenol	250000	zinc compounds	237005	manganese compounds	71686
1995	manganese compounds	170000	methanol	97436	4,4'-isopropylidene phenol	86000
1994	4,4'-isopropylidene phenol	224000	manganese compounds	148396	methanol	77939
1993	4,4'-isopropylidene phenol	430000	methanol	132352	chromium compounds	46669
1992	4,4'-isopropylidene phenol	286000	ethylene glycol	207450	manganese compounds	74872
1991	4,4'-isopropylidene phenol	372326	ammonium sulfate	306092	abestos (friable)	200000
1990	ammonium sulfate	817267	4,4'-isopropylidene phenol	554220	manganese compounds	93366
1989	ammonium sulfate	1281580	4,4'-isopropylidene phenol	778993	zinc (fume or dust)	263500
1988	aluminum oxide (fibrous)	4191000	sodium hydroxide solution	571310	4,4'-isopropylidene phenol	423804

^aBlank cells indicate that data not available because less than three chemicals were released

Table 123: Top three TRI chemical releases to water in Harris County, Texas

Year	Substance	Amount (lbs)	Substance	Amount (lbs)	Substance	Amount (lbs)
2002	methanol	5864510	nitrate compounds	2972526	--- ^a	--- ^a
2001	nitrate compounds	2511455	ammonia	189390	methanol	73907
2000	nitrate compounds	2515272	ammonia	125821	xylenes	51114
1999	nitrate compounds	7143748	ammonia	163266	sodium nitrite	38915
1998	nitrate compounds	6125393	methyl methacrylate	431639	ammonia	81756
1997	nitrate compounds	4515250	ammonia	149443	manganese compounds	29065
1996	nitrate compounds	3515730	phenol	688709	t-butyl alcohol	488379
1995	nitrate compounds	3157249	ammonia	222544	methanol	28660
1994	phosphoric acid	1100554	zinc compounds	433874	ammonia	140852
1993	ammonia	607370	methanol	32762	barium compounds	16060
1992	phosphoric acid	12000015	sulfuric acid	1200086	ammonia	1182832
1991	ammonia	746402	methanol	50630	zinc compounds	27687
1990	ammonia	900802	methanol	80285	zinc compounds	25226
1989	ammonia	797789	phosphoric acid	409400	sulfuric acid	148950
1988	ammonium sulfate	1128000	1,3-butadiene	110250	methanol	54408

^aBlank cells indicate that data not available because less than three chemicals were released

Table 124: USGS water quality data for top three chemicals detected in Harris County, Texas

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
29° 46'30"/95° 23'49"	1993	Surface	barium	210 µg/L	zinc	83 µg/L	manganese	16 µg/L
29° 46'30"/95° 23'49"	1993	Surface	barium	210 µg/L	zinc	23 µg/L	manganese	21 µg/L
29° 46'30"/95° 23'49"	1993	Surface	barium	190 µg/L	manganese	38 µg/L	zinc	17 µg/L
29° 46'30"/95° 23'49"	1994	Surface	barium	190 µg/L	zinc	55 µg/L	manganese	37 µg/L
29° 46'30"/95° 23'49"	1994	Surface	barium	110 µg/L	manganese	18 µg/L	zinc	14 µg/L
29° 46'30"/95° 23'49"	1994	Surface	barium	190 µg/L	zinc	16 µg/L	manganese	7 µg/L
29° 46'30"/95° 23'49"	1995	Surface	barium	39 µg/L	zinc	11 µg/L	manganese	8 µg/L
29° 46'30"/95° 23'49"	1995	Surface	barium	170 µg/L	zinc	18 µg/L	manganese	8 µg/L
29° 46'30"/95° 23'49"	1995	Surface	barium	92 µg/L	zinc	9 µg/L	manganese	2 µg/L
29° 46'30"/95° 23'49"	1996	Surface	barium	140 µg/L	manganese	29 µg/L	zinc	23 µg/L
29° 46'30"/95° 23'49"	1996	Surface	barium	130 µg/L	zinc	24 µg/L	manganese	11 µg/L
29° 46'30"/95° 23'49"	1996	Surface	barium	110 µg/L	zinc	21 µg/L	manganese	5 µg/L

Table 124: USGS water quality data for top three chemicals detected in Harris County, Texas

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
29° 46'30"/95° 23'49"	1988	Surface	barium	150 µg/L	zinc	25 µg/L	manganese	16 µg/L
29° 46'30"/95° 23'49"	1989	Surface	manganese	27 µg/L	zinc	27 µg/L	barium	19 µg/L
29° 46'30"/95° 23'49"	1989	Surface	barium	190 µg/L	zinc	20 µg/L	manganese	10 µg/L
29° 46'30"/95° 23'49"	1990	Surface	barium	170 µg/L	manganese	24 µg/L	zinc	19 µg/L
29° 46'30"/95° 23'49"	1990	Surface	barium	180 µg/L	manganese	14 µg/L	zinc	14 µg/L
29° 46'30"/95° 23'49"	1990	Surface	barium	170 µg/L	zinc	18 µg/L	manganese	11 µg/L
29° 46'30"/95° 23'49"	1991	Surface	barium	190 µg/L	manganese	29 µg/L	zinc	26 µg/L
29° 46'30"/95° 23'49"	1991	Surface	barium	150 µg/L	zinc	17 µg/L	manganese	11 µg/L
29° 46'30"/95° 23'49"	1991	Surface	barium	180 µg/L	manganese	22 µg/L	zinc	16 µg/L
29° 46'30"/95° 23'49"	1992	Surface	barium	150 µg/L	manganese	26 µg/L	zinc	14 µg/L
29° 46'30"/95° 23'49"	1992	Surface	barium	220 µg/L	manganese	21 µg/L	zinc	17 µg/L
29° 46'30"/95° 23'49"	1992	Surface	barium	170 µg/L	zinc	22 µg/L	manganese	13 µg/L

Table 124: USGS water quality data for top three chemicals detected in Harris County, Texas

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
29° 46'30"/95° 23'49"	1997	Surface	barium	202 µg/L	manganese	17.2 µg/L	zinc	16 µg/L
29° 46'30"/95° 23'49"	1997	Surface	barium	168 µg/L	zinc	36 µg/L	manganese	8.4 µg/L
29° 46'30"/95° 23'49"	1998	Surface	barium	182 µg/L	zinc	51 µg/L	manganese	25.6 µg/L
29° 46'30"/95° 23'49"	1998	Surface	barium	179 µg/L	zinc	27 µg/L	manganese	12.9 µg/L
29° 46'30"/95° 23'49"	1998	Surface	barium	148 µg/L	zinc	28 µg/L	manganese	8.7 µg/L
30° 02'09"/95° 09'12"	1988	Surface	barium	61 µg/L	copper	20 µg/L	zinc	3 µg/L
30° 02'09"/95° 09'12"	1988	Surface	barium	55 µg/L	copper	4 µg/L	zinc	<3 µg/L
30° 02'09"/95° 09'12"	1989	Surface	barium	69 µg/L	zinc	6 µg/L	copper	2 µg/L
30° 02'09"/95° 09'12"	1989	Surface	barium	75 µg/L	zinc	5 µg/L	copper	3 µg/L
30° 02'09"/95° 09'12"	2000	Surface	barium	64 µg/L	zinc	8 µg/L	copper	2.5 µg/L
30° 02'09"/95° 09'12"	2000	Surface	barium	56 µg/L	copper	2.5 µg/L	zinc	2 µg/L
30° 02'09"/95° 09'12"	2000	Surface	barium	60 µg/L	copper	2.1 µg/L	nickel	1.56 µg/L

Table 124: USGS water quality data for top three chemicals detected in Harris County, Texas

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
30° 01'58"/95° 07'46"	1988	Surface	barium	77 µg/L	---	---	---	---
30° 01'58"/95° 07'46"	1989	Surface	barium	62 µg/L	copper	3 µg/L	---	---
30° 01'58"/95° 07'46"	1989	Surface	barium	69 µg/L	copper	2 µg/L	---	---
30° 01'58"/95° 07'46"	2000	Surface	barium	52 µg/L	zinc	2 µg/L	copper	1.2 µg/L
30° 01'58"/95° 07'46"	2000	Surface	barium	51 µg/L	manganese	8.8 µg/L	zinc	2 µg/L
30° 01'58"/95° 07'46"	2000	Surface	barium	60 µg/L	copper	1.7 µg/L	nickel	1.17 µg/L
30° 01'58"/95° 07'46"	2000	Surface	barium	44 µg/L	manganese	5.9 µg/L	copper	3 µg/L
30° 01'58"/95° 07'46"	2001	Surface	barium	59 µg/L	manganese	4.2 µg/L	zinc	3 µg/L
30° 01'58"/95° 07'46"	2001	Surface	barium	62 µg/L	manganese	1.8 µg/L	copper	1.4 µg/L
30° 01'58"/95° 07'46"	2002	Surface	barium	59 µg/L	manganese	12.8 µg/L	zinc	6 µg/L
30° 01'58"/95° 07'46"	2002	Surface	barium	56 µg/L	manganese	2.9 µg/L	copper	1.7 µg/L
30° 01'58"/95° 07'46"	2002	Surface	barium	50 µg/L	manganese	8.4 µg/L	copper	1.2 µg/L

Table 124: USGS water quality data for top three chemicals detected in Harris County, Texas

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
29° 55'05"/95° 18'24"	1988	Surface	barium	210 µg/L	zinc	23 µg/L	manganese	12 µg/L
29° 55'05"/95° 18'24"	1989	Surface	barium	210 µg/L	manganese	19 µg/L	zinc	16 µg/L
29° 55'05"/95° 18'24"	1989	Surface	barium	240 µg/L	zinc	17 µg/L	manganese	12 µg/L
29° 55'05"/95° 18'24"	1990	Surface	barium	160 µg/L	manganese	52 µg/L	zinc	21 µg/L
29° 55'05"/95° 18'24"	1991	Surface	barium	250 µg/L	zinc	31 µg/L	manganese	9 µg/L
29° 55'05"/95° 18'24"	1992	Surface	barium	70 µg/L	zinc	30 µg/L	manganese	9 µg/L

^aBlank cells indicate that data are not available because less than three chemicals were reported

Table 125: USGS water quality data for top three chemicals detected in Knox County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
36°00'56"/83°49'54"	1988	Surface	barium	37 µg/L	copper	2 µg/L	chromium	<1 µg/L
36°00'56"/83°49'54"	1988	Surface	barium	35 µg/L	copper	2 µg/L	chromium	<1 µg/L
36°00'56"/83°49'54"	1989	Surface	barium	34 µg/L	copper	1 µg/L	chromium	1 µg/L
36°00'56"/83°49'54"	1989	Surface	barium	36 µg/L	copper	1 µg/L	chromium	<1 µg/L
36°00'56"/83°49'54"	1990	Surface	barium	33 µg/L	copper	7 µg/L	chromium	<1 µg/L
36°00'56"/83°49'54"	1990	Surface	barium	34 µg/L	copper	4 µg/L	chromium	1 µg/L
36°00'56"/83°49'54"	1991	Surface	barium	31 µg/L	copper	3 µg/L	chromium	<1 µg/L
36°00'56"/83°49'54"	1991	Surface	barium	31 µg/L	copper	1 µg/L	chromium	<1 µg/L
36°00'56"/83°49'54"	1992	Surface	barium	40 µg/L	---	---	---	---
36°00'56"/83°49'54"	1992	Surface	barium	27 µg/L	---	---	---	---

Table 125: USGS water quality data for top three chemicals detected in Knox County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°57'00.09"/84°00'58.92"	1992	Surface	zinc	150 µg/L	lead	14 µg/L	chromium	6 µg/L
35°55'46"/84°01'41"	1991	Surface	zinc	170 µg/L	lead	17 µg/L	copper	9 µg/L
35°55'46"/84°01'41"	1991	Surface	toluene	2.3 µg/L	---	---	---	---
35°55'46"/84°01'41"	1991	Surface	zinc	340 µg/L	copper	28 µg/L	lead	14 µg/L
35°55'46"/84°01'41"	1992	Surface	zinc	150 µg/L	copper	13 µg/L	lead	12 µg/L
35°55'46"/84°01'41"	1992	Surface	zinc	90 µg/L	copper	8 µg/L	lead	8 µg/L
35°54'58"/84°03'08"	1991	Surface	zinc	20 µg/L	copper	3 µg/L	---	---
35°54'58"/84°03'08"	1992	Surface	zinc	50 µg/L	chromium	7 µg/L	copper	6 µg/L
35°54'58"/84°03'08"	1992	Surface	zinc	50 µg/L	lead	5 µg/L	copper	3 µg/L
36°02'41"/84°03'35"	1989	Surface	zinc	10 µg/L	---	---	---	---

Table 125: USGS water quality data for top three chemicals detected in Knox County, Tennessee

Latitude/Longitude	Year	Water Source	Substance	Amount Detected	Substance	Amount Detected	Substance	Amount Detected
35°56'49.6"/84°10'50.1"	1998	Well	acetone	<5 µg/L	manganese	<3 µg/L	1,1,1-trichloroethane	0.05 µg/L
36°03'07.4"/83°48'46.6"	1998	Well	acetone	<5 µg/L	manganese	4.4 µg/L	--- ^a	--- ^a
36°05'57.3"/83°52'46.8"	1997	Well	manganese	25.5 µg/L	toluene	0.46 µg/L	--- ^a	--- ^a

^aBlank cells indicate that data are not available because less than three chemicals were reported

APPENDIX 3

Institutional Research Board Middle Tennessee State University

Institutional Review Board
P.O. Box 124
Middle Tennessee State University
Murfreesboro, Tennessee 37132
Office: (615) 898-5005

**MIDDLE
TENNESSEE**
STATE UNIVERSITY

April 25, 2005

Protocol Title: The Effect of the Dimensions of Learning Model on the Epistemological Beliefs of Students enrolled in a General Chemistry Course for Post Baccalaureate Premedical Students
Protocol Number: 05-229
cflaniga@mtsu.edu

Dear Ms. Wallace,

The MTSU Institutional Review Board, or representative of the IRB, has reviewed your research proposal identified above. It has determined that the study poses minimal risk to subjects and qualifies for expedited review under 45 CFR 46.110 and 21 CFR 56.110.

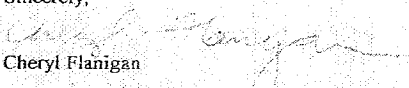
Please note that any unanticipated harms to subjects or adverse events must be reported to the Office of Sponsored Programs at (615) 898-5005.

Approval is granted for one (1) year from the date of this letter for thirty subjects

You will need to submit an end-of-project report to the Office of Research and Sponsored Programs upon completion of your research.

Please note that any change to the protocol must be submitted to the IRB before implementing this change.

Sincerely,


Cheryl Flanigan

Institutional Research Board Goucher College

GOUCHER COLLEGE

April 3, 2005

Darcie Wallace Duckworth
Supervisor/Lecturer Organic Chemistry Laboratory
Chemistry Dept.
Goucher College

Dear Ms. Duckworth,

This is to inform you that your Exempt IRB proposal for your research project, "The Effect of the Dimensions of Learning Model on the Epistemological Beliefs of Students Enrolled in a General Chemistry Course for Post Baccalaureate Premedical Students," has been approved. You may begin your research.

Thank you,

Dr. Kelly Denton-Borkaug
IRE Chair
Goucher College