5-8-2007

The Historical Production of Elemental Phosphorus in Pinellas County, Florida: An Environmental Assessment

Stephen D. Robinson
University of South Florida

Follow this and additional works at: http://scholarcommons.usf.edu/etd
Part of the American Studies Commons

Scholar Commons Citation
http://scholarcommons.usf.edu/etd/3849

This Thesis is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.
The Historical Production of Elemental Phosphorus in Pinellas County, Florida: An Environmental Assessment

by

Stephen D. Robinson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts
Department of Geography
College of Arts and Sciences
University of South Florida

Major Professor: Phillip Reeder, Ph.D.
Elizabeth Strom, Ph.D.
Graham Tobin, Ph.D.

Date of Approval:
May 8, 2007

Keywords: biologic, edaphologic, geographic, geomorphic, pedogenic

© Copyright 2007, Stephen D. Robinson
Table of Contents

List of Tables iii
List of Figures iv
List of Photographs v
Abstract vi

Chapter One - Introduction 1

Chapter Two - Review of Literature 4

Chapter Three - Research Design and Methods 10
  Research Design 10
    Problem Statement 10
    Objectives 10
    Research Question and Sub-Questions 11
    Background 12
    Research Justification 13
  Methodology 15
    Interviews 16
      Historical and Contemporary Ethnography 16
      Interview Methodology
        Ms. Joyce Gibbs 17
        Mr. Peter Hessling 19
        Mr. Charlie Ryburn 20
    Interview Questionnaire 21
  Historical Analysis 25
    Historical and Contemporary Archival Documentation and Analysis
List of Tables

Table-1 Interview Summary 16
Table-2 Appendix-A Timetable 121
List of Figures

| Figure-1 | Location of Pinellas County, Florida | 29 |
| Figure-2 | Municipal Locations of Pinellas County, Florida | 30 |
| Figure-3 | Location of Victor/Stauffer Study Area | 31 |
| Figure-4 | Aerial View of the Victor/Stauffer Study Area | 32 |
| Figure-5 | Detailed Aerial View of the Victor/Stauffer Study Area | 33 |
List of Photographs

Photograph-1  Tarpon Springs Public Library  26
Photograph-2  Federal Depository at the Tarpon Springs Public Library  26
Photograph-3  Stauffer Super Fund Site Looking South East  34
Photograph-4  Stauffer Super Fund Site Looking North West  34
Photograph-5  Stauffer Super Fund Site Looking South  35
Photograph-6  Stauffer Super Fund Site Looking East  35
Photograph-7  Gulfside Elementary School Looking North  36
Photograph-8  Stauffer Security Building  40
Photograph-9  Stauffer Warning Sign  41
Photograph-10  Stauffer Emergency Siren  41
Photograph-11  Anclote River Power Plant  43
Photograph-12  Study Area Single Family Home  43
Photograph-13  Anclote River Public Beach Looking West  44
Photograph-14  Anclote River Looking East  45
Photograph-15  Study Area Single Family Home  46
Photograph-16  Stauffer Warning Sign  106
Photograph-17  Study Area Old Home Site  106
Photograph-18  Gulfside Elementary School  107
Photograph-19  Anclote River Looking East  107
The Historical Production of Elemental Phosphorus in Pinellas County, Florida: An Environmental Assessment

Stephen D. Robinson

ABSTRACT

This thesis was completed in order to assess and document the environmental effects that are the result of elemental phosphorus production in Pinellas County Florida. The study utilized a collection of information resources that included: personal interviews, technical references, historical documents, legal documents and field observations. By utilizing five different sources of information a broad understanding of the problem was developed.

Pinellas County and Tarpon Springs officials were interested in creating a more diversified economy in the years following World War-II. The Victor Chemical Works Company responded to the interest in economic diversity by proposing to build an elemental phosphorus production facility in the area of greater Tarpon Springs, Florida. The elemental phosphorus production facility was completed and began operation in November of 1947. Three months after the facility commenced production local residents noticed damage to trees and painted surfaces on private properties. Seven months following commencement of elemental phosphorus production local residents filed suit against the Victor Chemical Works Company due to deleterious gasses.
and dust that appeared to be damaging to biologic health. The elemental phosphorus production facility operated from 1947 to 1981.

The 34-year operational period exposed workers, residents and biologic communities to extended periods of elevated sulfur dioxide, phosphorus pentoxide gas, phosphine gas, fluorine, lead, radium-226 and asbestos.

Utilizing personal interviews, technical document review, legal document review and field observations the thesis provided an amalgamation of diverse information upon which the conclusions were based. The research concludes that the production of elemental phosphorus exposed all physical and cultural environments of northwest Pinellas County to many complex adverse environmental impacts that continue to persist in 2007, approximately 26-years following the suspension of production.
Chapter One
Introduction

The purpose of this thesis is to identify and assess the environmental impacts that have resulted from the industrial production of elemental phosphorus in northwest Pinellas County, Florida. The research project utilizes personal interviews and the investigation of Federal depository documents, pertinent scientific studies and reports to analyze the adverse environmental impacts associated with elemental phosphorus production in Pinellas County. The environmental historical component of the study will track the history of the environmental impacts imparted by the production of elemental phosphorous in Pinellas County from (1947 to 1981) and the post production effects from (1981-2007). To understand the extended environmental history of the study area it is necessary to step back in time to gain a more fully developed perspective of the dynamics that helped to create the adverse environmental condition(s) that continue to exist today. In addition, the physical geography of northwest Pinellas County has imparted, important environmental components that imposes subtle dynamics that have helped exacerbate the adverse effects elemental phosphorus production to the adjacent communities of Pinellas County.

The project will also attempt to address the elements of public safety related to the production of elemental phosphorus Pinellas County, Florida. The incremental shifts in
the accepted industrial culture frequently accept and then later abandon industrial practices that could be detrimental to the safety of the public at large. Public safety has often been knowingly and unknowingly sacrificed by heavy industrial procedures. The disregard for public safety has frequently been a process of trial and error usually resulting in public safety improvements following an extended period of environmental hazards that were imposed on the public and the various ecological communities in the affected area.

Production of elemental phosphorus in Pinellas County created large airborne emissions of synthetic toxic gasses and dusts. The airborne synthetic toxic emissions were the result of melting raw phosphate rock from which elemental phosphorus, iron and fluorine could be collected and marketed. The local human and biologic communities were exposed to the pervasive clouds and gasses twenty four hours a day. The airborne emissions were dispersed by the micro-meteorology phenomenon that tended to magnify the adverse environmental impacts in a local context.

The industrial scale production of elemental phosphorus within northwest Pinellas County created numerous synergistic synthetic toxic (xenobiotic) compounds that are currently known to be hazardous to humans and various other soil and water biotic organisms. The industrial production of elemental phosphorus also spawned a plethora of synergistic toxic by-products that have only recently become known to the public in the surrounding community. The industrial production of elemental phosphorus also created significant damage to the commercial agricultural flora community. The commercial livestock community in the study area was decimated as a result of the bio-accumulation of synthetic toxins that were dispersed over the pasture lands. Private
properties in the study area were damaged from the caustic dust and gas clouds that emanated from the Victor Chemical Works and Stauffer Chemical Corporation production facility. Pinellas County residents became aware of the adverse environmental change approximately in January of 1948 approximately two months after production of elemental phosphorus commenced. In the summer of 1981 production of elemental phosphorus in Pinellas County came to an end and almost immediately the adverse air quality returned to safe ambient levels. However, the long term adverse environmental effects of elemental phosphorus production had not dissipated as quickly as the gas and dust clouds had. Pinellas County residents, properties and environmental resources were been damaged by persistent adverse toxic agents that did not dissipate with the large gaseous emissions created from 1947-1981. It is the coupled combination of residual and ephemeral environmental damage created by toxic agents that continues to manifest environmental degradation in Pinellas County, Florida.

Pinellas County and Federal environmental officials continue to toil with a politically astute public who are deeply concerned with their long-term health and welfare. The citizens of northwest Pinellas County are concerned that their physical health and economic wealth was and continues to be sacrificed in order to cater to the profitability of the powerful chemical industry (Ryburn, 2006).
Chapter 2

Review of Literature

This review of existing research amalgamates this project into the larger discourse of existing academic research. It specifically focuses on the adverse environmental aspects of elemental phosphorus residual contamination.

The Army Corps of Engineers (Racine, 1992) sanctioned a five-year study regarding the fate of elemental phosphorus called, *Persistence of White Phosphorus in Sediment*. The research was conducted at Eagle River Flats, Alaska at the location of an abandoned United States military artillery testing facility that had been used to test elemental phosphorus munitions. It was determined that white phosphorus indefinitely persisted in saturated sediments. Saturated soils are soils that have no dissolved oxygen components in the soil profile. It was further determined that elemental phosphorus was the cause of waterfowl deaths at Eagle River Flats. It was the more obvious loss of waterfowl that stimulated discussions what could be done to mitigate the adverse environmental effects of elemental phosphorus contaminated sediments.

During laboratory experiments, it has been determined that the sediment moisture content was the more important of the two factors tested in the context of the environmental persistence of elemental phosphorus in the Eagle River Flats sediments. As a solid parcel in reduced soils, elemental phosphorus is highly persistent and can exist unchanged for up to 10,000 years. However, in soils with adequate free pore space, it is
possible for elemental phosphorus to convert to a vapor phase and diffuse or be oxidized as orthophosphate. Diffusion of elemental phosphorus in soil has been shown to continue as long as there is sufficient free pore space to support diffusion processes associated with this synthetic compound (Baver, 1956).

The research project at Eagle River Flats, Alaska has revealed that elemental phosphorus has the potential to contaminate water and soil when it is held in a persistent reducing/anoxic environment. The research at Eagle River Flats is very relevant to Pinellas County because the Victor/Stauffer Super-Fund Site is contaminated with elemental phosphorus that has been buried in anoxic conditions since at least 1981. The study conducted at Eagle River Flats, Alaska asked the question; what is the ultimate environmental fate of elemental phosphorus in the soil? (Collins, and others 1995). The Victor/Stauffer Super-Fund Site might eventually provide the answer to this question within a sub-tropical context. Pinellas County soils do not freeze and this phenomenon would seem to enhance the dispersion of phosphine and orthophosphate gasses.

Clarkson (1991) determined that under anoxic conditions elemental phosphorus is an extremely toxic compound. However, when elemental phosphorus is held under aerobic conditions it has the potential to rapidly degrade to non-toxic phosphates. Under aerobic conditions elemental phosphorus usually dissipates from soil sediments as a more benign phosphine or orthophosphate gas. Before this specific study was completed in 1995 it had been hypothesized that elemental phosphorus was a benign non-persistent compound in the environment, including soils of all types (Collins, and others 1995).
This specific study clearly reveals that seasonal and permanently saturated hydric soil(s) and soils influenced by saline ground water can inhibit the chemical degradation of (P4) or elemental phosphorus (Clarkson, 1991).

In another relevant study, *Garbage Wars: The Struggle for Environmental Justice in Chicago*, (Thornton, 2000) research focused on the environmental risk the public was exposed to in Chicago, Illinois area garbage industry during the period from the 1800 to 2000. This specific research project closely parallels the thesis research within the context of public health risk and adverse environmental impacts that are associated with industry in close proximity to human concentrations. Collectively, the Victor/Stauffer Chemical Corporations and the garbage industry of Chicago have and to some degree continue to impose the greatest adverse environmental impacts on the public who were or continue to be politically disenfranchised. The Victor/Stauffer Chemical Corporation processing plant site was strategically placed in an area of northwest Pinellas County that had a pre-existing geo-political insular identity. Northwest Pinellas County in 1947 was located in an economically disenfranchised geographic realm with little to no constituent political power base. During 1947 the citizens of the northwest Pinellas County study area were aware that the economic conditions had weakened as the greater Tarpon Springs economy was declining.

Thornton (2000), states that people of color, low income and the politically disenfranchised tend to carry the heaviest burden in the context of pollution and solid waste hazards. He argues that eventually the elite and affluent will face the issue of environmental contamination in their workplaces and neighborhoods. The elites will eventually face contamination in their own homes because the industrialized North
America is creating more waste each year and the dependence on synthetic compounds and their polluting products cross all socio-economic gradients. Thornton’s conclusions also appear to hold true in Pinellas County as the lower income residents who had lower employment skills tended to accept the work opportunity at the Victor/Stauffer elemental phosphorus production facility.

In a project similar to my proposed thesis research project, Markowitz and Rosner (2002) (Deceit and Denial: The Deadly Politics of Industrial Pollution) attempt to reveal the conscious effort of the chemical industry in the United States to distort and conceal the public’s knowledge of highly marketed chemical compounds and environmentally dangerous products. In particular, the research focuses on the proliferation of lead as a particularly insidious material that was commonly sold and delivered into millions of American’s homes and buildings as a life-improving product.

The authors of this specific research work uncovered evidence and conducted numerous personal interviews with many of the significant individuals who were involved within the hidden recesses of industrial product development and marketing. Certain elements of the chemical industry perceived that environmental pollution was a significant hazardous issue that had long been denied by many in the industry at their own peril. However, knowing this, the chemical industry continued to act on a united front, saying that it could be trusted to safeguard the public and the environmental as a whole (Markowitz and Rosner 2002). The Victor/Stauffer Chemical Corporation Super-Fund Site represents another tangible example of deceit and denial that has been imposed on, in this case the people of northwest Pinellas County. The production facility was initially operated at the accepted industrial standard. However, as government codified
regulations tightened in the late 1970s it became very apparent that the corporate owner of the facility could not make the financial commitment to enhance public safety. This particular behavior ultimately evolved into industrial denial that left the citizens exposed to significant adverse environmental conditions over an extended period of time.

The Love Canal region of the Niagara River basin represents another comparable study area. Love Canal is the place name where the Hooker Chemical Company disposed of chemical by-products between 1942 and 1952. The Love Canal chemical disposal site has several repeating similarities that are shared at the Stauffer Chemical production facility. Both areas are active EPA-Superfund sites, both sites are in close proximity to large population areas, and each of these chemical facilities were being brought on-line when new and influential powerful chemical industries were gaining a foothold in the American economy. Another common connection both the Love Canal and the Stauffer Chemical production facility share is the fact that earthen burial was used as the means to dispose of unwanted toxic by-product compounds. The Hooker Chemical Corporation and the Victor/Stauffer Chemical Corporations both shared the need to dispose of the unmarketable by-products that synthetic chemistry was creating in great quantities (United States Environmental Protection Agency, 2002).

There were no State or Federal sanctioned statutes for the disposal heavy industry by-products at this time. Governmental oversight led to some disastrous consequences relative to corporate disposal techniques of toxic synthetic compounds. It is in this way, that the Hooker Chemical Company and the Victor/Stauffer Chemical Companies made disposal choices that continue to adversely affect the environment of the residents that
live or work near either of the subject EPA Super-Fund Sites (United States Environmental Protection Agency, 2002).

Another contaminated site, the Shattuck Chemical Corporation constructed and operated a uranium and mineral processing plant in an area that in the 1920s was rural, but by the 1960s became prime real estate. The uranium processing facility was gradually surrounded by very expensive winter vacation homes within the rapidly suburbanizing foothills of the Rocky Mountains. The site was assigned to the Super-Fund Interim Properties list in October of 1981, and due to the extensive contamination uncovered near areas of human occupation, the site was included on the National Priorities list on September 8, 1983 (EPA Region-8 Report, 2004).

The Shattuck Superfund site closely parallels the adverse environmental risks and exposure probabilities that took place and continue to exist at the Victor/Stauffer Chemical Super-Fund site. The Victor/Stauffer facility also had an extended period of production that exposed operational workers, area residents and non-human organisms to dangerous inhalation, oral and dermal exposure to elemental phosphorus, and the associated zenobiotic chemical byproducts that are coupled to high temperature elemental phosphorus production. It was only after the Stauffer Corporation production facility closed in 1981 that the full scope of elemental phosphorus hazards became known to the public at large.
Chapter Three

Research Design and Methods

Research Design

Problem Statement

This research project will provide a comprehensive case study utilizing personal interviews, historic literature analysis and technical documents to assess the short term and long term adverse environmental impacts that were imposed on the public and other biologic communities as a direct result of elemental phosphate production in Pinellas County. The study will reveal the environmental issues that existed in 1947 and continue to persist more than 26 years after elemental phosphorus production was suspended in Pinellas County, Florida.

Objectives

As part of gathering data from historical sources, interviews and various government and technical reports, this thesis will specifically focus on:

- Analyzing the historic literature and the institutional knowledge of Pinellas County employees regarding the environmental risk factors for past employees associated with the production of elemental phosphorus at the Stauffer/Victor facility.
• Analyzing the historical literature and the institutional knowledge of Pinellas County employees regarding the environmental risk factors for the human residents in the study area associated with elemental phosphorus production.

• Analyzing the existing technical literature and historic documents regarding the environmental risk factors of non-human organisms associated with elemental phosphorus production.

Research Questions and Sub-Questions

The over-arching research question for this research is:

What are the adverse environmental impacts resulting from the production of elemental phosphorus in Pinellas County, Florida?

In order to further assess the specifics of the adverse environmental impacts associated with the production of elemental phosphorus, this research will also utilize the following sub-questions:

• What are the adverse environmental impacts imposed on employees relative to air quality, water quality and other forms of exposure in the study area?

• What are the adverse environmental impacts imposed on citizens relative to air quality, water quality and other forms of exposure in the study area?

• What are the adverse environmental impacts imposed on the non-human organisms relative to air quality, water quality and other forms of exposure in the study area?
Background

In order to provide a broader context to the pervasive adverse environmental impacts of elemental phosphorus production the next section will connect Pinellas County to a broader collection of knowledge on this topic. Pinellas County, Florida is not the exclusive geographic host site to the production of elemental phosphorus in the United States. The production of elemental phosphorus has had adverse environmental impacts in other geographic locations of the United States. The cumulative adverse environmental effects of elemental phosphorus have also been documented in Montana, Alaska and Polk County, Florida. Pinellas County was exposed to the adverse environmental effects of elemental phosphorus production prior to many other geographic areas within the United States and therefore the Pinellas County scenario is a prototype.

The industrial incident that most parallels the Pinellas County scenario occurred in Garrison, Montana when a rancher sold 54-acres of his land to the Rocky Mountain Phosphate Company (Fisher, Prival 1973). The Garrison, Montana community eagerly awaited the arrival of the new industrial employment opportunities. The Rocky Mountain Phosphate Company facility had come with the promise of jobs and much needed tax revenues for the industry-hungry region. However, in less than five years, it was noted that the indigenous Ponderosa Pines and Douglas Firs were turning brown and necrotic, and that cattle on Garrison’s large ranches were becoming incapacitated as the result of fluorides that were being emitted from the high temperature processing of phosphate ore. The cattle industry was virtually destroyed in less than five years. It took six years of frustrating campaigning to the various regulatory agencies before the residents of

The production at the Victor Chemical Works elemental phosphorus processing facility (ownership changed to Victor/Stauffer in 1960) in Pinellas County, Florida commenced in November of 1947. As early as January of 1948 the residents of northwest Pinellas County were noticing the necrosis of Slash Pine (Pinus elliottii) and Longleaf Pine (Pinus palustris) trees and the declining health of bovine livestock that had flourished prior to the commencement of production at the new Victor Chemical Works facility. The industrial production of elemental phosphorus in northwest Pinellas County continued unabated over a thirty four-year period until 1981 when production ended (Environmental Protection Agency, National Priorities List 1994).

The period of 1947 to 1981 was a dynamic period when Pinellas County was attempting to transform from a poorly diversified agrarian and fishing economy and culture into the most densely populated metropolitan area in Florida. According to 1990 census data, approximately 14,000 people lived within a one-mile radius of the Victor/Stauffer site north of the Anclote River and approximately 4,700 people live within one mile south of the Anclote River (Agency of Toxic Substances and Disease Registry 2003).

Research Justification

It is anticipated that this research will create a broad basis of geographic environmental knowledge that will be derived from the collection, documentation and interpretation of pertinent data. The specific research will be conducted in order to provide a comprehensive geographic context of knowledge, and to produce a basis of
documented knowledge that can be built upon as a foundation for further understanding heavy industrial production in the region and to answer the stated research questions.

This research conveys an environmental history that developed within the confines of the insular northwest section of Pinellas County. The early stages of this particular environmental history has not previously been well documented, or formally presented in its totality to the public. The study will document and analyze the institutionalized recollections of the government employees and appointed officials who worked to safeguard the public’s welfare. The study documents and analyzes institutional knowledge over a period of 60-years. It was not until the late 1970s when issues regarding adverse environmental impacts were becoming politically prominent. Codified or enforceable environmental regulations regarding elemental phosphorus production were essentially non-existent during the time period of 1947-1981.

Pinellas County Commissioners attempted to diversify the Pinellas County economy following World War-II by courting heavy industry. In retrospect, the uninformed decision of public officials was meant to serve the constituents positively. This study shows that upon closer examination the public official’s good intentions opened the door to an extended period of time of environmental degradation in Pinellas County.

Public officials in Pinellas County did not have the technical analyses tools available to them in 1947 to make prudent long-term decisions based on public safety and environmental sustainability. The absence of technical environmental knowledge is a reoccurring phenomenon in this study. A broad understanding of local and regional hydrology, meteorology, geology, pedology, edaphology, human toxicology and
industrial techniques would have given Pinellas County public officials the tools they
needed to make a prudent environmental decision regarding the Victor/Stauffer facility in
northwest Pinellas County

The research therefore provides valuable insight into the establishment, proliferation and subsequent abandonment of the elemental phosphorus/phosphate industry in northwest Pinellas County. It is important that this research took place in that certain environmental contamination and degradation in northwest Pinellas County were systematically linked to the Victor/Stauffer elemental phosphorus production facility. By combining personal interviews, historical research, review of existing public and private literature a new perspective was gained on the adverse environmental impacts that have been imposed on Pinellas County as a result of 34-years of elemental phosphorus production. This study helps broaden the base of knowledge by adding additional information to the existing base of knowledge about the full adverse environmental implications of historic heavy industry in Pinellas County.

Methodology

This section of the study provides the framework for the collection of the various datum collection methods. The study is developed within the framework of an environmental assessment case study. This project will utilize a combination of archival records, personal interviews, participant observation, field observation and the review of public documents in order to reach its conclusions.
Interviews

Historical and Contemporary Ethnography Interview Methodology

Three personal interviews were completed with Pinellas County scientific and administrative staff members who were intimately involved with the monitoring of the Victor/Stauffer Chemical elemental phosphorus manufacturing facility while it was still in operation or during the post production EPA Super fund environmental coordination process. The interviews were conducted with the three officials (Table 1) between August 9, 2006 and August 31, 2006 to account for the fact that several of the Pinellas County scientific staff members who hold valuable institutional knowledge were approaching retirement status. It was the intention of the interview schedule to allow as much institutional knowledge as possible to be secured before it became unavailable in an open public context. Following the interviews, specific information relevant to this thesis were organized and fit into the framework of this study.

(Table 1)

<table>
<thead>
<tr>
<th>Ms. Joyce Gibbs</th>
<th>Pinellas County Real Estate, Coordinator</th>
<th>Employment: 1974-present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Peter Hessling</td>
<td>Pinellas County Air Quality, Administrator</td>
<td>Employment: 1976-present</td>
</tr>
<tr>
<td>Mr. Charley Ryburn</td>
<td>Pollution Recovery, Program Manager</td>
<td>1992-present</td>
</tr>
</tbody>
</table>

This portion of the research attempts to assemble institutional knowledge, in both a long-term and contemporary context from individuals in close proximity to the environmental issues regarding the production of elemental phosphorus in Pinellas
County, Florida. Based on specific management involvement in air quality, water quality and soil contamination in northwest Pinellas County: Ms. Joyce Gibbs, Mr. Peter Hessling and Mr. Charlie Ryburn were selected. Deliberate efforts were made to secure the institutional knowledge of local public officials that have tangible experience in the study area. Special care was taken to secure interviewees that were not financially or emotionally influenced by their past or current dealings with the events that transpired in the study area. Hence, the selected interviewees represented the strongest collection of technical and institutional knowledge that did not have conflicted interests with the study area.

**Ms. Joyce Gibbs**

Ms. Joyce Gibbs has been employed by Pinellas County Government since 1974. In 1974 Ms. Gibbs was chosen to serve as a charter member of the Pinellas County consortium exploratory environmental planning committee. The exploratory planning committee’s goal was to inventory and assess the outstanding environmental risks that existed within Pinellas County based on the directives of Federal legislation circa 1974. In 1975, Ms. Gibb’s title changed to Air Quality Chief of Pinellas County, and she was charged with developing the Pinellas County Air and Water Quality Division so that baseline ambient analytical knowledge for the Pinellas County air shed and water shed could be completed. Ms. Gibbs was the Chief of the Air Quality Division of the Pinellas County Department of Environmental Management from 1975-1986. Ms. Gibbs was charged with administering air quality policy for all of Pinellas County from 1975-1986 and this included the commencement of a progressive ambient testing and compliance program. Ms. Gibbs was fully responsible to research, manage and enforce Pinellas
County air quality standards. The Air Quality Division expended an extensive effort attempting to determine the content of the emissions emanating from the Stauffer Chemical Corporation elemental phosphorus production facility. Because of her frequent investigative inspections of the elemental phosphorus plant, Ms. Gibbs became very familiar with the day to day operations and procedures at the Stauffer Chemical Corporation elemental phosphorus production facility. This thesis relied heavily on the interview of Ms. Joyce Gibbs because of her 6-years of practical expertise relative to elemental phosphorus production emissions in the study area. The interview was conducted in order to extract her long-term institutional knowledge of the project area and the heavy industry operational conditions that created adverse environmental impacts in the study area.

Ms. Gibbs continues to work for Pinellas County in 2007, and she is currently employed as the environmental coordinator for the Real Estate Division of the Pinellas County Public Works Department. Although Ms. Gibbs is no longer a member of the Pinellas County Department of Environmental Management, she provides the most powerful link to the past production procedures at the Stauffer Chemical Corporation elemental phosphorus facility during 1974-1981. During 1974-1981 Ms. Joyce Gibbs was Pinellas County’s highest ranking air quality official that dealt with the adverse environmental impacts associated with air toxics. Ms. Joyce Gibbs was chosen as a research interviewee because of her diverse, knowledge regarding the production of elemental phosphorus in Pinellas County. Ms. Joyce Gibbs also possesses the intangible quality of long-term perspective which has allowed her to reflect on the adverse
environmental impacts of elemental phosphorus production in Pinellas County over a span of 33-years.

**Mr. Peter Hessling**

Mr. Peter Hessling has been employed by Pinellas County since 1976 when Pinellas County was in the earliest stages of developing an Environmental Protection Agency (EPA) sanctioned Air Quality Department. Mr. Hessling’s work history includes making frequent air quality field inspections of the Stauffer Corporation Elemental Phosphorus production plant on a complaint driven basis from 1976-1981, while under the direction of Ms. Joyce Gibbs. Mr. Hessling had access to the restricted areas of the study site during active production periods and has first hand knowledge of the adverse air quality impacts that resulted from the production of elemental phosphorus. Mr. Hessling was charged with the day to day inspections of the Stauffer Chemical Corporation facility. This required Mr. Hessling to walk amongst the steam pipes and catwalks of the facility. Hence, he became very familiar with production methodologies. Mr. Hessling was also responsible for comprehending the operational procedures of the elemental phosphorus production facility. As a result of his work charge, Mr. Hessling spent substantial time at the Stauffer Chemical Corporation elemental phosphorus production facility (1976-1981), inspecting the furnaces, chimneys, clarifiers and elemental phosphorus nodulizers. Because of his abundance of practical experience, Mr. Hessling has accumulated a substantial amount of institutional knowledge relative to elemental phosphorus production in Pinellas County. Mr. Hessling has also testified under oath as an expert witness at public depositions regarding the 1994 Stauffer EPA Super Fund hearings held in Pinellas County. Mr. Hessling progressed through the
various layers of the Pinellas County Air Quality Division and currently serves as the Division’s Administrator. Mr. Peter Hessling was selected as a research interviewee because of his level of operational knowledge regarding the day to day operation of the facility and the adverse environmental impacts resulting from high temperature elemental phosphorus production.

Mr. Charlie Ryburn

Mr. Charlie Ryburn has been employed by Pinellas County since 1992 and has helped to lead the Pinellas County Department of Environmental Management in the development of a pollution recovery program. Mr. Ryburn is primarily charged with coordinating the remediation of hazardous waste facilities or hazardous waste accident sites in Pinellas County, Florida. The pollution recovery program is also frequently referred to as environmental remediation. Mr. Ryburn serves as Pinellas County’s direct liaison to the 1994 Stauffer EPA Super Fund Site. In other words Mr. Charley Ryburn reports directly to the Pinellas County Commission regarding the day to day development associated with the 1994 Stauffer Chemical Corporation Super Fund Site. Mr. Ryburn has intimate knowledge of the degradation of soil and groundwater relative to elemental phosphorus production in Pinellas County, Florida. Mr. Ryburn is charged with reviewing and responding on Pinellas County’s behalf to all Stauffer Super Fund Site environmental remediation reports and proposals that are associated with the on-going litigation and negotiations based on the 1994 Stauffer Chemical Corporation Super Fund Site designation. Mr. Ryburn is currently employed by Pinellas County as the Program Manager of the Pinellas County Department of Environmental Management Pollution Prevention Program. Mr. Charlie Ryburn was selected as a research interviewee because
of the amount of knowledge on the site, that he has accumulated since 1994.

**Interview Questionnaire**

It was determined that a private interview session based on a series of open-ended questions would yield the most information for the study. All interviewees were encouraged to expound beyond the constraints of any question in order to reveal all pertinent institutional knowledge. The starting point for the interviews encompassed the following questions:

1). Provide your specific historical recollections of the Stauffer Corporation elemental phosphorus production facility in Pinellas County, Florida?

2). Describe the industrial/environmental hygiene conditions you observed at the Stauffer Corporation elemental phosphorus production facility in Pinellas County, Florida.

3). Describe the environmental conditions that employees were exposed to during the operational period of the Stauffer Corporation elemental phosphorus production facility in Pinellas County, Florida?

4). What were the environmental conditions that the surrounding community was exposed to during the operational period of the Stauffer Corporation elemental phosphorus production facility in Pinellas County, Florida?
5). Describe the tangible measures that were taken to minimize the adverse environmental impact to the facility workers and the surrounding commercial and residential communities?

6). What was/is the public opinion of the Stauffer Corporation elemental phosphorus production facility during it’s operational and post operational period?

7). What efforts were made at the local level in order to help assure the safety of the public relative to the Stauffer Corporation elemental phosphorus production facility?

8). What could be done within the realm of current industrial regulations to increase the safety of workers and the public relative to heavy industry?

9). What lessons have been learned from the production of elemental phosphorus in Pinellas County, Florida?

The interviewees were free to expound on any issue that they knew would be relevant to the study. As a result of the openness of the interview extensive information was collected outside of the formal framework of the above noted nine questions. During the course of the interviews additional institutional information was collected as each question provoked more comprehensive responses.

During all of the interviews it was paramount to follow accepted ethnographic interview procedures. The interviews were constrained by the following rules as defined by Atkinson et al (2001):
Listen well and respectfully, developing an ethical engagement with participants at all stages of the project; acquire a self awareness of our role in the construction of meaning during the interview process; be cognizant of ways in which both the ongoing relationship and the broader social context affect the participants, the interview process, and the project outcomes; and recognize that dialogue is discovery and only partial knowledge will ever be attained (Atkinson et al, page, 307, 2001).

The respondent(s) were passively encouraged to produce answers that are self evident in meaning. In order to accomplish this, I tried to keep the interviewees at ease by using non-intrusive open-ended inquiries. By not asking close-ended questions, the respondent(s) were given liberty to expand on an inquiry as much as they desired. By conducting an interview with exclusively open-ended questions it allows the respondents to gather his/her thoughts, and to concentrate on issues that are important to this research.

During the interview process I viewed it as critically important to allow the respondent to freely expound on the subject matter. In order to accomplish this, I adhered to the following guidelines for effective and free flowing inquiry (Evans, et al, 1984).

-Ask question(s) that cannot be answered with “yes,” “no,” or a simple fact.
-Ask question(s) that is/are on topic.

The interviewer should make open inquires to:
-Give respondents greater opportunity to discuss topics relevant to them.
-Gather information and help respondents explore and clarify their concerns.
-Put respondents at ease.
-Facilitate elaboration of a point.
-Elicit specific examples of general situations.

The interviewer should make closed inquires:
-Generally, as infrequently as possible.
-Specifically, when you need information that is important to the progress of the interview (Evans, et al, page 44, 1984).
As the interviewer I was fully aware that any one interview can yield a biased perspective that would be exclusive to that individuals own particular values and paradigm(s). In order to compensate for this natural human characteristic I attempted to conduct interviews across a broad cross-section of informed respondents.

As the interviewer, I took detailed hand written notes and made sketches/drawings to document technical details when appropriate. The sketches and drawings were used as cues to help me recall specific technical details divulged by the respondents. No tape recorder was used during the interviews.

The interview process included the collection of the institutional data from the three interviewees. The compilation of pertinent data required assimilation and distillation of approximately three hours of personal interviews and the interpretation of detailed line drawings and distilling the relevant details that were germane to the specific study. A hard bound journal book was used to record the dialogue of the interviews and to capture the detailed line drawings that the interviewees drew to help clarify their topic points. In many cases the interviewees drew descriptive line drawings to assist the study in the interpretation of specific details relative to location geography and the areas that were adversely affected. The transcriptions followed the dialogue of the interviewees, but excluded the extended dialogue pauses to collect thoughts and non relevant dialogue such as periods when the dialogue drifted to no subject matters. Therefore, the transcripts are not exact hand written recordings of every word that was expressed during each interview. The transcripts are detailed notes and quotes taken from each of the interviewees. Direct quotes relating to the topic questions and additional commentary verbage was captured as each interviewee responded to the series of questions. Research
data was extracted from the transcripts when the interviewees made comments that were pertinent to the over-arching research question and related sub questions.

The transcripts that were derived from the interviews were scrutinized for pertinent informational details that were relevant to the over-arching research question and sub questions. When information relevant to the research questions was located within the transcripts it was extracted and imposed into the supporting text of the thesis. The nine prepared interview question provided a basis of technical details that were able to help answer the associated research questions. The interviewing process also prompted several spontaneous responses from the participants that provided auxiliary institutional knowledge. The spontaneous interview responses were also scrutinized for details that could help to answer the research questions. The interview transcripts in totality were utilized as the depository of practical contemporary knowledge relevant to the Pinellas County research project. All details within the transcripts that were relevant to the research was extracted and imported into the research thesis narrative as supporting knowledge.

When relevant direct quotes from the interviews and/or literature are used, and in other instances, when themes or prevailing lines of thought are extracted from the transcripts direct quotes are not used, but the interview is referenced.

**Historical Analysis**

**Historical and Contemporary Archival Documentation and Analysis**

Additional information related to the elemental phosphorous processing in northwest Pinellas County was also gathered using historical and contemporary archival analysis, in
order to create an evolving collection of data that complimented the interview data base.

The process of historic document collection began in April 2003 as the public was afforded access to the Federal Depository in Tarpon Springs, (Photograph 1 and 2).

Photograph 1-Tarpon Springs Public Library
(Looking Southward)

Photograph 2-Federal Depository at the Tarpon Springs
Public Library

26
The archival research consisted of reviewing existing research, mostly from technical bulletins and reports. This phase of the research utilized the resources of the libraries at the University of South Florida, Tarpon Springs City Library (the Federal Depository for the Stauffer Super-Fund Site), the Pinellas County Department of Environmental Management technical library and archived files, the City of Clearwater Public Library and the internet.

Large amounts of data were located at the Federal Depository in Tarpon Springs, Florida. The research process required reading through a large volume of technical bulletins and reports that are located at the Federal Depository. The research reading was focused in order to find pertinent elements of environmentally related topics relative to the research project. Additional research data was gathered from the collective library and archived files of the Pinellas County Department of Environmental Management located in Clearwater, Florida. The archival research utilized the existing published texts and documents in order to draw together the collective concepts and perspectives of various research works that have similarities with my site specific local research project.

When historic and contemporary information relative to the research question and sub question was located it was extracted for the historic analysis portion of the research project. The study was able to acquire many of the hard copies of historic and contemporary documents over the course of the research project.

The documents usable by the research investigator can be considered under two broad categories: existing documents, which are not produced in connection with a specific study but are relevant to it, and elicited documents, which are produced at the instigation of the investigator by the individuals being studied (Dohrenwend, et al, page 16, 1965).
Geographers who utilize ethnography are able to use the records of previous fieldwork in two ways. They can incorporate it into his/her own research, and use it to extend their study backwards to compare past and present. They can also use it critically to re-examine their predecessor’s interpretations and conclusions (Ellen, 1984).

The historical information was derived from the agglomeration of data that initially appeared to be relevant to the over-arching research question and sub questions. Following a more comprehensive analysis of the collected historical data all relevant information was extracted and compiled for application. When information relevant to the research questions was located within the historic information it was imposed into the supporting text of the thesis as supporting knowledge. During the writing of the research thesis all relevant historical information was distilled and imported into the research project.
Chapter Four

Study Area

The specific area of study is located along the west central coast of Florida (figure 1). The project area is located within an unincorporated portion of northwest Pinellas County that is dominated by the geographic influence of the Anclote River and the Gulf of Mexico.

Figure 1- Location of Pinellas County, Florida

(Pinellas County Government GIS, 2005)
The study area in northwest Pinellas County is highlighted as a white inclusion immediately north of the purple highlighted area labeled as Tarpon Springs (figure 2).

Figure 2-Municipal locations of Pinellas County
(Pinellas County Government GIS, 2005)
The adjacent geographic area(s) within a one-kilometer radius of the specific study area retains sparse development. Located within a one-kilometer radius are: the Anclote River two private marinas, a mobile home park, single-family homes and widely scattered industrial businesses. The Victor/Stauffer Property is approximately 130 acres in size (figure 3 and 4).
Figure 4- An aerial view of the Victor/Stauffer site with the boundaries of the site within the yellow highlighted polygons.
(Pinellas County Government GIS, 2005)
Figure 5 provides a more detailed close up overview of the adjacent land uses and offers a clear view of the abandoned land that supported the production facility.
Photograph 3-Stauffer Super Fund Site
Fenced North West Entrance Road (Looking South Eastward)

Photograph 4-Stauffer Super Fund Site
Fenced Phosphate Slag Field (Looking North Westward)
Photograph 5-Stauffer Super Fund Site
Fenced Elemental Phosphorus Production Compound (Looking Southward)

Photograph 6-Stauffer Super Fund Site
North Side of Elemental Phosphorus Production Compound
(Looking Eastward)
Geology/Pedology

This section of the research project is provided in order to detail the physical geographic environmental attributes of the project area. The described geographic attributes are very specific to the research area and directly influence the potency of the adverse environmental impacts that were imposed on the population and biologic community.

The study area has experienced significant soil profile disturbance as a result of the development of the industrial infrastructure that was required to support a large-scale phosphate ore processing facility. Significant soil cutting and filling was conducted in the project area in order to accommodate structure construction and railroad
transportation infrastructure. The grading of the site was conducted primarily to level the land parcel in order to maximize land use for industrial applications. The project site is comprised of three distinct soil classifications.

The site is dominated by soil reworked by construction throughout the entire southern section from the Anclote River eastward to Anclote Road. These made land soil(s) are anthropogenic modifications of the existing soils in the area(s).

Made land (Ma) soil is frequently underlain by buried river and sandy bay bottom and also mucky Tidal swamp. Made land is comprised of various introduced materials that can consist of shell, rock fragments, mixtures of sand and clay that have been leveled by earth moving equipment. The introduced materials are spread over the existing native soils so that natural soil profiles become buried and mixed (United States Department of Agriculture 1972 Soil Survey of Pinellas County, Florida).

The northern limit of the site is comprised of Astatula fine sand. The Astatula fine sand is an excessively drained soil that was formed in relic coastal dunes. Astatula fine sand, 0 to 5 percent slopes (AfB) is an Entisol that has developed on the upland ridge of Pinellas County and it generally produces a level to gently sloping landscape. Under normal precipitation conditions Astatula fine sand will support a water table that is between (101.6cm to 152.4cm/40” to 60”) below the surface. Astatula series are highly droughty soils. The parent landscape and historic soils were formed on a geomorphic feature known as the Pamlico terrace (United States Department of Agriculture 1972 Soil Survey of Pinellas County, Florida).

The soil component within the study area have been worked and re-worked extensively by earth moving equipment from 1947-1981. As a result of this, the project
site is nearly level and supports primarily ruderal (a plant species that quickly recruits in waste places such as disturbed unoccupied soils) species of trees and shrubs. Due to anthropogenic activities no natural/relic coastal dune ridges or topographic anomalies remain.

**Climate**

All parts of Pinellas County are exposed to the temperature moderating effects of both Tampa Bay and the Gulf of Mexico. Pinellas County experiences extended periods of hot and humid weather during the summer season and relatively cool and dry winters. January provides the coldest weather period with average daily high temperatures of 22.2 degrees C or 72 degrees F and daily average lows of 12.7 degrees C or 55 degrees F. August provides the hottest weather with average daily highs of 32.2 degrees C or 90 degrees F and daily lows of 24.4 degrees C or 76 degrees F. November provides the lowest average monthly precipitation total of 4.32cm or 1.7 inches and July provides the greatest average precipitation total of 23.37cm or 9.2 inches (1972 Pinellas County Soil Survey).

The Victor/Stauffer specific study area is also highly influenced by its very close proximity to the Gulf of Mexico. During spring, summer and fall a dominant afternoon coastal sea breeze supports a prevailing westerly wind that moderates temperatures. Annual rainfall in Pinellas County is approximately 55 inches/139.7 centimeters. However, local micro-meteorological phenomenon can create significant annual deviations in precipitation totals. A single tropical storm event during any given year can significantly enhance precipitation totals well above the average total. Nearly 60% of the annual rainfall total occurs from June through September and tropical storms during this
time period can contribute significant amounts of rainfall in a 24-hour period (1972 Pinellas County Soil Survey). Rainfall in Pinellas County is rather acidic and it averages a pH of 5.15 (Pinellas County Department of Environmental Management, Air Quality Division Datum, 2005).

Between September 1981 and September 1982 the mean pH value for rainfall for the Pinellas, Pasco, Hillsborough County metropolitan area was 4.48 (Fernald and Patton, 1984).

Extended dry periods occur from April 15th-June 15th and from October 1st-December 15th. Pinellas County experiences temperatures of 32-degrees approximately 5-10 times each year. Winter temperatures drop to 28-degrees or lower approximately three times each winter (1972 Soil Survey of Pinellas County, Florida).

**Topography**

As previously noted, the study area’s natural topography has been significantly altered by earth moving equipment. The site has been historically leveled in order to accommodate industrial production and the supporting railroad transportation infrastructure. The 1995 United States Geological Survey quadrangle map indicates that the subject land parcel has two rather distinct planar units of elevation. The lower planar landscape unit adjacent to the Anclote River averages 1.52 meters or 5.0 feet National Geodetic Vertical Datum, 1929 (NGVD) and the more landward upper landscape unit averages an elevation of 3.48 meters or 10.0’ NGVD. The high point on the study site is approximately 3.66 meters or 12.0’ NGVD (feet above mean sea level). The topographic high point of the study site is located at the extreme northeast corner of
the land parcel adjacent to Anclote Road (United States Geological Survey, Tarpon Springs Quadrangle Map, 1995).

The study site exhibits virtually no evidence or erosion or mass wasting. This is in great part due to the very subtle topographic deviations that were created when the site was leveled. The study site is comprised of very fine textured soil and sands that have weak cohesion qualities. The ambient soil characteristics would normally create a site that would be highly prone to erosive and mass wasting influences.

**Land Use**

At this time, the 52.63 hectare or 130-acre Stauffer Chemical production site has been demolished except for two remaining administrative buildings located south of Anclote Road. The Stauffer Chemical site is currently staffed by two security guards who are housed in one of the two remaining administrative buildings during day light hours.

Currently, the abandoned 52.63 hectare 130-acre site is partitioned from public access with a six-foot tall barbed wire fence on all perimeters. The perimeter fencing is posted
with no-trespassing signs and United States Environmental Protection Agency Super
Fund Site informational and warning signs.

Photograph 9-Stauffer Chemical Company Super Fund Site Warning Signage
(North Fence Line Looking Southward)

Photograph 10-Stauffer Chemical Company Super Fund Site Emergency Siren
(North Fence Line Looking Eastward)
The study site supports a sparse collection of tree and shrubs. The fenced compound is mowed by Stauffer Management Corporation staff and this action reduces the opportunity for native tree and shrub recruitment. The altered droughty soils support a sparse coverage of Bahia grass (*Paspalum notatum*) and Bermuda grass (*Cynodum dactylum*) which are mowed on an as needed basis. A gated single-family sub-division named Meyers Cove is located adjacent to the west side of the abandoned Stauffer Chemical production facility. The adjacent parcel located to the south of the Stauffer Chemical facility is an operating commercial marina that caters primarily to non-commercial weekend boat traffic. An aluminum recycling business and a concrete pipe casting business are both located on the east side of the site. The aluminum recycling business and the concrete pipe casting business do not directly adjoin the Stauffer Chemical property.

The area located to the east of the abandoned elemental phosphorus production facility is described as light industrial, public utility (Anclote Progress Energy) and commercial by the Pinellas County Zoning Department. The single exception to industrial, public utility and commercial zoning within 0.5 kilometers of the Stauffer Chemical site is the Meyers Cove single-family subdivision.
Photograph 11-Anclote River Progress Energy Plant

Photograph 12-Anclote River Frontage Single Family Home
(Located 1.0 Kilometer West of the Stauffer Chemical Company Super Fund site)
Population

The extreme northwest corner of Pinellas County is truncated by an extensive system of river crenulations, bayous and marine swamps that have limited the areal extent of large home site development up to this time. Because of this, the extreme northwest corner of Pinellas County has not seen high-density development or redevelopment.

Photograph 13-Public Beach and Commercial Shrimping
(Mouth of the Anclote River Looking Westward)
The population within the research area has remained very stable since 1980. According to the 1980 census approximately 12,500 people lived within a one-mile radius of the research site north of the Anclote River and approximately 4,000 people live within one mile of the research site south of the Anclote River (Pinellas County Planning Department Abstract, 2000).

According to the 1990 census, approximately 14,000 people lived within a one-mile radius of the research site north of the Anclote River. Approximately 4,700 people live within one mile of the research site south of the Anclote River (Agency of Toxic Substances and Disease Registry, 2003).

Photograph 14-Anclote River
1.0-Kilometer West of the Stauffer Chemical Company Super Site
(Looking Eastward)
Photograph 15-Low Density Housing in the Project Area (Single Family Home Adjacent to the Anclote River (Looking Eastward))
Chapter Five

Results and Discussion

This section is a compilation of qualitative and quantitative informational findings that has been compiled and analyzed following an investigation of historic document, contemporary documents and from personal interviews of various officials associated with the environmental field in Pinellas County, Florida. Based on the analysis of the research data sources a scenario of 60-years of adverse environmental impacts to Pinellas County is demonstrated. The relationship of elemental phosphorus production and adverse environmental impacts in the study area are directly linked to the production location and the time of production. The phosphate industry of Florida began in 1879 when rock phosphate mining commenced in what is present day Hawthorn, Florida. The first commercial mining of phosphate pebbles occurred in 1882 within the Peace River Valley at Fort Meade, Polk County, Florida (Randazzo and Jones, 1997). The historic timetable of the phosphate industry of Florida is more fully detailed in Appendix-I.

Native Florida phosphate is an un-pure Apatite ore that contains numerous inclusions. Florida phosphate ore is an amalgamation of mineral impurities. Phosphate formation in Florida was reliant on numerous submergence and emergent oceanic sequences. The submergence and emergent oceanic rise and fall exposed the areas of Florida to nutrient rich seawater up-wellings. The oceanic up-wellings helped to create concentrations of biogenic compounds that are exploited from Florida’s phosphate ore.
The geologic amalgamation of numerous biogenic marine sediments created a nutrient rich geologic formation that is exploited for the latent phosphate.

Native phosphate ore is not currently considered to be a toxic compound. The toxic compounds within phosphate ore are realized only when it is synthetically altered by high heat and reducing conditions. The harsh conditions that are used to create elemental phosphorus liberate the toxic fluorine impurity from phosphate ore. The liberation of fluorine is just one example of the cocktail of toxic compounds to which elemental phosphorus production employees were exposed.

The following sections of the thesis will segregate the specific adverse environmental conditions that employees, citizens and the larger biologic community were exposed to during the operational and post operational years of the Victor/Stauffer elemental phosphorus production facility. This section of the thesis begins with the employees who worked at the 130-acre production facility during its 34-year operational period. The following sections will address each of the research sub-questions separately, with the questions:

1). “What are the adverse environmental impacts imposed on the employees relative to air quality, water quality and other forms of exposure in the study area?”

2). “What are the adverse environmental impacts imposed on citizens relative to air quality, water quality and other forms of exposure in the study area?”

3). “What are the adverse environmental impacts imposed on the non-human organisms relative to air quality, water quality and other forms of exposure in the study area?
These research sub-questions are examined in order to help answer the larger, over-arching research question, “What are the adverse environmental impacts resulting from the production of elemental phosphorus in Pinellas County, Florida?”

Employees

Air Quality Issues

This section of the research will concentrate on the adverse environmental conditions that are relevant to the employees that worked in the production of elemental phosphorus in Pinellas County. The production employees were exposed to the gas, fumes and dust associated with elemental phosphorus production during a 40-hour work week. The emissions created by the production facility produced adverse air, water and soil quality conditions that were most concentrated in the work area environment. This information for the following sections was extracted from the analysis of historical documents, technical references, media interviews and interviews of public environmental officials who hold specific institutional knowledge about the production facility.

The incineration of raw phosphate ore is not a simple benign process. The melting of native Florida phosphate rock results in the liberation of toxic compounds that escape as gasses and precipitations of aerosols. The twin 458 cubic meters/500 cubic yard capacity electric arc furnaces helped to ensure that copious amounts of gasses and dust emanated throughout the study area. A facility worker or resident could not escape the production facility’s geographically large and nearly persistent emission plume (Gibbs, 2006).
The large scale production of elemental phosphorus did not escape the scrutiny of Pinellas County’s earliest environmental planners. During the inception of environmental regulation in Pinellas County the following observation had been made:

The Stauffer elemental phosphorus processing plant was the only heavy industry located within Pinellas County at that time and to this day and it was without a doubt the most obvious environmental issue we faced in Pinellas County. After completing Pinellas County’s environmental consortium review in 1974 we deemed the Stauffer elemental phosphorus plant to be the greatest risk to the environmental quality in Pinellas County and the employees at the facility (Gibbs, 2006).

The following quotation highlights a particular danger to the production floor employees when a batch of phosphate ore had completed its production process. Every production batch created the need for a de-gassing phase.

During the de-gassing phase of production large quantities of phosphorus pentoxide, sulfur dioxide gas and fluorine gas was vented from the chimney of the furnace (Hessling, 2006).

This detail reveals the particular environmental degradation that occurred during the degassing phase. The degassing process marked the end of a batch production and typically the large amounts of gas overwhelmed the undersized ventilation hoods and chimney capacity. Phosphorus pentoxide and sulfur dioxide are severe respiratory irritants and chronic exposure can lead to lesions of the trachea and lungs. When phosphorus pentoxide is combined with atmospheric moisture a mild phosphoric acid can be formed and may disperse in thick white clouds of smoke. When atmospheric moisture is combined with sulfur dioxide a gaseous sulfuric acid is created. When gaseous fluorine is combined with atmospheric moisture an airborne fluoric acid is created. All of the fore mentioned acidic gasses can burn and ulcerate moist eye surfaces and
respiratory tissues. Along with burning human tissue sulfuric acid can also damage painted surfaces of cars and structures. Fluoric acid is a highly corrosive compound and if it is capable of etching glass.

Peter Hessling highlighted several of the adverse environmental conditions that production employees were frequently exposed to during a typical 8-hour shift. The following paragraph emphasizes the risks of working on the production floor after the furnaces were opened in the cooling phase. To further expand on this specific issue Mr. Pete Hessling provided the following institutional knowledge regarding operational procedures based on his field observations and investigations from his compliance inspections:

During the furnace breeching stage of production large quantities of sulfur dioxide and phosphorus pentoxide would have been liberated outside of the chimney and onto the work area floor apron. Much of the fugitive steam was generated when blasts of cool water from fire hoses were poured onto the hot phosphate slag (Hessling, 2006).

Another production phase known as the phosphate slag cooling process also put production employees at great risk. This specific process exposed the workers to the greatest air quality hazard during a production cycle (Hessling, 2006).

Peter Hessling also indicated that the phosphate slag cooling process created large quantities of steam that contained toxic phosphorus pentoxide gas. This particular gas component would cling to the land surface due to its' high specific gravity and would achieve densities that would obscure visibility to less than 30 feet within one mile of the production facility. Phosphorus pentoxide gas is corrosive and irritating to mucous surfaces of eyes, lungs and skin. Another major source of phosphorus pentoxide gas escape occurred when an excessively large hole was knocked out of the electric arc.
furnace plug during the tapping procedure. If this occurred a large down draft was created and this would actively pull large quantities of hot phosphorus pentoxide gas out of the furnace and the chimney. This particular operational phenomenon would create a large cloud of toxic gas that could empty the entire contents of the furnace and chimney onto the production floor. The floor production staff was not equipped with any type of lung or eye protection. Additional toxic compounds in the smoke emissions and dust included fluorine and sulfur dioxide (Hessling, 2006).

The local meteorology exacerbated the local damage resulting from the operation as prevailing winds pushed the plume of gasses, smoke and dust east and south eastward towards the more populated City of Tarpon Springs and Dunedin (Hessling, 2006). The local prevailing winds and topography would control the path and dispersion of the gaseous emission. It was common for the dense phosphorus pentoxide gas to move gravitationally to the Anclote River. The industrial releases of phosphorus pentoxide gas were never accurately measured at the Stauffer site during the production period because there was no EPA accepted means to assess concentrations circa 1975-1981 (Hessling, 2006).

According to Peter Hessling the phosphate nodule production furnace also generated large amounts phosphorus pentoxide at ground level. This condition endangered the production staff and all of the residents within one mile of the facility. The major problem with the phosphate nodule furnace was that it did not have effective dispersion designed into the chimney structure. The poor chimney design allowed clouds of phosphorus pentoxide, fluorine and sulfur dioxide to persist in the vicinity of the facility for extended periods of time with no means for rapid dispersion (Hessling, 2006).
Peter Hessling also stated that in many circumstances effective chimney and hood systems can move the toxic contaminant to atmospheric heights that allow meteorological dispersion processes to dilute the pollutant over a large geographical air shed area. At the Victor/Stauffer production facility observational evidence indicates that the geometry of the chimney and ventilation hoods were poorly designed and overwhelmed and atmospheric dispersion was not exploited (Hessling, 2006).

Joyce Gibbs stated that the environmental risks associated with the production of elemental phosphorus were numerous and included adverse conditions for workers and the residents in the vicinity of the pollutant plume of the production facility. The workers in the production facility were exposed to conditions that predisposed them to: asbestosis, chemical burns, physical burns, fluorosis, lead poisoning, radium-226, silicosis, phosphorus intoxication, sulfur dioxide, phosphorus pentoxide, phosphine gas and fugitive dust containing an amalgamation of by product materials (Gibbs, 2006).

The above list of toxic agents is not clinically conclusive as there are synergistic compound reactions that have not been researched. Asbestos is a toxic agent that is well understood in the context of 2007. However, in 1947 the risks associated with asbestos were not well understood or published. The extreme temperatures and pressures created during production at the Victor/Stauffer facility caused pipes and furnace structures to fatigue. As a result of this, frequent repair patching with asbestos cement was conducted by production workers.

Peter Hessling stated that the production of elemental phosphorus required the use of extremely high heat and this imposed great heat stresses on the facility’s pipes and heat connections. In order to repair heat fatigue damage, asbestos cement was used
extensively in the production plant. Asbestos cements were also used liberally to protect critical components from the high heat environment. Steam pipes and all observed voids in the furnace structures were coated or plugged with asbestos cement compounds. The asbestos compounds would eventually deteriorate and become fractured in and around the furnace production area. On rare occasions the asbestos plug that held the electrode in place would fall into the furnace and it would be vaporized and expelled in the chimney emissions. The vaporized asbestos cement would be dispersed through the chimney where it would settle over the adjacent properties in the area. There was never any accounting or inventory records keep so that asbestos cement volumes could be measured (Hessling, 2006).

Asbestos becomes a significant health risk to humans when it is fractured and dispersed into the air column. When asbestos fragments are inhaled by humans the asbestos filaments lodge deeply in the lungs and in order to wall of irritation the lung tissue responds by creating cystic tissue. Long term exposure to air borne asbestos can create asbestosis with is an untreatable chronic lung disease (Gibbs, 2006).

The dispersion of vaporized asbestos created a significant respiratory risk to the entire study area. However, production workers essentially worked in an extremely dusty environment that included minute fragments of asbestos. The absence of respiratory protection placed the production workers at great risk for asbestosis. Exposure to asbestos fibers can also create a condition that predisposes humans to lung cancer.

Over time the fibers (of asbestos) can work loose and, because they are small enough to float freely in the air or be inhaled, asbestos usage is now strictly controlled; exposure to its dust can cause cancer (Lindley and Moore, 1998).
In order to shelter the public from the appearance and operational emissions of the elemental phosphorus processing plant it was conveniently tucked away in the relatively unpopulated northwest corner of Pinellas County. However, the hazardous emissions could not be partitioned and were dispersed locally by meteorological processes. Joyce Gibbs stated,

During my public health driven inspections at the Stauffer Chemical elemental phosphorus facility from 1975-1981 I was taken back by the extreme dirtiness of the site. This was a real dirty heavy industry and Pinellas County had no other comparable facility. I was most amazed by the dust. The site was frequently shrouded in thick clouds of dust and fumes. I never observed any employees wearing lung or eye protection equipment. Following the completion of a batch the production furnaces would be tapped at the base using a battering ram. At this stage molten phosphate/silica slag would boil out of the furnaces along with large clouds of phosphorus pentoxide and fluorine gas. This was the most dangerous phase of the production as the vast amounts of burnt phosphate and slag would pour out of the furnace and onto the floor of the facility at temperatures near 3,000F. Plant workers were frequently burned by the steam and molten slag that could splash outside of the containment walls on the production floor. Workers were also burned by elemental phosphorus.

Related to this Joyce Gibbs said:

The overhead vent hood could not contain the large volume of gasses and fumes that poured out of the furnace during the breaching event. Because of this, there were frequent large clouds of phosphorus pentoxide that would loom over the immediate area of the facility. When phosphoric acid vapors are combined with abundant atmospheric moisture you create phosphoric acid clouds. Prevailing winds would generally push the phosphorus pentoxide cloud plumes to the southeast over the adjacent Flaherty Marina and towards the Tarpon Springs population (Gibbs, 2006).

In the preceding quotation, the issue of employee safety is more fully discussed. The completion of each batch of elemental phosphorus included the need to break open the face of the furnace so that the molten slag material could be cleared from the furnace.
It was during this phase of production that employees and residents in the project area were at the greatest environmental risk. As the furnace was tapped or broken open the specific gravity forces pulled large quantities of gasses from the belly of the furnaces. If the furnace was breached with too large of an opening the entire chimney could be drained of gasses and in this way the chimney and furnace gaseous constituents could end up at ground level for human exposure.

The pervasive dust and gas clouds contained a cocktail of synthetic compounds that are toxic to humans. Employees at the production facility had no way to effectively shield their bodies from the airborne chemical compounds. As a result of this, the employees were at great risk.

The vast majority of employees did not work at the production facility for extended periods of time. The turnover rate was very high and it does not appear that any employee worked in the production area for more than three years. The industrial safety conditions were very poor. Some employees wore dust masks but there were no respirators or face protections used. An issue that I was concerned with was fluorine poisoning as we had no accepted way to sample and quantify for this highly toxic compound. Employees who are exposed to fluorine will commonly develop dental disease(s) that can include weakening of the jaw. The employees would frequently smoke during breaks and lunch and it is possible that they inhaled fluorine as a cross contaminant from their cigarettes (Gibbs, 2006).

Joyce Gibbs also added that the Stauffer Chemical Corporation had a rudimentary on-site dental operatory where it appeared that dental work was conducted. People affected with phossy-jaw experience an erosion of the jaw bone structure and total tooth lose can occur along with mandible infections. The Stauffer Chemical Corporation provided in-house dental care for its employees. There was a dental chair in the building. A dentist facility was located in the employee’s locker room building. It would seem
logical that oral disease was managed by the company. The onsite dental facility was most likely used to resolve issues related to loss of calcium in the jaw bone and other dental diseases associated with fluorosis (Gibbs, 2006).

Another issue of concern is the adverse effect on kidneys from excessive fluorine absorption.

Two areas are of concern in regard to fluorine and kidneys. First, a fairly substantial body of research indicates that people with kidney dysfunction are at increased risk of developing some degree of skeletal fluorosis. Second, a small and inconclusive amount of research suggests that fluoride may actually cause or aggravate kidney disease (Hileman, 1988).

The workers at the Victor/Stauffer elemental phosphorus production facility were exposed to a collection of air quality hazards as they made repairs to keep the furnaces functioning. Former Stauffer Chemical Corporation workers tell stories of spending their work day in irritating gas clouds. The past employees recall moving bags of asbestos that would frequently break open. The workers clothes were full of a white dust that was created from the discharge of the giant furnaces. For many of the years the plant operated there was no breathing protection as laws did not require breathing protection for workers. Worker turnover at the elemental phosphorus plant was significant. Stauffer’s employee records indicate that only 25% of the employees stayed at the elemental phosphorus plant for more than one year. The 2003 ATSDR study concludes that employees must be protected by tough occupational hazard laws that have the ability to guard the employee from health hazards that they may not be fully aware of. The study also concluded that past employees at the Victor/Stauffer elemental phosphorus plant must receive ongoing health care since there is a high propensity for lung disease in
this group. On going heath care for the past employees might help them to live more extended lives with more comfort (St. Petersburg Times Editorial, December 29, 2005).

Joyce Gibbs provided the following comment regarding to the adverse conditions that workers were face with:

It was common for employees to receive both chemical and thermal burns while working in the production furnace facility. I saw several employees who had significant burn scar tissue on their arms from what appeared to be numerous burn events. Wounded flesh provides an opening for elemental phosphorus and fluorine absorption into the blood stream (Gibbs, 2006).

The greatest risk for humans from elemental phosphorus comes from frequent dermal exposure and associated absorption. Elemental phosphorus is highly soluble in the lipid environment of fatty tissues. Because of its enhanced solubility in fatty tissue many health experts believe that elemental phosphorus dermal injuries result in delayed wound healing. The absorption or ingestion of elemental phosphorus can result in pathogenic changes to the liver and kidney. Absorption or frequent small ingestions can result in subtle to significant changes to normal blood chemistry. Assimilated elemental phosphorus can result in increased blood phosphorus levels that are capable of replacing the essential calcium content in the blood chemistry. The reduction of calcium in the blood chemistry and the elevation of phosphorus levels in the blood chemistry can produce electro-cardiographic changes to the heart. Frequent consumption of very small amounts of elemental phosphorus can create pathologic changes in the kidneys, liver and fatty tissues and can lead to cardiac disruptions (Emedicine; eResidency.net, 2003).

Numerous workers and residents have been adversely affected by the 34-year period of active production. Most likely there are hundreds of people who lived and
worked near the plant who have paid a terrible price in health related issues that they may
have never been aware of. Stauffer workers were exposed to asbestos, sulfur dioxide,
phosphorus pentoxide and elemental phosphorus burns that could predispose them to an
increase risk of cancer and other health risks. Dangerous levels of arsenic and radium in
the soil at the Stauffer site may become a future health hazard if residential development
is allowed to occur there (Rondeaux, 2003). Radium-226 is a particular long term hazard
in the study area. The next paragraph explains the risk to elemental phosphorus workers
from radium-226.

Processing and slag waste handling in the Florida phosphate industry is
associated with (radium-226 derived) radiation levels of concern for
workers and the public. The level of (lung and dermal) protection for
these groups should be more similar to the level of protections that is the
state of the art in other industries, particularly the nuclear industry
(Connet, 2003).

Fluorine intoxication is an accumulative health risk that would have pervaded the
entire workplace environment. The vast quantities of processed Apatite would have
liberated up to 54,545 kilograms or 120,000 pounds of fluorine gas each day based on the
production capacities of the twin arc-furnace facilities.

**Water Quality Issues**

This research was unable to collect tangible data relevant to water quality that was
adverse to the workers of the Victor/Stauffer production facility. The Victor/Stauffer
facilities eating and drinking facilities were not open for public inspection during the
production years of 1947-1981. Because of the lack of access to water quality
information in the production area the research will focus on water quality issues in the
citizen’s section of the research outside of the production facility foot print.
The production workers were exposed to very hazardous conditions during a 40-hour work week. Even lunch hours and breaks for production workers provided no escape from production dangers as most employees remained in dusty clothing and frequently would drink, eat or smoke with a cocktail of toxic agents covering their face, hands and hair. Smoking cigarettes during work breaks with elemental phosphorus or fluorine contamination would have posed another significant health risk for production employees. When employees returned home work clothes could have been laundered with other family members clothing. Combining work clothes and non-work clothes during laundering would have created an opportunity for cross contamination of asbestos, fluorine, lead, radium-226, elemental phosphorus and silica to non-workers.

The next section, related to research sub-question #2, will focus on the adverse environmental conditions that the citizens were exposed to. The citizens in most cases were living as residents in the project area and therefore were exposed to the adverse conditions up to 24-hours a day.

Citizens

Air Quality Issues

This section of the research concentrates on the adverse conditions that are relevant to the citizens in the vicinity of the project area. The citizens in the project area were exposed to the gasses, fumes and dusts that are associated with the production of elemental phosphorus during its existence in Pinellas County from 1947-1981. The emissions created by the production of elemental phosphorus produced adverse air, water
and soil quality conditions that existed in the study area almost continuously for the residents.

The following paragraph provides additional evidence as to the geographic extent and concentration of the elemental phosphorus production toxic byproducts.

In 2003, the St. Pete Times printed an article outlining the known extent of gaseous adverse environmental impacts that were emitted from the Stauffer Chemical elemental phosphorus processing plant in northwest Pinellas County. During furnace venting events sulfur dioxide levels of greater that 860 parts per billion were measured within 1.5 miles of the plant at ground level. Sulfur dioxide is considered detrimental to humans at levels of 100 parts per billion or above. The 860 parts per billion that frequently occurred during furnace venting would have represented a severe health risk for all human habitation. At distances of up to 3.0 miles from the elemental phosphorus production plant sulfur dioxide concentration levels at ground level ranged between 500-840 parts per billion. At distances of up to 4.0 miles from the plant sulfur dioxide concentration levels at ground level ranged between 100-500 parts per billion. Current ATSDR standards reveal that sulfur dioxide in concentrations of 100 parts per billion or more might cause constricted airways in humans. There has also been strong empirical evidence collected by the Pinellas County Department of Environmental Management that indicates sulfur dioxide gas in concentrations of up to 100 parts per billion may have drifted as far south as Dunedin and Clearwater. The findings would indicate that the venting of the production furnaces was adversely impacting the human communities up to 9 miles away from the emission source (Rondeaux, 2003).
In the 2003 St. Petersburg Times article (Rondeaux, 2003) the following information was presented regarding the lingering adverse effect of adverse air quality in the study area:

ATSDR scientist findings postulate that there are still legitimate health concerns regarding the abandoned Stauffer elemental phosphorus plant. The scientist are recommending that all people who worked or lived near the plant or those who attended Gulfside Elementary School should be receiving regular medical check-ups. The research scientists are of the opinion that local doctors should be on the watch for lung disease or cancer. In addition to this, the ATSDR scientists advise that Stauffer Chemical employees were exposed to asbestos, fluorine, lead, phosphorus pentoxide, sulfur dioxide and various synthetic compounds with inherent health risks. People who lived, worked or went to school within one mile of the Stauffer Chemical facility during the operational years were exposed to toxic sulfur dioxide. According to the 1980 census it is estimated that 6,000 residents lived near the Stauffer elemental phosphorus processing plant. Sulfur dioxide levels were recorded at up to 8 times greater than safe thresholds for human habitation. People in the project study area with predisposed respiratory disorders would have suffered from the compounding effects of coughing fits, wheezing, and shortness of breath. Air quality monitoring in the project area since 1977 indicates that sulfur dioxide levels would frequently reach 840-parts per billion. Sulfur dioxide levels of 100-parts per billion can cause significant constriction of air passage ways. It is believed that people within the project study area during the operational years from 1947-1981 were exposed to an increased risk of cardiovascular disease (Rondeaux, 2003).

The previous paragraph alludes to the high density of pollutants that were dispersed at ground level where Pinellas County Department of Environmental Management air quality monitoring stations could quantify the contamination quantities. The effective dispersion of toxic gasses requires a chimney system that can exploit the influence of local prevailing winds to dilute industrial toxins over large geographic areas. Current chimney technologies utilize scrubbers to help reduce the dispersal of toxic agents (Hessling, 2006). The study confirms that the Victor/Stauffer production facility was equipped with ineffective chimney geometry, overwhelmed ventilation hoods and no
effective scrubber system and this allowed plumes of polluted air to concentrate within a relatively small geographic air basin.

Another example of the ineffective chimney geometry at the Victor/Stauffer facility is provided in the following quote from a Pinellas County Government air quality official. During a Florida Department of Environmental Protection inquiry of air pollution concerns at the Victor/Stauffer production facility, Peter Hessling of the Pinellas County Air Quality Division told an investigation ombudsman:

To the best of my knowledge, they (the Stauffer Chemical Corporation) never actually completed an emissions stack certification test while I was inspecting the facility. Something always went wrong, something was missing or didn’t work. The main problem was when they tapped the furnace. It looked like the gates of hell glowing in the dark, it gave off steam and lots of emission-phosphorus pentoxide (Agency for Toxic Substances and Disease Registry, 2000).

The high temperatures furnaces at the production facility frequently imposed smoke and gasses at ground level as a result of poor chimney design and geometry. The smoke stack geometry combined with ambient meteorological dynamics created adverse environmental impacts outside of the production facility. The stack design did not exploit meteorological ascendance and because of this dispersion of fumes was imposed to the local community in high concentrations. The poor stack design resulted in poor vertical smoke and gas dispersion. The smoke stack geometry deficiency imparted local horizontal dispersion of fluorine gas and phosphorus pentoxide gas throughout the project area at ground level and up to 8 miles down wind of the production facility (Hessling, Gibbs, 2006).

The plume of fluorine gas that was derived from elemental phosphorus production was never accurately sampled or analyzed during the years of production from 1947-1981.
Fluorine gas would have created an antagonistic health risk to all humans and biologic communities throughout the study area air shed.

Within the phosphate industry unintended fluoride dispersion remains a significant adverse environmental liability. The basis of the adverse environmental liability is primarily the result of the processing of raw phosphate’s unique chemistry. Raw phosphate ore derived from Florida mines can contain up to 4% fluoride or 40,000 parts per million (Connett, 2003).

The residents in the research study area were shielded only to a very small degree by geographic distance from the electric arc furnaces as local wind patterns moved the contaminants over much of northern Pinellas County. The primary risk to the resident population was the daily inhalation of sulfur dioxide, phosphorus pentoxide and fluorine gasses that were contained in the gaseous and dust dispersions that emanated from the furnaces in large quantities particularly during the furnace degassing and tapping procedures. The desired vertical ascendance of gasses and aerosols was frequently inhibited during night time operations as local meteorological phenomenon produced low dispersion dynamics. The daily exposure to the mixture of toxic gasses was of sufficient potency to cause: chronic asthma, burning of eye tissues, coughing fits, sore throats, shortness of breath, possible heart and lung damage and fluorosis. Residents with pre-existing heart or pulmonary disease would have been at an even greater risk of adverse health (Gibbs, Hessling, 2006).

As further evidence of the adverse air quality in the study area Ms. Gibbs provided the following recollection as to the severity of the toxic compounds that frequently shrouded the project area outside of the production compound.
Old photos I observed that were taken by the Flaherty family showed that visibility on the adjacent Flaherty Marina was under 30-feet following a furnace tapping event. I saw a picture that showed an obscured view of a child riding a tricycle who was only 30-feet from the camera. The picture was taken only a few minutes after a furnace tap event. Depending on atmospheric conditions it was possible for the area to be shrouded in a phosphorus pentoxide cloud for more than 3-hours. Phosphorus pentoxide is highly irritating to the lungs and trachea. The normal moisture contained within the lungs and trachea can create phosphoric acid burns to the lungs and trachea. The production site and surrounding community was terribly dusty and it was inescapable. Large accumulations of residual phosphorus dust was accumulated everywhere. The public was frequently exposed to huge clouds of sulfur dioxide, phosphorus pentoxide and fluorine gas. It was the public who kept us informed based on very frequent complaints of air quality. People had trouble breathing as a result of the dense clouds of phosphorus pentoxide gas. The sulfur dioxide gas concentration issue was very concerning to us as a public health risk. When the biologic moisture source of the lungs and trachea are exposed to sulfur dioxide gas a sulfuric acid compound is formed within the respiratory system. Sulfuric acid in the respiratory system is highly corrosive and could cause ulcerations (Gibbs, 2006).

The previous quote provides a tangible example of the air quality conditions that residents and workers were exposed to during the daily operational discharge cycles. The local atmospheric conditions are mentioned as a factor that exacerbated the residence time of the toxic clouds. The local meteorology of the project area is strongly influenced by both sea breeze and land breeze phenomenon. During spring, summer and fall the effects of land breeze and sea breeze are magnified and become the dominant diurnal weather phenomenon. Unfortunately, the land and sea breeze phenomenon creates extended periods of slack air movement between commencement of land and sea breeze development. It is during the 3-4 hour slack breeze period that toxic dust and gasses would not be dispersed by prevailing wind phenomenon. It is under the diurnal slack breeze conditions during spring, summer and fall that the greatest environmental degradation occurred.
Three months after the Victor/Stauffer plant came on-line the residents were already aware of their degraded environment. In June of 1948 the residents in the study area initiated a law suit against their new industrial neighbor. The law suit was supported by the deposition of three prominent local residents who had become aware of a sudden and alarming change in the local environmental condition. Mr. J. M. Turnpaw a local boat repair company owner provided the following observations of the adverse environmental conditions he believed were caused by the gaseous emission emanating from the Victor Chemical Works elemental phosphorus production facility in 1948.

I noticed the lead paints or anything you put on the boats they would discolor, and sometimes would be spotty or kind of blurry on the paint and I went over it two or three times to try to catch it, if it wasn’t quite dry. I varnished several boats like that and noticed the dust and smoke coming from over there, and you could take hold of it just like a piece of paper and pull it off the boats (Wilson, 2000).

When asked how long the adverse air quality problem lasted, Turnpaw stated,

That all depends a good deal on the conditions of the weather and the winds, and with other conditions. I noticed it more with a west or northwest wind, I get a gas smell in the atmosphere.

When asked if the plants emissions affected his health and if he coughed as a result of the emissions, Turnpaw replied,

I cough quite a bit and my mouth is dry and tasted like a mouth full of copper (Wilson, 2000). Mr. Turnpaw was not the only citizen that witnessed the dangerous air quality associated with the production facility.

The adjacent human community was a direct recipient of the synthetic adverse air quality. In several cases the adverse air quality conditions were so deleterious that the public ducked for cover during periods when local meteorology and production practices
made outdoor activity impossible. The following synopsis is an example of the adverse conditions that the public were exposed to on a daily basis.

Mr. Everett Trader who worked just a few hundred feet from Stauffer at Sun Coast Paving provided his recollections as to the day to day air quality conditions within the research project area he worked in. Mr. Trader remembers observing the daily occurrence of thick yellowish-white smoke that would descend over the Sun Coast Paving where he worked in the vicinity of Anclote Road and Wesley Avenue. The gasses and vapors in the air made it difficult to breath for the Sun Coast Paving employees. The employees of Sun Coast Paving would retreat to the safety of their air-conditioned work trailer so as to escape the caustic clouds of dust and gas coming from the Victor/Stauffer production facility (Rondeaux, 2003).

They used to call it blow-off. When it would get bad, I’d tell everyone to come in. They would duck in the trailer and then about a half an hour later someone would stick their nose out to see if it was all clear (Rondeaux, 2003).

The prevailing sea breeze would push toxic dust and gas plumes eastward and south eastward in the direction of the City of Tarpon Springs. It is for this reason that the more populated City of Tarpon Springs was vulnerable to a degraded air quality and dust accumulation during the extended period Victor/Stauffer elemental phosphorus production.

Joyce Gibbs provided the following details relative to operation methodology. The Stauffer elemental phosphorus processing plant worked on three 8-hour shifts per day. The Stauffer plant would attempt to complete a maximum number of batches per furnace during the non-peak hours. This was done so that Stauffer could benefit from
off-peak energy costs associated with Florida Power. The night time operations would result in gas and fume releases when local wind conditions would be dead calm and this especially true in the summer weather season. It was during the night time operations that much of the production emissions would go visually unnoticed. Unfortunately, the residents and workers were exposed to a longer periods of phosphorus pentoxide exposure during night operations. The elemental phosphorus production plant used so much electric power that it would frequently consume more energy than Florida Power was equipped to provide to its total clientele. Due to its large consumption of electric power; parts of Pinellas County would be exposed to brown-outs when the Stauffer production plant was operating at full capacity. The Florida Power plant located north of the Victor/Stauffer facility also contributed to some of the poor air quality in the project area however it’s contributions were relatively small (Gibbs, 2006).

The 24-hour production of elemental phosphorus would have spanned two periods when local winds would normally experience stagnant or slack periods. During night time period from sunset to midnight local meteorological phenomenon processes produce a period of slack winds. In addition to this the other period of slack winds occurred after sunrise and lasting into early afternoon prior to sea breeze development. The morning period of slack winds frequently lasted for up to 6-hours. When afternoon sea breezes developed the air parcel over the project area would be pushed eastward and south eastward towards the more populated Tarpon Springs city limits. The sea breeze meteorological phenomenon would enhance gaseous dispersion in the study area.
When asked what were the primary pollution constituents of the emissions of the Stauffer elemental phosphorus production plant that may have been present in the surrounding communities? Joyce Gibbs responded:

Air quality monitoring in the late 1970s was in its infancy. There were very few ambient air standards on the books. Because of this we (Pinellas County) monitored primarily for sulfur dioxide as it was better understood. We were not capable of sampling for fluorine gasses. Pinellas County installed the first air monitoring station in the county just south east of the Stauffer property. We were concerned about sulfur dioxide, phosphorus pentoxide and in particular fluorine. In the 1970s there were no accepted methods for monitoring fluorides and there were not any standards for air quality relative to fluorine. We tried to understand the facility and the contaminants it was producing. We were fortunate that the plant did not create organic solvent materials. The inorganic compounds were materials we were more comfortable in diagnosing (Gibbs, 2006).

The previous quotation provides framework to the fact that air pollution determinations were not well formulated during the entire time period that the Victor/Stauffer production facility was in operation. In the context of 1948 there was no government oversight for air pollution issues in the study area, hence it was difficult to assess the effect of discharges on the area surrounding the facility. However, citizens provided their own qualified assessment of the adverse environmental impact resulting from elemental phosphorus production. The resident Mr. Mickler provided his own qualified description of the adverse air quality in the study area (Wilson, 2000).

When asked about the smell of the gaseous emissions from the Victor Chemical Works, Mr. Mickler responded:

Well, it don’t smell like sulphur [sic]. It smells like a burnt phosphate to me. Of course, knowing that there is phosphate there, it makes you think of that more than anything else. It makes your throat dry, and you taste it, and it tastes kind of coppery. I get asthma from it, just like Mr. Crider stuffed up yesterday [sic]. I can go out here and get in the way the wind is
blowing and be in it three minutes and have to take something for my throat. Yes sir, I cough (Wilson, 2000).

Through time public safety concerns grew in the vicinity of the elemental phosphorus production facility. Because of the mounting qualitative evidence of environmental concern Pinellas County initiated an EPA sanctioned air quality quantitative monitoring program in the project area in 1977. Air samples were collected at the southeast corner of the study area for specifically sulfur dioxide emissions. Samples were collected by a 24-hour bubbler device and a 3-hour continuous monitoring device. The air sampling indicated that sulfur dioxide levels in the air exceeded the Florida State standard until the plant facility began to shut down operations in 1980. Following the gradual shut down of the production facility there was a significant decline in sulfur dioxide levels (Air Pollution from the Stauffer Chemical Phosphate Plant, December 29, 2000, ATSDR).

Frequent complaints from the public were received by the Pinellas County Department of Environmental Management Air Quality Section. The public was clearly concerned about their physical health and in particular air quality concerns. In order to address the public’s concern site inspections were made to ascertain air quality.

Joyce Gibbs stated:

We made regular site inspections to the Stauffer production facility. We responded to the numerous complaints of the citizens and we installed the first air quality monitoring station in Pinellas County just outside of the production facility. Pinellas was not able to gain the support of the FDEP regional office in Tampa or the Tallahassee office and this was very frustrating. Without the support of the State of Florida we were unable to impose effective regulatory actions. The mining industry had numerous shielding provisions within law and policy that are administered by the State of Florida. We did not get the active support from the State of Florida. We did what we could at that time and you have to keep in mind
that air quality issues were in their infancy and they had not been able in most cases to challenge accepted industrial standards. In many ways our hands were tied. As I mentioned before, there were no accepted monitoring methodologies for fluorine (Gibbs, 2006).

The adverse air quality in the study area had not registered with the Pasco County School Board when it came to finding a location for a new elementary school. To expand on this point Mr. Ryburn stated that:

The entire elemental phosphorus production issue from 1947 to present is a direct result of the failure to see the long-term adverse implications of dirty heavy chemical industry. Pasco County’s Gulfside Elementary School was built in 1977 within approximately 2,000 feet of the established Stauffer Chemical elemental phosphorus production plant. The Pasco County School Board was fully aware of the proposed school location relative to the existing active Stauffer plant. The Pasco County School Board was most likely looking for inexpensive real estate to build a new elementary school. Unfortunately, the low real estate cost for the Pasco County public school came within a degraded environment. The final environmental price may never be known for the students and teachers who breathed the degraded air for over four years (Ryburn, 2006).

The previous comment provides a perspective on the lack of understanding as to the pervasive dangers associated with the processing of phosphate ore. It had been common knowledge from (1947-1981) that only fertilizer was manufactured at the Victor/Stauffer elemental phosphorus production plant. It was not well understood that numerous synthetic compounds were emanating from the elemental phosphorus production facility and were greatly endangering the citizens within project area (Hessling, 2006).

The physical geography within the project area supported various underpinnings that made for a unique elemental phosphorus contamination scenario. The close proximity to the Gulf of Mexico places the research area under the pervasive influence of
a sub-tropical maritime climate and micro-climate. Prevailing wind patterns in the study area are influenced by diurnal sea breezes that are the result of the close proximity of the Gulf of Mexico and the uneven heating of land mass versus an adjacent large water body. The persistent sea breeze within the project area had the propensity to push gas and dust dispersals to the east and southeast over the more populated area of greater Tarpon Springs. Cold fronts during the late fall and winter produce prevailing northwesterly winds which also would have moved gas and dust discharges to the east and southeast over populated areas. The local meteorology had the propensity to move quantifiable chemical discharges as far south as Dunedin, Florida which is approximately 8 miles to the southeast of the Stauffer/Victor elemental phosphorus production facility. Therefore, it can be stated that the adverse influence of elemental phosphorus production occurred in quantifiable amounts up to 8 miles south and southeast from the production facility discharge location.

**Water Quality Issues**

This section of the study will emphasize the adverse conditions that have been imposed on the water resources of the citizens of the project area.

The following paragraphs is from a Federally funded 1994 Stauffer Super Fund site synopsis of the various layers of adverse environmental conditions present in the study area, as summarized by the Federal Registry in 1994. The synopsis was created shortly after the project area was designated as an EPA Super-Fund site in 1994. The following paragraphs from the findings of the Environmental Protection Agency (EPA),
highlights the environmental vulnerability relative to several physical geographic characteristics.

The Stauffer Chemical Super Fund site study area is located in an industrialized area between Anclote Boulevard and the Anclote River in Tarpon Springs, Pinellas County, Florida. The Stauffer Chemical Super Fund site is approximately 1.6 miles east of the Gulf of Mexico.

The Stauffer Chemical Corporation purchased the production facility from the Victor Chemical Works in 1960. During the years of operation, a number of processing wastes were disposed of on the site. A system of seven unlined lagoons, about 600 feet from the Anclote River, received discharges of waste, scrubber liquid and phosphorus enriched water, as well as overflow from a calcium silicate slag pit.

At some time two of the lagoon pits were dredged, and the dredged material, composed of calcium sulfate/sulfite, calcium silicate, calcium fluoride, phosphate sand, and calcined phosphate dust was placed in two piles approximately 40 feet from the Anclote River. Other on-site disposal activities included the dumping of furnace dust in an isolated pond and the burial of 900 drums of calcined phosphate sand consisting of 20% elemental phosphorus.

Over 500,000 tons of chemical wastes were disposed of on the site between 1950 and 1979. The site is underlain by a surficial/vadose aquifer composed primarily of sand and the Floridan/phreatic Aquifer composed of limestone. Water is reached at an average depth of 8 feet below the land surface. The Floridan Aquifer is encountered at 17 to 37 feet and is approximately 100 feet thick in the area of the site. On-site monitoring wells into both aquifers are contaminated with barium, chromium, lead, vanadium, zinc, copper and arsenic according to EPA tests conducted in 1988 and 1989. An estimated 8,500 people in the Tarpon Springs area receive drinking water from 23 public wells located within 4 miles of the site. Because of the depths of the aquifers, all drinking water wells within 4 miles of the site are potential targets.

The EPA’s 1988 and 1989 tests also detected most of the same heavy metals in the Anclote River. Surface water runoff from the facility could flow south/southwest and enter the Anclote River, which is used for fishing. From there, the Anclote River flows 1.6 miles and empties into the Gulf of Mexico. Although no surface water intakes are located along the drainage pathways of the site, numerous county parks, state parks and beaches are extensively used. In addition, several wetlands that support a number of endangered and protected species are located along the surface water pathway (Federal Register Notice: May 31, 1994) (URL:http://www.epa.gov/oerrpage/superfund/sites/npl/nar1328.htm).
The previous paragraphs provide a poignant summary of the collection of synthetic toxic compounds that were introduced into the environment as a result of high temperature elemental phosphorus production. The various constituents of production degraded the study area ground water and surface waters. Previous sections of this research have revealed the collection of compounds that degraded the air quality. The combination of degraded air and water quality had adverse effects on the human population. However, there were additional organisms that were also damaged as a result of the footprint of anthropogenic pollution. The extensive size and density of the toxic compound plume also damaged and killed plant communities and bovine livestock.

Charley Ryburn stated that:

The vast majority of the long time residents in the vicinity of the Stauffer production facility had relied on private wells that provided for their domestic potable water needs. All of those wells as of 1994 have been deemed to be contaminated. Residents had used potentially contaminated potable water sources for approximately 47-years (Ryburn, 2006).

The local geology posed an additional risk to the residents who used local well sources for potable water. The historic geologic processes within the project area produced a thin veneer of Holocene oceanic sediments that were deposited over Pleistocene limestone. The mantled Karst landscape and the associated ground water resource can be easily contaminated by materials that are stock piled at the surface or that have been buried. Acidic compounds such as sulfuric acid or fluoric acid that are introduced into a Karst landscape can hasten natural dissolution processes that are usually dominated by mild atmospheric nitric acid. The Karst landscape in the study area
predisposes the residents to a much higher risk of ground water contamination when toxic materials are not effectively segregated from the surficial/vadose or Floridan/phreatic water resource. Karst environments can provide copious amounts of water that can be easily contaminated due to the juvenile nature of the local water resource. In this regard, the project area presents a geologic/hydrologic condition that could greatly endanger human health.

The specific geology of the abandoned production site has produced considerable uncertainty for the EPA, Stauffer Corporation and the residents of the surrounding community. The thin veneer of soil that was deposited over the Hawthorn Formation has been altered for construction and from 1947 until 1981 had been used as a subterranean means of disposal for industrial by-products. Elemental phosphorus has an extremely persistent chemical identity (10,000-year half life) when it is contained within an anaerobic (oxygen deprived) environment. In order to keep the extremely toxic elemental phosphorus contained the Stauffer Management Co. has contracted with various geological consultants to verify the geologic integrity of the project area relative to a mound and cap proposal. The following section provides excerpts from recent geophysical reports.

The most recent groundwater report studied among other things, the layer of clay, or confining layer, that separates the shallow (vadose) aquifer from the deeper (phreatic) zone. One of the things this study shows is that the contamination at Stauffer is really not moving anywhere. It’s pretty much staying in place (Quioco, 2003).
In the second of three new reports, a geo-physical consultant to Stauffer Management Co. has concluded that most of the Stauffer Super-Fund toxic waste site is sinkhole-free and geologically stable.

Therefore, the consultant concludes, there is no reason that Stauffer shouldn’t go ahead with a plan to pile up contaminated dirt on the property and cover the mounds with a watertight cap (Danielson, 2003).

The EPA was poised to let Stauffer go ahead with the mound and cap plan until 2003. In 2003 the residents and the local, state and federal officials, including U.S. Rep. Mike Bilirakis, Republican-Tarpon Springs, convinced EPA officials to pause and study the risk of sinkholes and groundwater contamination. Since 2003 the Stauffer Corporation has spent $3-million on three new hydro-geologic studies, and got ideas and advice on the work from a variety of agencies before starting (Danielson, 2003). The next section of the research will concentrate on the more insidious issue of soil contamination relative to the citizen component. Soils that have been contaminated with toxic compounds are one of many avenues of oral and dermal introduction that humans and other biologic organisms can become exposed to.

**Soil Quality Concerns**

Another insidious aspect of environmental pollution also occurred at the conclusion of a production batch. As the phosphate slag was cooled it was transported and sorted for use as road bed material or building pad material. The processed phosphate slag has a low grade radium-226 radioactive identity. There are no tangible records as to the final resting place for the phosphate slag waste materials. It has been hypothesized that the vast majority of the phosphate slag was sold as road bed material.
Had it been used as a home pad material low grade gaseous radium-226 could be another environmental risk to homeowners within the project area.

Peter Hessling provided the following production details that yielded large amounts of phosphate slag and silica waste products following each production cycle:

When the residual phosphate slag was sufficiently cooled it was loaded back into railroad gondola cars and it was transported 2,000 feet to the north where it was graded for size and texture in an open aggregate storage yard. The phosphate slag was marketed as a roadbed construction material. The slag material was used extensively as the primary roadbed constituent in the greater Tarpon Springs area. The slag material is known to contain low levels of radium-226. It is possible that some of the slag material was used for home site development such as foundation pads (Hessling, 2006).

It is possible that silica rich phosphate slag has been dispersed throughout the study area for home site slabs and for roadbed material. No records can be located that provide the possible inventoried locations for the silica enriched slag material. Study area residents could be exposed to pervasive gaseous radon poisoning if the radium-226 containing slag was used as building slab fill material (Gibbs, Hessling, 2006).

In 1994, the EPA was aware that the Super-Fund site contained high levels of arsenic, lead and radium-226, as well as other contaminants that are known to or suspected of causing lung cancer (Danielson, 2003).

Steve Richardson who is an environmental health scientist with the Agency for Toxic Substances and Disease Registry (ATSDR) is of the opinion that the Stauffer Super-Fund site is a past public health hazard and it may be a future public health hazard because of the quantity of the contaminants that are still there in the soil (Rondeaux, 2003).
The soil contaminants include: asbestos, fluorine, radium-226, calcium silicate and potentially very large volumes of buried elemental phosphorus (Gibbs, Hessling, Ryburn, 2006). Soil borings were recently conducted in 2006 an attempt to locate and inject grout into toxic buried materials. During the exploratory drilling efforts a small portion of buried elemental phosphorus was exposed to oxygen. The soil boring activity resulted in a spontaneous subterranean fire that forced work crews to flee from the work area. Fire rescue crews arrived and determined that the subterranean elemental phosphorus fire should be allowed to burn itself out. The subterranean fire and large phosphorus pentoxide clouds that emerged from the soil provided more tangible evidence that elemental phosphorus is buried in relatively shallow depths of soil at the 1994 Stauffer Super Fund site (Ryburn, 2006).

The soils in the study area are contaminated with a collection of toxic compounds that are hazardous to humans and the plant and animal communities. The next section of the research will focus on the fauna and flora community that has been exposed to the adverse environmental conditions in the project area that are directly associated with the production of elemental phosphorus.

**Biologic Flora/Fauna Community**

This section of the research, related to research sub-question #3, will concentrate on the adverse conditions that are relevant to the broader biologic community outside of the production worker and citizen groups. The flora and fauna in the project area were exposed to the nearly continuous dispersal of gasses, fumes and dusts that are associated with the production of elemental phosphorus. The emissions created by the production of
elemental phosphorous produced adverse air, water and soil quality conditions that had the opportunity to interact with the various biologic communities.

**Air Quality Issues**

It has been determined that gaseous dispersions of sulfur dioxide reached levels of up to 860ppb at ground level and high concentrations were common within the project area air basin. Within three miles of the production facility it was common for sulfur dioxide concentrations to reach 500-840ppb at ground level. Sulfur dioxide is able to combine with atmospheric moisture to create sulfuric acid gas that is corrosive to plant tissues (Gibbs, 2006).

Sulfur dioxide can readily erode the protective cuticular wax of vascular plants. If the cuticle of a vascular plant is eroded it exposes the vulnerable epidermis of the leaf and bark structure. Removal of the protective cuticular wax exposes fragile epidermis tissue and this results in unregulated loss of turgor pressure. Plants readily wilt and desiccate when the protective cuticular wax is removed. Damage or removal of the cuticle also exposes the subject plants to primary and secondary pathogenic/disease damage. Vascular plants without a protective cuticle desiccated quickly and turn brown (Cuda, 2007). The previous paragraph helps to clarify the antagonistic processes that the native plant community and agricultural crops were exposed to during the production period of 1947-1981.

Plants that are exposed to elemental phosphorus suspended particles can display numerous adverse reactions to toxic concentrations. Elemental phosphorus smoke can
induce spontaneous leaf drop/abscission, floral abortion, desiccation, foliage chlorosis and leaf tip burn or browning (Van Vorris et al, 1987).

It has been determined that fluorine levels in the coniferous plant community ranged from 300-500 parts per million as early as June of 1948. Coniferous trees and Citrus trees are severely damaged by air born fluorine concentrations of 400 parts per million or greater as was confirmed by the analytical findings paid for by the citizens in the study area in 1948 (Wilson, 2000).

The native Pine (\textit{Pinus} spp), Oak (\textit{Quercus} spp) plant community and the agricultural Citrus (\textit{Citrus} spp) plant community was severely damaged by the daily dispersal of fluorine gas. The Citrus trees within the study area were virtually wiped out during the late 1940s and early 1950s. For the most part no citrus tree production returned to the research project area (Wilson, 2000).

As early as January of 1948 area residents were becoming aware of environmental degradation that appeared to coincide with the opening of the Victor Chemical Works elemental phosphorus production facility. The concerned citizens filed a formal nuisance suit complaint in 1948 against the Victor Chemical Works regarding gas and fume damages relative to plants and animals. The following excerpts, that are derived from the legal deposition, provide the earliest tangible evidence of adverse environmental conditions that had already been imposed on the human and larger biologic community in the research project area:

In June 1948, less than a year after the plant’s opening, eight local residents and landowners filed a nuisance suit (for gasses and fumes) in the Federal District Court for southern Florida, Tampa Division (II). The suit alleged that fumes and gasses from the operation were adversely impacting human health and plants, not only in the immediate area, but as
far as 8 miles away, and that noxious gasses and fumes escape there from smokestacks connected with the said plant and by other means and are carried by the prevailing winds over a radius of some four miles from the elemental phosphorus plant, that the said gasses and fumes are highly deleterious to animal and plant life for the said distance, cause throat irritations and coughing by persons and animals breathing same and the death of young fowls, that said gas is especially harmful to teeth and causes decay and kills and destroys plant life (Wilson, 2000).

In a more directed deposition Bartley Mickler alleged that his personal property including trees, cattle and pigs were being injured by the air pollution that was emanating from the Victor Chemical Works plant.

He stated in his deposition that since the Victor plant opened he had lost livestock. He indicated that he lost a lot of pigs and about 100 head of cattle. Mickler also indicated that pine trees on his 5,000-acre property were affected by the plant. He indicated that in January or February of 1948, he noticed pine needles turning red and brown and falling from the trees. His estimate was that at least half of the trees were adversely impacted. New growth would bud out and then die back without being replaced. Mickler also stated that was less forage grass and berries and that this had caused damage to quail and game birds. The grass normally comes out the first of the year. But just prior to the lawsuit; the grass has come out and then died, resulting in forage grass production being down by 40 percent. Mickler also stated that fumes and gasses from the plant settled on palmetto bushes on his property. Samples from palmettos and pine from across his property were sent to the state plant board for analysis. Mickler traced the damage based upon the way the smoke from the Victor traveled, at least 7 miles from the plant. He described the smoke looking like a hazy gas substance and you can see it settling for miles through the woods under the tops of trees (Wilson, 2000).

The deposition of Mr. Mickler clearly punctuates the pervasive adverse effects of gaseous fluorine poisoning in the native flora. The native Slash Pine (Pinus elliottii) and Longleaf Pine (Pinus palustris) coniferous species are highly susceptible to fluorine toxicity. The evergreen character of coniferous plants allows an extended period of time to absorb fluorine gas without a seasonal leaf abscission event. Sulfur dioxide and
phosphorus pentoxide gasses are also caustic to leaf and bark cuticles. However, gaseous fluorine and associated fluoric acid is toxic and bio-accumulates so that exposure is compounded by the persistent buildup of toxicity in the plant tissue and the supporting soil profile. The precipitated fluorine emissions are also stored in the soil and it is readily absorbed in an aqueous solution along with essential nutrients. In this way, toxic fluorine is imposed on the plant community by way of natural nutrient procurement processes. Organisms that consume the fluorine contaminated plant material are also poisoned as a result of pervasive bio-accumulation. (Cuda, 2007).

The following quote taken during the January 1948 hearing provides a tangible account as to the plant damages that occurred on private lands following the commencement of elemental phosphorus production.

S. E. Mickler’s Deposition (B. Mickler’s father) stated:

That he was concerned about fumes and dust prior to the construction of the Victor plant and met with Paul Crider who worked for Victor. Crider told Mickler that, “You need not worry about it Mickler, it will not happen here with our plant. Around January of 1948 approximately 300 people signed the petition about the same time Mickler indicated that he began noticing offensive odors and harmful effects from the plant. He noted that he smelled the odors in Tarpon Springs, and as far away as 6 to 7 miles in the pastures. The gas has been so bad that in low spots when the atmosphere would bring it down it would be just like a fog. Mickler estimated that one-sixth of the trees on his property were affected. He carried samples of pine needles and palmettos to a Tampa chemist who reported that some of the materials showed 300, 400, 500 parts per million of fluorine. Mickler further indicated that he helped Archie Clement, Tarpon Springs city attorney gather materials that the city manager had sent the samples to the State Plant Board in Tallahassee. Representatives of the Forestry Division visited the Mickler property four or five times. Mickler recounted that, they said it had to be fumes or gas or something. They said it was not the weather wet or dry (Wilson, 2000).
The deposition’s reference to pine needle samples that contained 300, 400 and 500 parts per million of fluorine provides strong tangible evidence of chronic fluorine toxicity in a native Coniferous plant species. Fluorine is highly toxic to nearly all vascular plants and it is especially toxic to conifers as they retain foliage throughout the dormant season and this allows a more continuous absorption of fluorine gas. Fluorine concentrations accumulate in plants as there is no natural process for decontamination. Mr. Mickler’s additional deposition provides his field observations.

Regarding observed damage to trees, Mickler said,

> Well, I came in to dinner in town (Tarpon Springs) and I never noticed anything. When I came back out, and just as I went to make the curve, as you run by the oil company and go back towards the plant, I noticed the leaves on the trees being red. I stopped my car and said to my self, ‘darn there has been a fire here since I have been along.’ I stopped the car and looked and there wasn’t no fire. I observed the trees had been burned by something, I don’t know what (Wilson, 2000).

The necrosis resulting from fluorine results in rapid desiccation of leaf tissue. The fluoric acid pollution component also erodes the leaf cuticle and this also accelerates foliage desiccation and browning.

The Victor Chemical Works had also hired the services of a preemptive expert witness named John Claypool in March of 1947. John Claypool’s Deposition (for the Defense of the Victor Chemical Works) states that:

> Victor Chemical Works also submitted to the court the deposition of John Claypool, an expert witness, questioned only by Victor’s attorneys. John Claypool was from West Hempstead, Long Island, New York. He received a B.S. from DePauw University in Chicago, and took advanced and special courses in the College of Agriculture at Purdue University, Indiana, until 1912. He taught pre-vocational and vocational agriculture and in 1916 went to Teachers College as a professor of agricultural
education. In 1920, he worked for a chemical manufacturing company and a copper smelting company in New York, taking over the investigation and experimentation of the effects of certain smokes or gasses and fumes. Over the next 30 years Claypool studied the effects of gasses and chemicals in eight states, including Florida (Wilson, 2000).

Claypool first visited Tarpon Springs on March 1, 1947, while the elemental phosphorus plant was under construction. Regarding the findings on this visit, he stated,

Vegetation in that vicinity at the time was not in a good state of growth. There had been an early season of drought, followed by unseasonably cold weather. Some plants, notably the pines, showed a scorched appearance of needles in places. It was not universal. There were dead trees in the vicinity, confined to the pine family. I also found some dead citrus trees in a small orchard near the Victor site. In looking over plant life in Tarpon Springs, I covered, as closely as I could without trespassing or attracting undue attention, within a radius of two miles in all directions (Wilson, 2000).

Claypool estimated that five to ten percent of the pines in the project area were dead. He also said that he saw two men remove and replace dead trees in a citrus grove. The workers explained that the trees had died of either root rot or crown rot and that the orchard had not been well fertilized or sprayed (Wilson, 2000).

Citrus trees in the study area were severely damaged following the commencement of elemental phosphorus production (Wilson, 2000). The fluorine that is liberated from incinerated phosphate ore provided a continuous source of fluorine intoxication. Fluorine toxicity in Florida agriculture appears to be directly related to the relative geographic proximity of phosphorus processing facilities. Citrus production tends to decline when ambient air quality fluorine levels are elevated by the synthetic alteration of phosphate ore (McBride and Walker, 1958).

Fluoride toxicity in citrus trees is caused exclusively by exposure to gaseous, airborne fluorides. Fluoride toxicity associated with citrus species (Citrus spp) has only
been noted in Florida. Fluoride damage to other plant species has been observed in other states. Fluoride toxicity in Florida associated with citrus has only been observed within close proximity to manufacturing facilities that discharge gaseous fluoride. The symptoms of fluoride toxicity in citrus are typically found in groves which are located geographically down wind relative to the prevailing winds from the gaseous fluoride emission source. A diagnostic chlorosis (absence of chlorophyll) is linked to acute gaseous fluorine toxicity in citrus. In more advanced cases of fluorine toxicity a tip and edge burn of citrus tree leaves can occur. If citrus trees are exposed to fluorine toxicity for an extended period of time it is common to see a gradual reduction in the size of the tree foliage. Grapefruit appear to be the most sensitive of the Citrus genus and Oranges appear to be the most tolerant to exposure to gaseous fluoride. The inter-vienal chlorosis resulting from fluorine toxicity closely resembles damage caused by manganese deficiency. At this time, there are no remedies for fluorine toxicity in citrus. Location of citrus in an environment that is free of gaseous fluoride would represent the best management practice (McBride and Wander, 1958).

After analysis of the deposition has been completed it appears that the Victor Chemical Works anticipated that there could be adverse consequences to the plant community resulting from elemental phosphorus production. The Victor Chemical Works pro-actively hired the consulting botanist John Claypool to help assess the pre versus post production conditions of the surrounding plant community. The next section provides John Claypool’s observations during a sworn deposition hearing in June of 1948.
When asked about the appearance of the area’s vegetation, John Claypool said,

Vegetation, generally speaking, did not appear to be in a fine, flourishing condition at all, anywhere. I would not say that it was universally scorched in appearance. I did not trespass to examine closely. From the roads, there were signs that there had been a fire at some time. I was not acquainted with the plant, I did not know whether this was a seasonal thing, whether fire brought these conditions about, but that was the condition of the scrub palmetto at the time. Pale green to yellow (Wilson, 2000).

On February 18 and 23, 1948, John Claypool returned to Tarpon Springs in response to a request from Victor, because of unrest among neighbors in close proximity of the production plant and the conditions of vegetation. With the production plant in full operation, Claypool surveyed the area for approximately 2.5 miles in all directions, and describes what he found on his trip:

In February of 1948, there was some noticeable discoloration of the tips of pine needles or foliage within a distance of a half mile in generally southeast or east-southeast direction. There was, on the date of my arrival, which was the 18th, some loss of green color on the tips of pine foliage, which by the 23rd, upon my return, had become a definite browning of the tips. That appeared to extend almost to the location of some oil tanks along the Anclote River, which is less than a half mile from the operating part of the plant. I continued my close up inspection by walking along the railroad tracks to the north and found no evidence of anything unusual to vegetation in that direction. There was no noticeable damage to the Flanagan and Turnpaw properties. Foliage westerly or north westerly appeared to show no change since my visit a year before. Sunset Hills, the general condition of vegetation appeared to be better at that time than it had been the previous year (Wilson, 2000).

Mr. Claypool is describing chronic fluorine toxicity in the indigenous coniferous forest Slash Pine (Pinus elliottii) and Longleaf Pine (Pinus palustris) in the study area. Coniferous trees do not drop foliage during the winter season and are more biologically active in the winter than most deciduous plant species. This particular characteristic allowed the Coniferous plant community to absorb fluorine in larger amounts during the
first three months of production at the Victor/Stauffer facility. It could be logically deduced that an evergreen plant community would assimilate fluorine more effectively than a deciduous plant community during the winter of 1947/1948.

When asked, Well from your experience of more than 30 years, did you form any opinion as to the cause of the discoloration of the pine needles of the foliage at Tarpon Springs John Claypool answered, In my opinion, it was caused by a gas or fumes. I believe it was probably from a fluoride compound (Wilson, 2000).

After two exploratory forestry investigations Mr. Claypool was able to come to the conclusion and make the admission that it was most likely a fluoride compound that has damaged the local plant community.

The resident Mr. Mickler observed a decline in the health of the native plant community during his daily travels throughout the study area. Mr. Mickler makes the observation that the gaseous emissions are capable of weakening the leaf structure of Saw Palmetto (Serenoa repens).

The emissions (from the plant) looked like a fog, and from a distance an observer could not see through the mixture. Trying to describe the emissions (from the plant) which impact the plants (trees and shrubs), Mickler went on to state, You can see it on oak and palmetto anywhere in the woods. It is a kind of dusty concern, although not much dust to it, either. It looks oily. For instance, on palmetto, when it first hits it, it will limber up and look like it has oil on it. It limbers up a leaf and kind of parches it (Wilson, 2000).

The previous deposition statements by John Claypool detail his field observations over an extended period of time. Even though he was hired by the Victor Chemical Company, he was able to ascertain that fluorine emissions were the causal agent of necrosis in the flora community.
Another deposition was provided by Genevieve Flanagan who had complained that gasses and fumes became bothersome at her trailer park in January of 1948. She said the following:

We smelled it [the gasses], to begin with, and you could see it, and then many trees started dying. It killed a lot of them [trees and shrubs] and it is killing my pine and oak trees as well. All of the natural pines turned completely red, and two oak trees died within a week, the water oaks the leaves just burned; the others lost a lot of their leaves but some of the growth has come back; I don’t know whether they will live or not; and two of the large water oaks died within that week, and one large orange tree died. All of my palms; as soon as they put out a new leaf by the time they were out two or three weeks they turned. The Plumosa Palms, I trimmed a lot of them, about two weeks, and just as fast as they put out the new growth they just turned again (Wilson, 2000).

The Stauffer Chemical Corporation was consciously aware of the emission issues that adversely affected the project area (Hessling, Gibbs, 2006).

Joyce Gibbs stated:

The manufacturing facility commonly conducted two of three batch cycles per day during the night and evening hours. This served a two-fold purpose. This allowed the plant to benefit from the use off peak hourly rates when energy rates would be lowest. Night production helped to reduce production costs. Secondly, the nightly production of elemental phosphorus allowed the clouds of phosphorus pentoxide and sulfur dioxide gasses to go visually un-noticed by the surrounding public. Another issue that has gone rather unnoticed is the fluorine toxicity issue. The burning of phosphate rock liberates significant amounts of fluorine gas that is a natural component of phosphate ore. Fluorine in the gaseous state or in solution is highly toxic to all plant species. The plants in the vicinity of the elemental phosphate production plant showed classic symptoms of fluorine toxicity. Plant growth had not returned to normal levels even after the production facility had been closed for 26 years. This has left the site with a denuded and harsh appearance. My observations are that no recovery has occurred in the plant community since my observations began in 1975. I think the soils of the area are probably highly acidified from the effects of fluoric acid, phosphoric acid and sulfuric acid (Gibbs, 2006).

Joyce Gibbs recalled another issue relative to gaseous fluorine’s adverse impact:
I spoke to Stauffer operations staff and suggested to them on several occasions that they could reduce some of the dust dispersal if they were to plant several rows of trees around the production facility. Stauffer operations staff always met my suggestion with approval. However, they never followed through on the tree planting suggestion. It’s my opinion that Stauffer was hesitant to plant trees around the production facility since they were concerned the trees would have most likely died from the toxic fluorine emissions. I think Stauffer was aware the trees would have done poorly or died and this was not the type of condition they wanted to display (Gibbs, 2006).

Fluorine has also had very deleterious effects on the domesticated fauna community in the study area. A similar adverse condition to Pinellas County’s was simultaneously occurring in Polk County, Florida where numerous phosphate processing plants had been constructed after World-War-II were also releasing damaging gasses and fumes. The following two paragraphs provide details from a former Polk County Cattlemen’s Association president relative to Polk County, Florida agriculture that was in close proximity to a phosphate processing facility (Linton, 1970).

Approximately seventy-miles to the east in Polk County, Florida approximately 150,000 acres of cattle production pasture were abandoned and 25,000 acres of citrus were adversely affected by phosphate processing plant emissions from 1953-1963. Between 1953 and 1960 the cattle population of Polk County was diminished by approximately 30,000 head (Linton, 1970).

The Polk County incident of both cattle and citrus production losses are very similar relative to geographic location to an elemental phosphorus production facility. The larger geographic size of the Polk County agricultural industry dwarfs Pinellas County. The 25,000 acre loss of citrus production in Polk County resulting from fluorine
toxicity would represent approximately twice the geographic area of Pinellas County’s peak production of 13,500-acres of citrus in 1950 (Linton, 1970). The Polk County cattle decline resulting from fluorosis closely resembles the smaller Pinellas County study area were approximately 5,000 acres of pasture land was poisoned with fluorine derived compounds (Wilson, 2000 and Linton, 1970).

Fluorosis in cattle that have grazed on contaminated land has now become clinically well understood. The following paragraph provides technical data from a veterinarian’s manual:

Skeletal fluorosis generally results in the accelerated resorption of bone structure. Metabolically active rib, mandible and long bones are most adversely affected by the development of chronic fluorosis. The actively growing bones of young animals are greatly affected. Cattle with chronic fluorosis are lame, and feeding and water uptake and weight gain are decreased. In advanced stages of fluorosis cattle may move around on their knees due to painful spurs and bridging in joints. When the bone tissue has become saturated with fluorine the soft tissue becomes impregnated with fluorine spill over. The next stage is for the spill over to contaminate the blood supply and this is followed by extreme listlessness and suppression of appetite (Merck & Company, 2006).

Polk County rancher Mr. Cridder noticed in 1953 that there was a significant downturn in our cattle’s health and vigor. The cattle were not able to put on bulk weight as they usually are able to. As the decline continued our cattle were actually loosing weight. Following the observed downturn in the cattle’s health our cattle were afforded the highest quality pastures we had and used all methods we were aware of in an attempt to restore the health of our cattle. We incorporated supplemental dermal nutrient drenches and de-wormed the cattle in hopes it would restore vigor but this did not improve the vitality of the cattle. The cattle gradually lost their teeth and became gaunt and their legs were noticeably deformed and the cattle limped and staggered. In 1953 the
rate of calf production dropped and if a cow had a calf it was gaunt or a stillborn. After our efforts to improve the health of the cattle failed the veterinarians diagnosed the adverse condition as massive fluoride poisoning (Linton, 1970).

The source of the fluoride poisoning within Polk County, Florida was traced back to the gasses and dust dispersed by prevailing winds from the smokestacks of phosphorus processing plants in proximity to citrus groves and pasture lands of Polk County, Florida (Linton, 1970).

As mentioned above gaseous fluorine poisoning can produce adverse environmental conditions in domesticated animals on a large scale.

The most important problem concerning damage to animals by air pollution is, no doubt, the poisoning of domesticated animals caused by fluorine in smoke, gas, or dust from various industries; industrial fluorosis in livestock is today a disorder well known by veterinarians in all industrialized countries (Connet, 2003).

Fluorides derived from processed phosphorus ore are liberated into the atmosphere as hydrogen fluoride (a gaseous state) or as silicon tetrafluoride (a solid particle). The fluorine can be absorbed or it can accumulate on or may be metabolized within vegetation surfaces downwind of the source point. If the fluorine contaminated vegetation is consumed by livestock it can cause severe adverse health conditions, in particular to cattle. Over ninety five percent of consumed fluorides become an amalgamation within the bone matrix of the consuming animal. Fluorine that is not absorbed into the bone matrix is metabolized and excreted in either urine or feces. The teeth of cattle are permanently damaged by fluorine if intoxication occurs within the first 36-months of birth. Severe intoxication with fluorine can cause cattle to develop rapid tooth erosion/destruction, stiff joints and profound lameness. Lameness of cattle induced by fluorine intoxication is caused by brittle abnormal bone tissue formations that replace
normal bone tissue in the metatarsals and metacarpals of the bovine hoof. The lameness and associated pain of walking and standing reduces the time cattle can graze which can lead to lower milk yield, reduced body weight and possible starvation (Fischer and Prival, 1973).

The following excerpt further expands on the toxic nature of fluorine relative to domesticated livestock:

Poisoning occurs where the fluorine content of dry grass exceeds 250ppm. Prior to death, the poisoning causes lesions in the nose, mouth and hair around the mouth tends to fall out (Gregory, 1996).

The danger of fluorine in the food chain has not been limited to just Pinellas County, Florida as can be seen in the following paragraph as well.

The Canadian Broadcasting Corporation (CBC) has used the word Pandora’s Box to describe the insidious pollution sources that are derived from the phosphate industry. The CBC states that the phosphate processing did bring enterprise to the agricultural community. However, the phosphate processing industry brought severe environmental damage into the agricultural community. The CBC describes the adverse impact of phosphate processing at one specific site were farmers first noticed that pepper plants and the pepper fruit were burned and dwarfed and gas and fumes damaged nearly everything that grew. A substance in the air was damaging the agricultural crops. This specific adverse environmental case was first noted in 1961 and then again in 1962 near Dunville, Ontario. Grain production was cut by 50%. After arduous investigations it was determined that the adverse agent was fluorine concentrations in the pasture grass and dry hay. The cattle were becoming disabled with swollen legs, loss of teeth, painful mouths and hooves such that the cattle simply lost the ability to stand and would lie down and
die. The cause of the loss of hundreds of cattle in Dunville, Ontario was from chronic fluorine poisoning of the air and pasture grasses (Connett, May 2003).

In 1969 an article in the Good Housekeeping magazine featured an article that described the demise of cattle in Garrison, Montana resulting from chronic fluorosis:

The fluorine induced blight afflicted the cattle also. Some of the cattle lay in the pasture, barely able to move. Others limped and staggered on swollen legs, or painfully sank down and tried to graze on their knees. After being ingested day after day, the fluorine contaminated pasture had caused tooth and bone disease in the cattle, so that they could not tolerate the anguish of standing or walking. Even eating or drinking was an agony. Their ultimate fate was dehydration, starvation and death (Connett, 2003).

The previous paragraph provides a tangible example as to the pervasive adverse impacts that can be generated from the synthetic alteration of benign Apatite/Phosphate ore. The high temperature of elemental phosphorus production liberates many toxic synergistic compounds that are injurious to mammals and plant communities. When the Victor Chemical Works plant came on line in 1947 it had two state of the art carbon-arc furnaces that could achieve operational temperatures of 1,650 degrees C/3,000 degrees F. The 1,650 degrees C/3,000 degree F furnace temperature was sufficient to melt phosphate ore and produce up to six large batches of elemental phosphorus on a daily basis. The elemental phosphorus by product emissions included air suspensions of: toxic fluorine, sulfur dioxide and phosphorus pentoxide. Each of the two furnaces had an operational capacity of approximately 458 cubic meters/500 cubic yards of raw phosphate ore. The carbon-arc furnace dimensions were approximately 7.6 meters/25 feet in diameter and 8.55 meters/28 feet in height. The vast quantities of processed phosphate ore at the
Victor/Stauffer facility assured a nearly constant cloud of synthetic compounds would exist in northwest Pinellas County (Gibbs, 2006).

**Soil Quality Issues**

The other aspect of physical geography that imposes a unique risk in the study area is the presence of mantled karst topography. The Stauffer Management Corporation has spent significant capital in an attempt to determine if the karst environment is active or in a state of inactivity (paleo-karst). It has been determined by several geo-physical tests that active karst processes are currently absent on 90% of the 130-acre land parcel. A mound and cap remediation proposal has been offered by the EPA based on the conclusion that subsidence activity is not active at this time. When and if a subterranean subsidence event will occur is rather difficult to predict. Soil borings of up to 100’ in depth have been the basis for the conclusion that there is a low risk of sinkhole development in the project area (Wilson, 2000).

Another aspect of physical geography that imposes additional risk in the project area is the soil characteristics. The soils in the project area are derived primarily from urbanized Astatula fine sand. This particular aridisol is of siliclastic origin and is a soil which exhibits very low cohesive characteristics and very low organic content. The low cohesive forces of this soil and the relative low ground water elevations coupled with low organic content create a low fertility and highly droughty and unstable condition for native plant colonization. The damage to the native plant community resulting from fluorine toxicity left the project area devoid of plant cover and exposed to colonization from opportunistic exotic and invasive plant species. When opportunistic noxious plant communities become established they can impose antagonistic/allelopathologic
influences on competing plant species. The very low fertility level and droughty character of urbanized Astatula fine sand makes anthropogenic restoration of native plant communities problematic. The Victor/Stauffer site’s contamination scenario also affected local plant communities.

It is well understood that fluorine is not mobile in soils and toxic levels can exist within the soil horizon for extended periods of time (Meister, 1991). However a scattering of residents within the project area have been successful in growing Citrus trees. Damage to Pine and Oak trees resulting from fluorine toxicity has allowed for opportunistic colonization from exotic and invasive plant species. The project area currently supports a large population of Brazilian Pepper (Schinus terebinthifolius) which has been able to exploit the low fertility of the disturbed Entisols in the study area. The study was not able to determine if Brazilian Pepper plants are tolerant of fluorine contaminated soils. The existing native tree and shrub vegetative character of the study area is very sparse and supports very few recruiting plants. If Brazilian Pepper are as part of the shrub and tree plant community the areal coverage of tree and shrub plant species would be below 20%. The Stauffer Management Corporation has recently conducted a Brazilian Pepper removal program on its 130-acre parcel in 2000 as an attempt to minimize the seed source of this highly invasive plant species in the study area. Research regarding fluorine persistence in Entisol soils is not well understood. The project area would represent an excellent opportunity to conduct future fluorine soil residue research in the context of Florida coastal Entisols.

Another issue of concern within the study area is the possible effect of unintended anthropogenic acidification of the native soils. Where the soils in the project area
chemically altered by the emissions of fluorine, phosphorus pentoxide, phosphine and sulfur dioxide gasses? Phosphorus derivative aerosols have the ability to increase acidity in soils depending on the buffering capacity of a specific soil (Van Vorris et al, 1987).

When soil pH is reduced by an acidification agent it is possible that essential macro and micro elements essential to plant growth can become bound to the soil and become unavailable for assimilation. When soil pH values fall below (5.4) toxic aluminum can be liberated from siliclastic parent soils. It is therefore possible that plant damage in the project area that had been observed over the past 59-years could be in response to soil acidification and toxic aluminum liberation.

ATSDR ombudsman Ronnie Wilson is of the opinion that, the Stauffer Super-Fund site has fallen through the cracks. The assessment of the public health threat was rushed and because of this it was very incomplete and virtually useless for his agency to act on (Rondeaux, 2003).

The Stauffer Super-Fund site has been under close scrutiny by the EPA since 1994 when politicians began to champion the cause of the Tarpon Springs community. During this period various studies to assess risk have been conducted by both governmental and by contracted consulting services who have been hired by the Stauffer Corporation. As of this time, no single risk/hazard study has been declared conclusive by the EPA (Ryburn, 2006). The 2003 Agency for Toxic Substances and Disease Registry (ATSDR) health study concluded that the workers were faced with working in unhealthy working conditions with little or no protection from contamination.
Chapter Six

Summary and Conclusions

This thesis attempted to determine the extent of adverse environmental impacts that occurred in Pinellas County as a result of elemental phosphorus production. The research gathered and assessed the combined resources of historical documents, technical bulletins and institutional knowledge to create a base data that upon analysis revealed new knowledge about the complex cultural and environmental issues associated with elemental phosphorus production in Pinellas County, Florida. This analysis allowed the sub-research questions and the over-arching research question, to be answered.

The research project was framed within scope of three sub-research questions and the one over-arching research question. The sub-research questions that framed the research are: “What are the adverse impacts imposed on employees relative to air quality, water quality and other forms of exposure in the study area? What are the adverse environmental impacts imposed on the citizens relative to air quality, water quality and other forms of exposure in the study area? What are the adverse environmental impacts imposed on the non-human organisms relative to air quality, water quality and other forms of exposure in the study area?” The over-arching research question that framed the research was: “What are the adverse environmental impacts resulting from the production of elemental phosphorus in Pinellas County, Florida?”
Regarding the first sub-research question, based on the historical, technical and interview research findings, employees at the Victor/Stauffer facility were exposed to a constant source of toxic gas and dust emissions. The gas and dust emissions were the vehicle that conveyed numerous toxic synthetic materials into the respiratory and digestive system of the workers. The high temperature processing of phosphate ore, silica, and coke resulted in the liberation of gaseous/aerosol clouds containing: asbestos, fluorine, phosphorus pentoxide, phosphine, radium-226, and silica. Independently each of these toxic components represented a significant exposure health risk to the workers. When workers are exposed to the agglomeration of synthetic compounds listed above, a synergistic complex of toxic agents is created. The complex of toxic agents were pervasive and as such the production workers inhaled, absorbed and ingested the gasses, aerosols, and associated precipitates. The research found that the workers were frequently burned both chemically and physically. The research determined that the workers were exposed to airborne asbestos that can induce asbestosis. The research revealed that employees were exposed to fluorine gas that can result in chronic fluorosis. The research also determined that production facility workers were also exposed to phosphorus pentoxide gas that in sufficient concentrations can burn and ulcerate lung tissue. The dental facilities located within the elemental phosphorus production facility provide tangible evidence that the Stauffer Chemical Corporation was fully aware of dental risk associated with working in an enhanced phosphorus environment. Oral diseases including “Phossy-jaw” were one of many possible adverse environmental impacts imposed on the employees that worked in close proximity to the enhanced phosphate and fluorine environment. No written records were located in this study that directly link the
in-house dental facility to the existence of chronic oral disease associated with the production of elemental phosphorus at the Stauffer production facility. It is highly likely that oral disease issues associated with the work environment were handled within the company sanctioned dental facility. This particular issue may never be fully clarified as there does not appear to be an avenue to investigate past dental records.

The second sub-research question asked: “What are the adverse environmental impacts imposed on citizens relative to air quality, water quality and other forms of exposure in the study area?” Based on the historical, technical and interview research findings, local citizens within the study area were exposed to persistent clouds of toxic gasses and dust emissions. Unlike workers who had 40-hour per week work exposures, the resident citizens had the potential for up to 168-hours of exposure time per week. The citizens in the study area were exposed to nearly all of the adverse impacts that were associated with the workers. The citizens were only excluded from the physical burn adverse condition that the workers were exposed to. However, due to the vast quantities of gaseous and aerosol emissions, the citizens were frequently breathing and living in the same adverse air quality that the workers were exposed to. All citizens in the study area were exposed to adverse health risks associated with living in an area that was permeated with: asbestos dust, fluorine gas, phosphorus pentoxide gas, sulfur dioxide gas, radium-226 and silica dust. Citizens also suffered from contaminated private wells that were fouled by fluoric acid, phosphoric acid, radium-226 sulfuric acid. Citizens may have relied unknowingly on contaminated private well water resources for up to 47-years.

The third sub-research question asked, “What are the adverse environmental impacts imposed on the non-human organisms relative to air quality, water quality and
other forms of exposure in the study area?” Based on the historical, technical and interview research findings the biologic community within the study area was also adversely impacted by the pollutant constituents of the Victor/Stauffer elemental phosphorus production facility. Less than three months following commencement of production the local residents were noticing a rapid decline in the health of the plant and animal communities. Gaseous fluorine intoxication in the project area produced highly adverse growing conditions for the large citrus industry of northwest Pinellas County. The well drained Astatula soil (Entisols) of northwest Pinellas County provided Citrus growers with manageable moisture conditions to should have produced high quality Citrus trees. The fluorine gas emissions resulted in reduced production in most Citrus species. Grapefruit were by far the most vulnerable of the Citrus genus in the study area. Gaseous fluorine levels in the 300ppm-400ppm range can result in the persistent defoliation of Citrus (Citrus spp.) and Pine (Pinus spp) trees. Chronic defoliation events eventually deplete a vascular plant’s carbohydrate reserves and therefore impose phyto metabolic decline or necrosis.

The historical documents revealed that the citizens were qualitatively and quantitatively aware of the adverse environmental impacts that the Victor/Stauffer production facility had imposed within the study area. The persistent emissions from the Victor/Stauffer facility over a 34-year period had destroyed the livestock, citrus and much of the native plant community. Fluorine intoxication was a bioaccumulation hazard within the project study area during the time of active elemental phosphorus production. Ruminating livestock consumed the improved pasture grasses Bahia grass (Paspalum notatum) in the project area over an extended period of time. The daily
consumption of fluorine contaminated forage resulted in highly elevated levels of fluorine in the bone structure matrix of all animals feeding within the local trophic web. Fluorine preferentially replaces calcium in all boney structures. The boney structures that exhibit the greatest wear and tear such as knee and ankle structures are most quickly replaced. Therefore, weight bearing bones such as leg bones and jaw bones were predisposed to fracture and structural abnormalities. During the years of operation of the elemental phosphorus production facility all local livestock production would have been at risk from systematic fluorosis intoxication in large part due to prevailing winds and the pervasive compounding effect of bioaccumulation. Bovine calves would have been at the greatest risk as feeding from their mother would have resulted in several magnitudes of toxic fluorine bioaccumulation. Bone structures of mammals became malformed from chronic fluorosis and disease symptoms are manifested in chronic oral and podiatry diseases that gradually killed livestock by incapacitation and starvation. As of this time the native plant community has not recovered to levels of density or vigor that can be observed outside of the study area. There has been no recovery to the agricultural component in the study over the past 26-years since production at the facility was suspended. At this time, the research study area supports only a stressed ruderal plant community.

The larger over-arching research question asked: “What are the adverse environmental impacts resulting from the production of elemental phosphorus in Pinellas County, Florida?” Based on the collective findings of the sub-research questions it can be qualitatively and quantitatively determined that adverse environmental impacts resulting from the production of elemental phosphorus were diverse and pervasive.
throughout the study area. The research study was able to determine that workers and citizens were exposed to quantifiable levels of phosphorous pentoxide gas, sulfur dioxide gas and qualifiable levels of fluorine gas, asbestos, radium-226 and silica. The study was able to determine that the non-human (flora-fauna) communities were exposed to quantifiable levels of fluorine and qualifiable levels of asbestos, phosphorus pentoxide, radium-226, sulfur dioxide and silica. The study was able to determine that elemental phosphorus, fluoric acid, phosphoric acid, radium-226, and sulfuric acid have contaminated the surficial and Floridan water resource within the study area. As a result of the extensive ground water contamination all of the private wells within 4-miles of the production facility have been abandoned by the Pinellas County Health Department as of 1994. It can be concluded that the agricultural industry in northwest Pinellas County was adversely impacted by the deleterious effects of elemental phosphorus production. The cattle and citrus components were significantly damaged by the antagonistic effect of the fluorine gas and vapors that settled over the project area. The symptoms of fluorine toxicity are perhaps the most glaring adverse environmental impact that influenced the project area in the largest geographic context. It may never be known how many oral diseases resulted from the wind driven dispersion of fluorine gas throughout the study area. Visual observations provided by numerous environmental officials since 1981 has helped to confirm that native plant colonization in the project area has been greatly inhibited. It could be deduced that the retarded native plant community colonization is the result of fluorine contamination or excessive anthropogenic acidification of the soils. The influence of the elemental phosphorus production facility did create adverse conditions for the geologic and biologic communities. The humans, livestock, wildlife,
soils and surficial water resource were adversely impacted by the numerous toxic synthetic compounds that were created from phosphate ore processing. It is much more difficult to ascertain the continuing risks that will continue to persist at the research project site. It has been determined in a previous study at Eagle Flats, Alaska that elemental phosphorus has a half-life of up to 10,000 years when it is held in an oxygen deprived environment.

The proposed mound and capping method of remediation that the EPA has sanctioned for the Victor/Stauffer elemental phosphorus production facility will attempt to compartmentalize the buried elemental phosphorus waste materials within a Portland cement vault. The mound and capping remediation project will actually perpetuate the period of time that elemental phosphorus will remain within the study area as a contaminant. The persistence of anaerobic elemental phosphorus is roughly equal to the current length of the geologic Holocene Period. It is therefore possible that the hermitically contained elemental phosphorus in the Northwest Pinellas County study area could persist into the next climatic cycle following the Holocene Period.

The study was unable to determine if water resources within the elemental phosphorus production facility were contaminated. If public health records confirm that no municipal water sources were provided to the Victor/Stauffer production facility; it could be deduced that workers would have had access only to a private water well resource that would have been another source of adverse environmental impact to them.

Interviews with past employees and supporting exploratory ground penetrating radar (GPR) has lead the EPA to conclude that up to 600 55-gallon drums of elemental phosphorus has been buried in the study area. Employees of Victor/Stauffer indicate that
it was common practice to bury the waste barrels below the water table so that no oxygen could reach the elemental phosphorus. The citizens are concerned as to the fate of the barrels during extended drought. Extended drought could result in lowered groundwater and this could expose the elemental phosphorus to small amounts of oxygen that might be present in the soil profile. Based on the 1972 Pinellas County Soil Survey the soils in the study area support a water table that can rise to within 40” of the soil surface during extended wet periods and can drop to greater than 60” during periods of extended dryness. Extended dry periods could result in a lowered vadose water table which could allow oxygen to permeate through the soil profile to the buried drums. The result of such a low water table scenario could result in the subterranean combustion of vast quantities of elemental phosphorus (Ryburn, 2006).

The current EPA inventory of the Stauffer Chemical EPA Super-Fund site indicates there are three major hot-spots were buried contamination is concentrated. These areas include: 1) the electric-arc furnace zone, 2) the elemental phosphorus clarifier zone, 3) the elemental phosphorus barrel dumping zone (EPA, Stauffer Assessment, 2003).

Charley Ryburn provides the following statement:

The EPA currently anticipates consolidating the three toxic burial “hot-spot” areas as much as is practical. The consolidation procedure will be followed with the addition of clean fill soil that will cover the hot-spot areas with more compacted overburden. This procedure will be done in order to build a more effective oxygen depriving soil buffer. The final step will be to bring a drilling rig on site in order to bore numerous exploratory grout injection holes into the buried hazardous materials. The soil grout injection will be
an attempt to structurally segregate the hazardous materials from adjacent soils and groundwater sources. It is currently believed that at least 600 55-gallon drums of elemental phosphorus remain buried on-site (Ryburn, 2006).

The long term adverse environmental impacts in the study area continue to include the toxic effects to ground water from fluorine, elemental phosphorus, lead, radium-226, silica, sulfuric acid and phosphoric acid contamination. Another ongoing adverse environmental impact would include the issue of soil contamination. Residents who plant and consume food sources from vegetable or fruit bearing plants could be ingesting fluorine contaminants. It is in this context that the long-term residents are placed in a double jeopardy scenario. The residents in the study area were adversely impacted during the production years of 1947-1981 and yet in 2007 the insidious risk continues to persist as there are no plans to remediate or monitor the soil component. The full magnitude of adverse environmental impacts created by the production of elemental phosphorus in Pinellas County may never be fully understood.

The research project has contributed an additional body of evidence as to the pervasiveness and synergistic adverse environmental impacts that occur as a direct and indirect result of elemental phosphorus production. The research has provided additional evidence that native and agricultural plant communities have been damaged within the project area as a direct result of elemental phosphorus production. The research clarifies that observable damage to the native and agricultural plant community occurred within 90-days of operational commencement and has remained evident for a period of 26-years following the closure of the production facility. The study has concluded that the
dispersion of fluorine gas has killed and continues to curtail native plant species colonization in the project area for a period of 60-years.
Photograph 18-Gulfside Elementary School 100 Meters North of Phosphate Slag Field (Looking Westward)

Photograph 19-North Bank of Anclote River 1.0 Kilometer Down Stream of the Victor/Stauffer Elemental Phosphorus Production Facility (Looking Eastward)
Future Research

The research conducted on this project provides the opportunity for further exploration of the numerous aspects of adverse environmental impacts within the study area. Future research opportunities could include the following questions:

1). What are the long term adverse effects of soil borne fluorine on native plant communities?
2). What are the effects of 34-years of anthropogenic acidification of Entisols and the affect on the associated plant communities?
3) Does the introduction of anthropogenic soil acidifying compounds accelerate normal dissolution processes in Florida’s mantled Karst topography?
4). Do some exotic plants such as Brazilian Pepper (*Schinus teribinthifolius*) have the ability to tolerate and assimilate soil borne fluorine. If so, could tolerant plant species be used as fluorine remediation trap plants?
5). Can pumped concrete grout meet the intent of an air tight containment methodology for buried elemental phosphorus?

Following the release of a third comprehensive geo-physical study/assessment of the Stauffer Super Fund site in June of 2003 it was determined there was sufficient clay confining layer to keep the site’s contamination from reaching the deeper aquifer Quioco, 2003). In this context, another future study could investigate if the mantled Karst topography of the study area is geologically isolated from the Floridan Aquifer.
The pervasive adverse environmental impacts associated with elemental phosphorus production of the past are now more fully comprehended. The continuing adverse environmental impacts will require additional and on-going analysis so that the voluminous buried contamination materials are effectively managed. The persistent half-life of buried anoxic elemental phosphorus only reinforces that the long-term adverse environmental influences resulting from the production of elemental phosphorus in northwest Pinellas County will continue unabated. Future research could also focus on tracking the effectiveness of the proposed entombment and burial remediation methods that are proposed for the abandoned production facility.

The research continued to point to the possibility of damage to the native soils in the project area. In this regard, future research could investigate the possible contamination of the native soil resource. The introduction of the acidification compounds of fluoric acid, phosphoric acid and sulfuric acid into siliclastic soils can greatly reduce pH levels. When siliclastic soils become highly acidic (5.4 or less) then can release toxic aluminum. If the native siliclastic soils were highly acidified it is possible that native plant recruitment could be significantly reduced due to secondary aluminum toxicity. Future studies could investigate if this probable soil toxicity phenomenon has taken place as a result of 34-years of elemental phosphorus production in Pinellas County, Florida.
**Glossary of Research Terms**

**Entisol:** A soil order with very poor horizon development and weak pedologic maturation.

**Allelopathology:** The chemical inhibition of a new plant community from the presence of an antagonistic existing plant community.

**Edaphology:** The science of soil and its underpinning relationship to other biologic organisms.

**Elemental Phosphorus Plant:** A facility that processes phosphate ore in order to produce elemental phosphorus. The facility will include high temperature calciners and nodulizing kilns. (United States Environmental Protection Agency Regulatory Statutes, July 1, 2001, page 67)

**Fluorine:** An acidic gaseous element that can be liberated from phosphate rock. Phosphate rock of Central Florida can contain 3%-4% fluorine by weight.

**Hawthorn Formation:** The Hawthorne Formation is a geologic feature comprised of fuller’s earth, limestone, land pebble phosphate, marl and clay. The Hawthorne Formation is located over the regolith geologic feature and constitutes the upper most geologic feature in Northern Pinellas County. The Hawthorne Formation can act as an impervious or semi-impervious confining layer.
**Holocene Period:** The time period following the Pleistocene Period. The Holocene Period began approximately 10,000 years before present. The Holocene Period is marked by the stabilization of oceanic levels and relatively stable climatic conditions to include the present.

**Karst Topography:** A geologic landscape that has been highly modified by carbonate dissolution resulting in the creation of subsidence features. The associated subsidence features have the propensity to propagate small to regional sized closed drainage basins that typically lack surface stream features.

**Leaf Abscission:** The botanic process that imparts chemical and physical stimulation processes to impose leaf drop.

**Mantled Karst Topography:** A Karst geologic landscape that has been reworked by sediment deposition.

**Pedology:** The study of soil development and soil evolution processes.

**Phreatic Zone:** The geologic zone that supports a deep circulating water table located below a geologic confining layer.

**Pleistocene:** The geologic time period preceding the Holocene period when Florida shrank in geographic extent as a result of climatic change. The Pleistocene geologic period was marked by landscape removal and sediment depositional events.

**Stratigraphy:** The study of geological features based on vertical location in the earth.

**Vadose Zone:** The unsaturated geologic zone located above the Phreatic Zone. An unconfined Vadose Zone receives influences from the land surface and responds to atmospheric precipitation infiltration.
References Cited


Agency for Toxic Substances and Disease Registry, September, 1997, Public Health Statement for White Phosphorus CAS # 7723-14-0

Agency for Toxic Substances and Disease Registry, December 29, 2000, Ombudsman Report of Findings and Recommendations Regarding the Stauffer Chemical Company Site


Collins, C., C. Racine, and M. E. Walsh. 1995. Persistence of White Phosphorus Particles in Sediment, Cold Regions Research & Engineering Laboratory (CRREL) REPORT, 95-23 prepared for the Army Corps of Engineers (ACOE),


Danielson, R., *Saint Petersburg Times*, June 26, 2003 *Clearwater Times Section*, page 6


Danielson, R., *Saint Petersburg Times*, August 31, 2005 *b North Pinellas Section*, page 1


Editorial, (No Author Listed), *Saint Petersburg Times*, July 15, 2005 *a Clearwater Times Section Editorial*, page 2

Editorial (No Author Listed) *Saint Petersburg Times*, December 29, 2005, *b Clearwater Times Section Editorial*, page 2


Koch, N., *Saint Petersburg Times*, June 4, 2005, Section B, page 4


Linton, R., 1970, *Fluoride Pollution from Phosphate Industry in Polk County, Florida*; 46 Fluoride Action Network
Love Canal Agency for Toxic Substances and Disease Registry. EPA Habitability Decision Love Canal Declaration Area Super-Fund Site Study Summary

Markowitz, G., and D. Rosner, 2002, Deceit and Denial the Deadly Politics of Industrial Pollution, Berkeley and Los Angeles, California: University of California Press


Quioco, E., Saint Petersburg Times, June 12, 2003 Clearwater Times Section, page 3


Rondeaux, C., Saint Petersburg Times, April 3, 2003, a North Pinellas Times Section, page 1

Rondeaux, C., Saint Petersburg Times, April 9, 2003, b North Pinellas Times Section, page 1


Stein, R., Van Sant, Will., Saint Petersburg Times, October 29, 2005, Clearwater Times Section, page (1, 8)

Stein, R., Saint Petersburg Times, February 16, 2006, Section B, page 3


United States Department of Agriculture Soil Conservation Services, 1972, *Soil Survey of Pinellas County, Florida*.


United States Environmental Protection Agency, *S.W. Shattuck Chemical Operable Unit #8, Special Report Five-Year Review Report for Denver Radium Site*; In Response to EPA Contract Number 68-D7-0001, November 12, 1999


United States Environmental Protection Agency, Region-8. 2004. *Shattuck Chemical Region 8 EPA Super-Fund Site - S.W. Shattuck Chemical Operable Unit #8*


Wilson, R. 2000. *Air Pollution from Stauffer Chemical Phosphate Plan*, Agency For Toxic Substances And Disease Registry
Geographic Figures

Geographic figures 1, 2, 4 and 5 are digital products derived from the Pinellas County Geographic Information System, 2005. Geographic figure 3 is a product derived from the Pinellas County Geographic Information System, 2006.
Historical Timetable Sources

Agency for Toxic Substances and Disease Registry (1997); and personal interview with Ms. Joyce Gibbs, Mr. Peter Hessling and Mr. Charley Ryburn, August 2006.
Appendices
Appendix A: Timetable

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1674</td>
<td>German alchemist Hennig Brand is the first to identify elemental phosphorus.</td>
</tr>
<tr>
<td>1823</td>
<td>Peninsular Pinellas is permanently settled by people of European decent.</td>
</tr>
<tr>
<td>1845</td>
<td>Florida achieves statehood.</td>
</tr>
<tr>
<td>1868</td>
<td>Peninsular Pinellas gains access to the City of Tampa by a traversable road.</td>
</tr>
<tr>
<td>1879</td>
<td>Rock phosphate mining begins in Hawthorn, Putnam County, Florida</td>
</tr>
<tr>
<td>1882</td>
<td>Commencement of commercial mining of phosphate pebbles in the Peace River Valley near present day Fort Meade, Polk County, Florida</td>
</tr>
<tr>
<td>1888</td>
<td>Railroad service reaches Peninsular Pinellas/West Hillsborough County (later to become Pinellas County). Railroad access to an expanding northern market invigorates Pinellas County to rapidly expand citrus production.</td>
</tr>
<tr>
<td>1899</td>
<td>Florida Power provides alternating current electric power to Peninsular Pinellas/West Hillsborough County.</td>
</tr>
<tr>
<td>1910</td>
<td><strong>(October 1st)</strong> White Phosphorus Matches (Prohibition) Ordinance enacted. This particular prohibition was the first in the United States to protect the public from elemental phosphorus exposure, mainly the sucking of matches containing elemental phosphorus which results in Phossy Jaw and possible death from secondary oral infections.</td>
</tr>
<tr>
<td>1911</td>
<td>Pinellas County is chartered as a new county following separation from Hillsborough County. Full economic severance from the port city of Tampa.</td>
</tr>
<tr>
<td>1926</td>
<td>The Florida Land Boom collapses and real estate values plummet. Local tax bases are severely damaged and the Florida economy retracts.</td>
</tr>
<tr>
<td>1929</td>
<td><strong>(October)</strong> The Great Depression begins. This Great Depression global economic downturn event in Florida is considered the second depression following the 1926 economic collapse.</td>
</tr>
<tr>
<td>1941-1945</td>
<td>Northern Pinellas County is used as an army military training facility during World War-II and this particular event exposes thousands of young American soldiers to a new sub-tropical destination.</td>
</tr>
</tbody>
</table>
Appendix A: (Continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945 (March 9th and 10th)</td>
<td>Tokyo, Japan is targeted with a two day massive elemental phosphorus incendiary bombing campaign. More than 100,000 people are killed immediately and most of Tokyo is left in ruin. This particular bombing effort exceeding the lethal effects of the combined atomic bomb utilization and created the greatest one day loss of human life during World War-II.</td>
</tr>
<tr>
<td>1945/1946</td>
<td>Returning World War-II veterans of Pinellas County face a devastated sponging industry in the Tarpon Springs area. Pinellas County Commissioners and City of Tarpon Springs City Commissioners look for interested industries to locate in the Tarpon Springs area to help diversify the local economy of North Pinellas County.</td>
</tr>
<tr>
<td>1946 (February 16th)</td>
<td>The Victor Chemical Works purchases a 130-acre land parcel adjacent to the Anclote River in northwest Pinellas County that will be utilized for the construction and operation of an elemental phosphorus production facility. Construction of the twin arc-furnace elemental phosphorus production facility begins.</td>
</tr>
<tr>
<td>1947 (March 1st)</td>
<td>John Claypool an agricultural scientist came to the Tarpon Springs area for the Victor Chemical Works in order to determine the existing ambient condition of trees and vegetation prior to the commencement of elemental phosphorus production.</td>
</tr>
<tr>
<td>1947 (March)</td>
<td>Foundations are poured and steel structures erected on the Victor Chemical Works $3,000,000 elemental phosphorus production plant.</td>
</tr>
<tr>
<td>1947 (November 19th)</td>
<td>The Victor Chemical Works completes the construction of the electric-arc elemental phosphorus production facility in Northwest Pinellas County. Twenty four hour production commences.</td>
</tr>
<tr>
<td>1948</td>
<td>The phosphate industry in Florida commences with a new method of “chemical processing” of phosphate ore in order to produce more potent fertilizers for the post World War-II Green Revolution. High heat process and wet process become the new extraction technologies that liberate more potent phosphorus from the raw ore.</td>
</tr>
<tr>
<td>1948 (January)</td>
<td>Ms. Genevieve Flanagan of Tarpon Springs notices damage to her Pine and Oak trees and relates the observed damage to the new Victor Chemical Works elemental phosphorus plant.</td>
</tr>
</tbody>
</table>
**Appendix A: (Continued)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1948 (January)</strong></td>
<td>Approximately 300 residents of the Tarpon Springs area sign a petition complaining of offensive odors in Tarpon Springs and blame the Victor Chemical Works elemental Phosphorus plant as the source of adverse air quality.</td>
</tr>
<tr>
<td><strong>1948 (January-February)</strong></td>
<td>Bartley Mickler of Tarpon Springs observes his normal wintertime loss of pigs and calves is unusually high and notices that the numerous Pine trees on his 5,000-acre property are turning brown.</td>
</tr>
<tr>
<td><strong>1948 (February 18th and 23rd)</strong></td>
<td>John Claypool working as Victor Chemical Works consultant returns to Tarpon Springs on behalf of the Victor Chemical Works to determine the existing health status of trees and vegetation following the commencement of elemental phosphorus production in Tarpon Springs, Florida</td>
</tr>
<tr>
<td><strong>1948 (June)</strong></td>
<td>Nuisance law suit filed against Victor Chemical Works in the Federal District Court Division II for South Florida alleging adverse gasses and fumes are emanating from the newly operating elemental phosphorus production facility</td>
</tr>
<tr>
<td><strong>1948 (June 14th)</strong></td>
<td>Test of plant tissue samples are completed and confirm that there are very high concentrations of fluorine in Pine needles that were collected near the production plant</td>
</tr>
<tr>
<td><strong>1961</strong></td>
<td>The Stauffer Chemical Corporation purchases the elemental phosphorus production facility from Victor Chemical Works. Stauffer Chemical Corporation takes over the operations of the elemental phosphorus production facility</td>
</tr>
<tr>
<td><strong>1962 (December 13, 14)</strong></td>
<td>Devastating late fall advective freeze event with record low temperatures destroys nearly all of the Pinellas County citrus industry. The citrus industry in Pinellas County never fully recovers as urbanization development pressures quickly displace historic agriculture.</td>
</tr>
<tr>
<td><strong>1970</strong></td>
<td>The Clean Air Act of 1970 is enacted by Congress and signed by Richard M. Nixon</td>
</tr>
<tr>
<td><strong>1972</strong></td>
<td>The Clean Air Act is revised and expanded to a more comprehensive piece of practical legislation</td>
</tr>
<tr>
<td><strong>1974</strong></td>
<td>Following the Federal lead; Pinellas County local governments form a consortium of local scientist and planners from Pinellas County, Clearwater and St. Petersburg to research the need for codified environmental reform. The Stauffer Chemical Corporation elemental phosphorus plant is deemed the highest environmental priority for Pinellas County</td>
</tr>
</tbody>
</table>
Appendix A: (Continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>The Pinellas County Department of Environmental Management is formed by an act of the Pinellas County Board of County Commissioners</td>
</tr>
<tr>
<td>1975</td>
<td>Joyce Gibbs is hired as the first air quality division employee for Pinellas County Government.</td>
</tr>
<tr>
<td>1975</td>
<td>Pinellas County Department of Environmental Management receives the first complaints taken from the public relative to the Stauffer Chemical Corporation elemental phosphorus plant</td>
</tr>
<tr>
<td>1975</td>
<td>Joyce Gibbs acting as the chief of the Air Quality Division of the Pinellas County Department of Environmental Management initiates site inspections of the Stauffer Chemical Corporation elemental phosphorus production plant</td>
</tr>
<tr>
<td>1977</td>
<td>Pinellas County initiates an ambient air quality testing program for sulfur dioxide.</td>
</tr>
<tr>
<td>1977</td>
<td>Pinellas County installs a 24-hour air quality sulfur dioxide sampling station at the southeast corner of the Stauffer Chemical Corporation elemental phosphorus production facility</td>
</tr>
<tr>
<td>1977</td>
<td>The project area maximum annual level of sulfur dioxide is measured at 0.28ppm.</td>
</tr>
<tr>
<td>1978 (October 23rd)</td>
<td>The Florida Department of Environmental Regulation (FDER) produces a memorandum that states, the ambient sulfur dioxide violations are almost entirely the result of the emissions from the Stauffer Chemical Corporation elemental phosphorus production facility.</td>
</tr>
<tr>
<td>1978</td>
<td>The project area maximum annual level of sulfur dioxide is measured at 0.35ppm.</td>
</tr>
<tr>
<td>1979</td>
<td>Mr. Peter Hessling is hired as an environmental specialist/field inspector for the Air Quality Division of the Pinellas County Department of Environmental Management.</td>
</tr>
<tr>
<td>1979</td>
<td>The Stauffer Corporation is cited for dust violations by the Occupational Health and Safety Administration (OSHA) at the Tarpon Springs elemental phosphorus processing plant.</td>
</tr>
<tr>
<td>1979</td>
<td>The highest pollution standard index (PSI) of 400 measured at Tarpon Springs was the highest level ever to be recorded in Florida. The 400 (PSI) at Tarpon Springs surpassed the previous Florida State (PSI) maximum by 300%.</td>
</tr>
</tbody>
</table>
Appendix A: (Continued)

Table 2

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>The project area maximum annual level of sulfur dioxide is measured at 0.23ppm.</td>
</tr>
</tbody>
</table>

**1979 (May to July)** The owners of Flaherty Marina kept a log in order to record the daily air quality condition on the land parcel adjacent to the Stauffer Chemical Corporation property. The following log provides the observed visibility conditions for specific times and days:

- May 31, 1979 (7:50pm) Could not see even with headlights (seven witnesses)
- June 11, 1979 (6:10pm) Complete blackout, seemed to come from the base of the new stack
- June 15, 1979 (2:11pm) 100% visibility loss
- June 16, 1979 (8:30am) 100% visibility loss
- June 18, 1979 (3:12pm) 70% visibility loss
- June 20, 1979 (4:00pm) 90% visibility loss
- June 23, 1979 (1:10pm) 100% visibility loss
- July 4, 1979 (8:10am) 100% visibility loss
- July 4, 1979 (9:10am) 90% visibility loss
- July 4, 1979 (10:40am) 75% visibility loss
- July 15, 1979 (11:45am) 90% visibility loss

**August 1979** Stephen Robinson, the study author, is hired by Pinellas County as an adjunct Soil Conservationist/County Agricultural Agent for the Institute of Food and Agricultural Science (IFAS) in Largo, Florida.

**1980 (February 25, 1980)** Joyce Gibbs, Chief of the Pinellas County Air Quality Division of Air Quality, sends a memorandum to the Director of the Florida Department of Environmental Regulation stating that the ambient sulfur dioxide violations are almost entirely due to the emissions that emanate from the Stauffer Chemical Corporation phosphate electric arc furnace stacks.

**1980 (April 17th)** Electric arc furnace malfunction and forces a shut down and results in the creation of a phosphorus pentoxide smoke plume at ground level that covered the study area for a period of 9-hours. Local spring season meteorology limited the dispersion of the phosphorus pentoxide smoke. This emission episode created the highest concentration of sulfur dioxide gas ever measured in Florida.

**1980** The project area maximum annual level of sulfur dioxide is measured at 0.08ppm. This particular measurement shows an approximate 200% reduction from the previous year as a result of the gradual reduction of production at the Stauffer Chemical Corporation elemental phosphorus production facility.
Appendix A: (Continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980/1981</td>
<td>Smoke stack testing events at the Stauffer Chemical Corporation elemental phosphorus plant are cancelled due to structural deficiencies.</td>
</tr>
<tr>
<td>1981 (Spring)</td>
<td>Stauffer Chemical Corporation begins a significant reduction of production.</td>
</tr>
<tr>
<td>1981 (Spring)</td>
<td>Sulfur dioxide ambient levels in the project area begin to decline</td>
</tr>
<tr>
<td>1981 (August)</td>
<td>Stauffer Chemical Corporation suspends all production at the elemental phosphorus production facility</td>
</tr>
<tr>
<td>1981</td>
<td>The project area maximum annual level of sulfur dioxide is measured at 0.06ppm. This particular measurement was documented following a significant reduction of production and the suspension of production in 1981.</td>
</tr>
<tr>
<td>1981 (September)</td>
<td>Stauffer Chemical Corporation conducts some limited demolition of the production facility</td>
</tr>
<tr>
<td>1986</td>
<td>Stauffer Chemical Corporation conducts large scale demolition of the production facility</td>
</tr>
<tr>
<td>1992</td>
<td>Charley Ryburn is hired as a pollution control specialist for the Pinellas County Department of Environmental Management.</td>
</tr>
<tr>
<td>1994</td>
<td>The United States Environmental Protection Agency (EPA) designates the 130-acre area utilized by Victor and Stauffer as an EPA Super Fund Site. The Super Fund site is fenced and secured by a two person security team. An alarm siren is installed at the north end of the Super Fund site in case a fire and smoke event that might threaten the surrounding public.</td>
</tr>
<tr>
<td>1994</td>
<td>The Tarpon Springs City Library is designated as the Federal Depository (with public access)</td>
</tr>
<tr>
<td>1996 (October)</td>
<td>Spontaneous combustion of elemental phosphorus occurs when contractor attempts to excavate contaminated materials at the Stauffer Corporation Super Fund site.</td>
</tr>
<tr>
<td>1997 (December)</td>
<td>United States Corps of Engineers completes Special Report 97-30 relating to Composite Sampling of Sediments Contaminated with White Phosphorus. The study produces new conclusions on the environmental fate of elemental phosphorus in</td>
</tr>
</tbody>
</table>
Appendix A: (Continued)

Table 2

<table>
<thead>
<tr>
<th>Event Date</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003 (April)</td>
<td>During a consultation site visit to the Stauffer Management Corporation, Charley Ryburn and Stephen Robinson observe the spontaneous combustion of soil at the northeast corner of Anclote Road and County Road 47.</td>
</tr>
<tr>
<td>2003 (April)</td>
<td>Stephen Robinson begins preliminary project research with a preliminary visit to the Tarpon Springs Public Library Federal Depository for the Stauffer Chemical Super Fund site.</td>
</tr>
<tr>
<td>2003 (April 2nd)</td>
<td>Agency for Toxic Substances and Disease Registry concluded that the Victor/Stauffer site produced discharge plumes of sulphur dioxide at concentrations of greater than 100ppb up to 8-miles to the south and southeast of the production facility. Areas within 1-mile of the production facility were adversely impacted by sulfur dioxide levels up to 840ppb.</td>
</tr>
<tr>
<td>2003 (June 10th)</td>
<td>Three new comprehensive geo-technical reports funded by Stauffer Management Corporation indicate that the Stauffer Corporation Super Fund Site is largely free of an active sinkhole threat. The geo-technical report states that 120-acres of the Stauffer Super Fund site is geologically stable. The geo-technical report states that 10-acres of the Stauffer Super Fund site show signs of sinkhole activity more than 40,000 years ago. The geo-technical report states that a continuous layer of clay material extends over 92% of the site. The clay material has an average thickness of 96”. The geo-technical reports that five areas were found that might contain large amounts of buried metal materials.</td>
</tr>
<tr>
<td>2005 (August 31, 2005)</td>
<td>Environmental activist Mary Mosley states that a mound and cap solution is not acceptable to the surrounding community. “All the carcinogens will be left. There’s no concrete in the world that doesn’t crack.”</td>
</tr>
<tr>
<td>2005 (December 29, 2005)</td>
<td>A St. Petersburg Times authored editorial revealed that after medical test results were analyzed it was determined that former workers at the Victor/Stauffer elemental phosphorus production facility have a higher than normal incidence of lung problems (pneumoconiosis).</td>
</tr>
<tr>
<td>2006 (January)</td>
<td>Stephen Robinson presents thesis proposal to supervisory committee at USF.</td>
</tr>
<tr>
<td>2006 (February)</td>
<td>Spontaneous combustion of previously buried elemental phosphorus occurs when exploratory drilling conducted by geo-technical consultant imparts oxygen...</td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>2006 (May/June)</td>
<td>Pinellas County Commissioners ask technical staff to investigate the feasibility of using the Stauffer Super Fund site as a possible future public marina facility.</td>
</tr>
<tr>
<td>2006 (August 10)</td>
<td>Interviewed Ms. Joyce Gibbs with the Pinellas County Public Works Department. Formerly the Ms. Joyce Gibbs was the Chief of Air Quality Division of the Pinellas County Department of Environmental Management.</td>
</tr>
<tr>
<td>2006 (August 14)</td>
<td>Interviewed Mr. Charley Ryburn, Program Manager for the Pollution Prevention Section of the Pinellas County Department of Environmental Management.</td>
</tr>
<tr>
<td>2006 (August 31)</td>
<td>Interviewed Mr. Peter Hessling, Division Administrator of the Air Quality Division of the Pinellas County Department of Environmental Management.</td>
</tr>
</tbody>
</table>
Appendix B: Elemental Phosphorus Technical Data Summary

Elemental Phosphorus Production and Associated By-Products

This section of the research is provided in order to help the reader to clarify the potential for adverse environmental contamination within the project area. In order to assess the environmental risk that is presented in the research it is important to first understand the chemical nature and properties of the contaminants in question. The toxicology framework provided in this section will help to qualify the spatial and temporal adverse environmental impacts created by the Victor/Stauffer facility.

This section of the research provides the reader with a practical context of industrial production of elemental phosphorus that was conducted within the project area. It is important to note that elemental phosphorus production in Pinellas County was a heavy industrial process; and as such, it was a large scale user of energy and raw materials. In addition to this the elemental phosphorus production facility also generated large scale gaseous and dust emissions. Elemental phosphorus production in Pinellas County, Florida was conducted in two very large high heat electric arc furnaces that were capable of chemically altering natural mineral components. The elemental phosphorus production plant in Pinellas County is not comparable to the existing super phosphate fertilizer production facilities in Florida. Industrial production of elemental phosphorus results in the high temperature liberation of numerous synthetic compounds that have
Appendix B: (Continued)

only recently become understood. An elemental phosphorus production facility must be framed within the context of an industrial facility that melts large quantities of impure phosphate ore in order to exploit the chemical constituents of raw phosphate ore.

Chemical Summary of Elemental Phosphorus

Elemental phosphorus is a synthetic compound that is has numerous industrial applications. One industrial application of elemental phosphorus is that it can be used as a constituent to create powerful phosphorus fertilizers. Phosphorus is one of the three primary or macro elements that are essential to sustain plant growth. Phosphorus is essential in plants to construct structural components of nucleic acids, phospholipids and adenosine triphosphate (ATP). Unfortunately, phosphorus is readily removed when plants are harvested and because of this many of the world's soils are chronically deficient in available phosphate. Soils that are deficient in available phosphate cannot support the complex processes of cyclic phosphorylation that drives the internal plant energy cycle. As an agricultural benchmark the American agricultural industry has determined that 40 pounds of phosphorus is required from the soil profile for each 100 bushels of corn produced. Agriculturally exploited soils must contain significant quantities of available phosphorus if an independent farmer or corporate farmer is going to be competitive in the agri-business that exists in the current world economy. The production of elemental phosphorus results in the creation of powerful phosphoric acids which are a product that can be readily and economically transformed into soluble phosphorus for worldwide agricultural utilization. The large-scale use of synthetically
Appendix B: (Continued)
derived phosphate fertilizers has allowed for the large-scale production of commodity food crops in regions of the world that would otherwise be sustained by some other economy (Keeton, 1980).

Elemental phosphorus manufacture is one of several technical steps in the chain of chemical manipulations that is needed in order to create large economical quantities of phosphoric acid. Phosphoric acid is the primary nutrient constituent in high phosphate fertilizers that can effectively fortify low natural phosphorus levels in soil. In order to create the primary constituents for phosphate fertilizers; it was learned that large scale (scale of economy) manufacturing of elemental phosphorus was the most cost effective means to produce the building blocks of high phosphorus fertilizers. The high temperature reduction of raw phosphate ore has become one of the economical sources of soluble phosphorus for the world wide agricultural industry (Farm Chemicals Handbook, 1991).

Elemental phosphorus products are highly diverse and have unique chemical properties that have been utilized to kill and maim during periods of warfare. But, conversely synthetic elemental phosphorus products also have the ability to fortify nutrient poor soils and this helps to feed the every burgeoning world population that has become reliant on agri-science and the green revolution.

Chemical Indenitity and Properties

Elemental phosphorus (P4) can not be derived from any natural sources or resources as it is the product of anthropogenic creation. Large amounts of energy must be expended in
Appendix B: (Continued)

order to synthesize elemental phosphorus to an industrial technical grade. Elemental phosphorus can be created by melting and reduction of raw phosphate ore, silica and coke in an electric furnace that can exceed temperatures of (1,648 degrees C or 3,000 degrees F). The reductive high heat process liberates elemental phosphorus gasses that are highly reactive in the presence of oxygen. In order to control the oxidation process elemental phosphorus is contained in an anoxic environment. Under industrial production conditions elemental phosphorus is usually held under a thick blanket of stagnant water that acts as an oxygen barrier. When elemental phosphorus is held under anoxic conditions it exists as a nearly transparent pellet shaped/crystalline white waxy solid material. The individual particles of elemental phosphorus look similar to small off-colored pearls. When technical grade (99.8% pure) elemental phosphorus is held under controlled laboratory conditions it retains a chunky morphology and is yellowish white in color. Elemental phosphorus can not be dissolved in water. The specific gravity of elemental phosphorus is 1.82 and this quality allows it to sink to the bottom of lakes, streams and holding ponds where it can remain in an un-oxidized stable state for indefinite periods of time. Elemental phosphorus has a boiling point of 280 degrees C at standard barometric pressure. The melting point of elemental phosphorus is 44.1 degrees C or 136.98 degrees F (The Condensed Chemical Dictionary, 1981).

It is believed that the German alchemist Hennig Brand was the first person to specifically identify elemental phosphorus in 1674. Brand's original synthesis of elemental phosphorus was produced from crude laboratory precipitations derived from animal urine(s) in 1669. It is believed that precipitations of bovine urine were used to
create the original batch of elemental phosphorus (Webster's New World Dictionary of Science, 1998).

**Elemental Phosphorus Constituents**

The constituents of natural forms phosphorus can be derived from raw phosphate rock such as impure Ca$_3$(PO$_4$)$_2$, in Apatite or [Ca$_5$(PO$_4$)$_3$F]. The natural forms of phosphorus are essentially derived from biogenic sources. The biogenic or natural sources of phosphate are generally low in the total content of available phosphorus. The most potent biogenic source of phosphorus is known as raw bone meal. Phosphorus sources such as bone meal were the staple of agriculture prior to the creation of phosphate containing synthetic fertilizers. The raw bone meal of well nourished bovine livestock can yield as much as a (22%) dry weight volume of available phosphorus. However, in contemporary agriculture the use of raw bone meal has become a public hygiene problematic. The recent outbreaks of Mad Cow Disease in Europe and Canada has raised concern with regard to public health and because of this the use of slaughtered livestock bone material has been greatly curtailed. The industrial and food chain hygiene concern has resulted in most sources of raw livestock bone meal and steamed bone meal to be pulled from the shelves of agricultural commodity market sources in order to help assure the safety of the public. When compared to natural sources of phosphate elemental phosphorus is a very high-density form of phosphorus. The industrial standard technical grade for elemental phosphorus is a (99.8%) minimum purity by dry weight. The highest grades of elemental phosphorus can exceed (99.8%) purity and the technical
Appendix B: (Continued)

grades that exceed (99.8%) purity are used for integrated circuitry and semi-conductor components (The Condensed Chemical Dictionary, 1981).

Elemental phosphorus is an anthropogenic synthetic compound and as such it has unusual chemical characteristics that make it potentially dangerous to the uninformed public. The highly reactive nature of elemental phosphorus creates significant production, storage and handling issues that are not encountered when working with naturally occurring phosphoric compounds.

Elemental phosphorus is very reactive in the presence of atmospheric gasses found within the lower levels of the troposphere. Because elemental phosphorus is a very unstable and potentially oxidative in atmospheric gasses, it must be stored and shipped under very controlled anoxic conditions in order to safeguard against spontaneous ignition and fire. Safe storage and shipping conditions of elemental phosphorus must provide air tight segregation from all oxidizing agents especially atmospheric oxygen. Elemental phosphorus spontaneously burns when exposed to the air (atmosphere). Elemental phosphorus is an acid-forming elemental material that readily combines with oxygen to create the oxide phosphorus pentoxide and phosphoric acid (P2O5). The phosphoric acid (P2O5) will readily combine with atmospheric water or ground water to create orthophosphoric acid (H3PO4). The acidic reaction created by combining elemental phosphorus and water can have adverse effects on groundwater chemistry (Farm Chemical Handbook, 1991).
Appendix B: (Continued)

Industrial Applications

Elemental phosphorus is used in the creation of carbonated drinks and numerous cleaning compounds. The computer industry utilizes large quantities of elemental phosphorus in the production of semi-conductors and integrated circuitry. Elemental phosphorus continues to be used in large scale applications by the military industry as an incendiary agent or as an explosion igniter for munitions. Elemental phosphorus is commonly found as a constituent in hand grenades, mortar and artillery round where it functions as an initiator. Elemental phosphorus has been the mainstay component in incendiary bombs since 1862 and smoke bombs since World War-I. When elemental phosphorus is discharged in the field it will burn under normal atmospheric conditions at 400 degrees C or 752 degrees F. The 752 degree F temperature is sufficient to weaken the structural integrity of poured concrete. The high burning temperature can rapidly heat combustible materials and this quality is exploited as an incendiary material. When exposed to atmospheric conditions elemental phosphorus ignites spontaneously and is rapidly oxidized into a thick cloud of phosphorus pentoxide gas and phosphine gas. The elemental phosphorus will continue to spontaneously oxidize until the phosphorus is consumed or when the oxygen source has been depleted. Oxidizing elemental phosphorus creates a brilliant yellow flame and produces a dense white smoke that contains toxic phosphorus pentoxide and fluorine. When humans are burned by elemental phosphorus medical staff will attempt to access the burned tissue under water and in darkened conditions so that the phosphorescent compound can be found and surgically removed from the victim (CBRNE-Incendiary Agents, 2002).
Appendix B: (Continued)

The international military establishment has also created a very large demand for the explosive and incendiary qualities of white phosphorus. The military application for elemental phosphorus was first employed as a strategic weapon during the American Civil War. During the early phases of the American Civil War the Confederate States of America spy network attempted to incinerate several iconic New York City buildings by covertly placing wet phosphorus soaked sheets of paper in large buildings throughout the cultural capital of the North. As the inconspicuous sheets of paper dried they burst into a spontaneous self-feeding 752 degree F fire source that resulted in several structural fires of targeted wooden buildings. This particular use of elemental phosphorus was the leading edge of technology in the 1860s. (PBS Television, 2002)

The incendiary qualities of elemental phosphorus were well understood prior to the American Civil War. There have been numerous refinements and military exploitations of elemental phosphorus as a strategic weapon. The means to disperse elemental phosphorus on the battlefield was fully exploited during World War II when major cities such as: London, England; Coventry, England; Dresden, Germany and Tokyo, Japan were systematically burned from an aerial assault of elemental phosphorus containing incendiary bombs. In larger fire bombing campaigns heavy explosives can dropped onto the burning phosphorus in order to add a turbulent mixture of oxygen to the existing fire storm to further enhance the pyro-genic quality of elemental phosphorus (Wikipedia, 2006).

The Korean War saw the first large-scale use of phosphorus bombs and napalm bombs used in conjunction. During the Vietnam War field campaign (1962-1975)
elemental phosphorus and napalm were again used extensively to bomb Viet Cong military positions that were cloaked under dense tropical vegetation. In 2003, the United States military continued the use of elemental phosphorus in artillery and mortar rounds to initiate the lethal explosive charge. Military assaults made in open landscapes frequently require concealment behind a dense smoke screen. The United States Army frequently utilizes elemental phosphorous smoke generating munitions to mask military assaults under a cloak of white smoke (GlobalSecurity.org, 2006).

Elemental phosphorus has been utilized as a component of high phosphorus fertilizers, rodenticides/rat poisons, insecticides, smoke screens, incendiary devices and analytical chemistry. During war time elemental phosphorus becomes a powerful tool of destruction and troop and ground forces disruption. During World War II elemental phosphorus was used in the Nazi fire bombing of London that destroyed large amounts of the urbanized city. During World War II allied forces retaliatory air strikes used massive quantities of white phosphorus incendiary bombs to incinerate large urban center targets such as Dresden, Germany and Tokyo, Japan. The following quotation expands on this point.

The United States bombing strategy of 1942-44 against Japan was expanded in a big way in March of 1945. This began with the fire bombing of Tokyo on March 9 and 10, 1945. The area of Tokyo selected was four miles by three miles, a zone with a civilian population density of 103,000 per square mile. A high concentration of incendiary (white phosphorus) bombs dropped from the huge U.S. B-29 Superfortresses ignited a series of fires, fanned by brisk winds, which raged out of control within half an hour, the result of which was more than 15 square miles of Tokyo was burned out. About 100,000 men, women and children were killed and another 100,000 were made homeless. According to the U.S. Army Air Forces:
Appendix B: (Continued)

No other air attack of the war (World War-II), either in Japan or Europe, was so destructive of life and property (Colhoum, 2001).

During the Vietnam War, American military utilized a combination of napalm and white phosphorus bombs as anti personnel weapons against Viet Cong ground troops in heavy jungles and open fields. The second and third degree burns of human flesh inflicted by elemental phosphorus are not always lethal. A sub-lethal burn exposes the targeted human subject to secondary infection. An injured soldier especially those with severe chemical burns require tremendous amounts of intensive medical care. The medical demands of burned soldiers place a major strain on the advancing or occupying armed forces and this consumes large numbers of potential soldiers who are relegated to transporting burned soldiers to field hospitals. Severe burns imparted by elemental phosphorus require very large amounts of blood material in order to support the transfusions that a burn victim will require if he or she is to likely to survive. Elemental phosphorus munitions are intended to burn or firebomb the opponents, in other words, to effectively produce widespread damage but not necessarily kill the enemy (Agency for the Toxic Substances and Disease Registry [ATSDR], 1997).

Elemental Phosphorus Production Techniques

At the present time large scale elemental phosphorus production can be created using either of two industrial methods. The industrial process that was utilized at the Victor/Stauffer production facility in Pinellas County, Florida and Garrison, Montana production facilities is known as the high temperature or process one method. The industrial preference since the 1980s is a process called the wet process or process two.
The following section provides a brief description of each process and the distinct differences of each.

High temperature reduction of phosphate ore was the preferred method of producing elemental phosphorus until the 1970s when energy costs reduced its profitability. The industrial reduction of phosphate ore is accomplished by the blending of adjuvant coke, silica sand with phosphate ore in an oxygen deprived high temperature (1,648 degrees C or 3,000 degrees F) electric arc furnace. The liberated phosphorus vapor product is driven off by hydraulic forces and condensed under a barrier of water. A clarification process removes impurities during the production phase. The Victor/Stauffer elemental phosphorus production facility utilized only the high temperature reduction method. Elemental phosphorus can also be created by reaction of phosphate rock with sulfuric acid. The residual calcium sulfate product is removed utilizing a filtration process. The concentrated phosphoric acid product is removed utilizing an evaporation process. The sulfuric acid reaction process is commonly known in the phosphate industry as the wet process. The more contemporary wet process is much less energy consumptive than the high temperature method. The more contemporary phosphate industry utilizes the wet process in order to reduce operational costs (The Condensed Chemical Dictionary, 1981).

Elemental phosphorus is highly reactive in atmospheric oxygen and requires special storage conditions so that spontaneous combustion is prevented. The complete deprivation of oxygen is required if the elemental phosphorus is to be stored safely. In order to reduce the potential combustion risk during storage elemental phosphorous is
Appendix B: (Continued)

usually retained under a deep pool or column of water so that it is shielded from all potential free oxygen. The accepted industrial standard is to store elemental phosphorus under a minimum of six foot depths of water. The six-foot pools of water are commonly constrained by either an earthen berm or dike system. The Victor/Stauffer used a lagoon system in order accommodate water depths of 72”. Another means to reduce reactivity can be accomplished by converting elemental phosphorus into a less reactive form called red phosphorus. Red phosphorus is a much more stable compound for shipping and storage purposes and it greatly reduces the risk of spontaneous combustion. The less reactive red phosphorus is created by heating elemental phosphorus to approximately 400 degrees Celsius or 777.6 degrees F under an atmosphere that is free of oxygen. Usually, an inert gas such as such as nitrogen or argon can be used as an inert medium in the process of converting elemental phosphorus into red phosphorus (ADF, Walsh EN, 1987).

Elemental Phosphorus Toxic Symptomatology

The earliest documented poisoning caused by elemental phosphorus in humans was associated with the use of matches, rodent poisons and fireworks. Elemental phosphorus was frequently ingested by accident when matchsticks were often sucked on or used as tooth picks. Chewing or sucking on these matches provided the opportunity for small amounts of elemental phosphorus to be ingested on a frequent basis. Elemental phosphorus intoxication from sucking on matches had become well documented as early as the 1830's. Other documented poisonings occurred in the American firecracker
Appendix B: (Continued)

manufacturing industry where dusty work areas allowed workers to become contaminated with the inhalation or ingestion of elemental phosphorus. Elemental phosphorus is able to displacing calcium in the blood stream with phosphorus. The loss of calcium can destabilize the heart rhythm and create weak pulmonary contractions. In clinical trials elemental phosphorus and peanut oil was feed to domestic female rats. The test resulted in a loss of appetite and retardation of weight gain in the rat subjects (EPA, 1993).

Elemental phosphorus is extremely poisonous in humans. Elemental phosphorus has been directly linked as a causal agent of the bone disease Osteomyelitis commonly referred to as phossy jaw. Phossy jaw is the chronic dental disease symptom that develops after absorbed phosphorus has displaced structural calcium jaw bone structure with abnormal phosphoric bone structure. Osteomyelitis is a systemic degenerative bone disease that can develop when frequent exposure levels of phosphorus gas enter the body through existing tooth cavities or structurally compromised fillings resulting in the necrosis of the lower mouth bone structure. The onset of phossy jaw commonly begins as a mild dental disturbance that evolves into a major dental infection eruption. If a suspect tooth is extracted the victim of who is suffering from phossy jaw will also be effected by the pressure of an infectious discharge. Following the extraction of the suspect tooth the patient will experience a failure of the empty tooth socket to heal properly. If there is a failure of the tooth socket to heal the attending dentist may choose to allow the infected bone material to separate and then remove it surgically. A dentist might choose to use this strategy in an attempt to conserve as much viable bone structure
The conservation of natural bone structure will help to avoid possible permanent facial disfigurement of the victim (International Labour Office, 1983).

The cause of Phossy-jaw disease initiation is not well understood. However, it is believed that small quantities of elemental phosphorus enter into the jawbone via dental cavities or leaking fillings. The elemental phosphorus reacts with the ambient mouth flora community and the oral flora reaction precipitates a general infection and the Phossy jaw disease commences as a pervasive bone necrosis (EPA, 2003).

**Lethal Dose: Oral/Dermal**

The lethal dose of test animals is typically determined by exposing a certain controlled population to a toxic dose that kills approximately 50% of the sample population. This particular method of determining toxicity to a given population is a clinically determined lethal dose to 50% of a population or what is known as an L.D.-50 dose. As a general rule female rats are used as the sample population and all results are extrapolated to the larger mass of humans. The human oral lethal dose/L.D.-50 of elemental phosphorus has been determined to be approximately 1mg/Kg of body weight. It has been determined that doses as small as 0.2mg/Kg of body weight may produce adverse effects in humans. The acute ingestion of elemental phosphorus poisoning of humans appears to have two distinct phases of progression. The initial phase of oral elemental phosphorus poisoning creates a quickly developing condition of severe gastrointestinal effects and pain to the victim. The initial symptoms of elemental phosphorus poisoning may include: nausea, belching with a strong odor of garlic and vomiting with a strong garlic smell. The initial
Appendix B: (Continued)

stage of elemental phosphorus poisoning may occur within 30 minutes after the ingestion event has occurred. Death from cardiovascular collapse is possible within a 12-hour period. A period of symptom subsidence and apparent recovery lasting about 48 hours frequently occurs. The secondary phase of elemental phosphorus oral poisoning is characterized by the return of the gastrointestinal pain. Elemental phosphorus poisoning symptoms can also include cardiovascular function interference and kidney disorders. A high cardiac pulse rate and low blood pressure along with jaundice are also a strong collection of diagnostic symptoms. In both phases of elemental phosphorus poisoning smoking, luminescence, and garlic odor feces and vomit are characteristic. The fatty tissues of the body appear to preferentially accumulate elemental phosphorus prior to other tissues. It appears that the catastrophic degradation of the fatty tissues comprising the liver and kidneys is the most common causal reason for death following the ingestion of a lethal dose of elemental phosphorus (Clayton and Clayton, 1993-1994). The combustion of elemental phosphorus causes second and third degree burns on skin contact and may also cause systemic symptoms similar to those listed in the previous paragraph from dermal absorption at the burn site. The elemental phosphorus compound is highly toxic to humans as it is readily absorbed by the fatty tissues. The acute fatal oral dose of elemental phosphorus in an adult human ranges: from (15 to 100mg) or an LD50 rate of (1mg/Kg of body weight). Records indicate that humans have survived ingestions of elemental phosphorus exceeding 1 gram. Based on the oral dosage rate of (15 to 100mg) the fatality rate for humans varies between (20% and 50%). The prognosis
for survival is good if an affected patient survives 6 days after the ingestion event has occurred (Ellenhorn, M.J. and D.G. Barceloux, 1988).

Elemental phosphorus can be summarized as an anthropogenic chemical that has been exploited for numerous industrial applications. Elemental phosphorus is a chemical that requires large-scale chemical production in order to create scale of economy returns on the initial production investment. The final product of elemental phosphorus production is the building block for numerous agricultural, industrial and military applications under the current economic paradigm. Until the late 1970s when energy costs escalated the production of elemental phosphorus was most often carried out in large manufacturing facilities that are dominated by very high temperature electric-arc furnace facilities that liberated large quantities of synthetic pollutants. However, there are many other potential issues that may adversely affect the human and biologic community that is located in the vicinity of an elemental phosphorus manufacturing facility. The complete chemical inventory of all the synergistic by-products of elemental phosphorus production is still not fully understood. The incomplete understanding of chemical synergy has left the public and the biologic community at risk.