

**HISTORICAL USE OF LEAD ARSENATE AND SURVEY OF SOIL RESIDUES
IN FORMER APPLE ORCHARDS IN VIRGINIA**

by

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Abstract

Inorganic pesticides including natural chemicals such as arsenic, copper, lead, and sulfur have been used extensively to control pests in agriculture. Lead arsenate (PbHAsO_4) was first used in apple orchards in the late 1890's to combat the codling moth, *Cydia pomonella* (Linnaeus). The affordable and persistent pesticide was applied in ever increasing amounts for the next half century. The persistence in the environment in addition to the heavy applications during the early 1900's may have led to many of the current and former orchards in this country being contaminated. In this study, soil samples were taken from several apple orchards across the state, ranging from Southwest to Northern Virginia and were analyzed for arsenic and lead. Based on naturally occurring background levels and standards set by other states, two orchards sampled in this study were found to have very high levels of arsenic and lead in the soil, Snead Farm and Mint Spring Recreational Park. Average arsenic levels at Mint Spring Recreational Park and Snead Farm were found to be **65.2 ppm** and **107.6 ppm**, respectively. Average lead levels were found to be **354.5 ppm** and **442.3 ppm**, respectively. Based on these results, Virginia needs to look at setting standards for lead and arsenic in soil to determine if cleanup of former agricultural lands will be necessary.

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Introduction

In the late 1800's inorganic pesticides were used extensively to control pests in agriculture. These natural chemicals, including arsenic, copper, lead, and sulfur, were mixed into varying formulations and were quite effective in controlling the damage caused by pests to meet the increasing standard of quality imposed by the consumer. Newly emerging pests and multiplying labor costs led to an increased use of pesticides by growers.

Lead arsenate (PbHAsO_4) was first used in apple orchards in the 1890's to combat the codling moth, *Cydia pomonella* (Linnaeus), a destructive insect of apples. This inorganic pesticide was very popular among farmers due to its immediate effectiveness. It was also inexpensive, easy to mix and very persistent. Over the next six decades, lead arsenate was sprayed in ever increasing amounts to control apple pests in multiple applications per season. This increase in use eventually resulted in pesticide resistance, which decreased its efficacy and required growers to increase rates and applications (Frear and Worthley, 1935) to compensate for a loss in efficacy. This loss in efficacy resulted in growers eventually switching to more viable alternate methods of treatment, such as DDT. The characteristics of the compounds that created this persistence, namely the basic nature of the elements in the pesticide, and the increase in use and rates are the key factors contributing to the contamination of thousands of acres of land across Virginia and the United States.

Apple production in the late 19th and early 20th century was very widespread. This high production reflected a localized agricultural market and lower production of fruit per acre. This was a drastic difference to today's world market and higher production, which has reduced acreages in Virginia alone to less than 18,650 acres (bearing and non-bearing) (Tuckey et al., 2000) [15,000 acres in 2002 – based on Virginia Agricultural Statistics Service (VASS) data]. Today, the total number of commercial apple growers in Virginia (2005) is about 250 (15,000 nationally). Yields of apples in Virginia were often measured in bushels. In 1914, there were 15 million bushels of apples harvested in Virginia (Fig. 1), and that was the high for the years 1906-1925 (Mattice, 1927). There

were 300 million pounds of apples harvested in Virginia in 2004 [(7,143,000 bushels @ 42 lb/bushel), Virginia Agricultural Statistical Bulletin, 2005].



Fig. 1. Orchard workers harvesting apples with horses and wagons. – Virginia Tech Digital Archives, Newman Library (date unknown).

As an increasing post World War II population began migrating out of urban areas into the American rural landscape, farmland was developed into subdivisions. Economic trends caused dramatic changes in agricultural practices. Foreign trade globalized farming and shut down many small farms. Farms could not compete with modern technical and manufacturing jobs that paid higher wages in rural areas. Farms were sold off as land values increased in parallel with the decreasing ability of common farmers to maintain a profitable enterprise. Today, housing developments occupy the land where productive apple orchards of seventy-five years ago once stood (Fig 2). This continues to be an ongoing problem that affects modern landuse in our communities.



Fig. 2. Subdivisions in Staunton, VA (left) and in Waynesboro, VA (right) built in former apple orchards.

As more homeowners become aware of historical pesticide use and its persistence in the environment, the questions that arise are these:

- 1. What are the potential risks for families living on these former agriculture lands?*
- 2. What are the potential risks for domestic animals, livestock, or wildlife?*
- 3. Is lead arsenate, once used as a pesticide, found in the soil at high enough levels to warrant concern?*
- 4. Can these chemicals move off-site and pose a hazard elsewhere?*
- 5. How do people who live on these lands deal with the issue?*

Throughout the country many states have recognized this potential problem and have set state-specific standards for arsenic and lead residues, in soil and in drinking water. The Environmental Protection Agency (EPA) has also set national standards for arsenic and lead in drinking water and for lead in bare soil. However, Virginia has yet to set standards for these elements in soil leaving property owners with many questions regarding the future use of their land.

This thesis will examine the scope of the issue in the Commonwealth of Virginia. Samples were taken from across the state to determine the levels of lead arsenate still present in the soil. Secondly, this thesis will develop conclusions regarding the

seriousness of the risk posed by the level of lead arsenate still present in the soil of our communities by comparing lead and arsenic levels found in Virginia apple orchard soils to standards set by other states and the EPA.

For this study, soil samples were taken from many apple orchards across the state, ranging from Southwest Virginia to Northern Virginia. However, due to real estate disclosure laws almost all of the samples analyzed for lead and arsenic for this study were taken from former commercial orchard sites now located on public land. Because Virginia has no set soil standards for arsenic and lead, results from this study were compared to standards set by other states and the EPA to determine the potential contamination levels in Virginia.

The first step of this process was to examine previous research completed on this subject and its relevance to this study.

Literature Review

During the Industrial Revolution, the nation's population grew and families migrated from rural settings to cities to secure steady employment. This population shift caused a greater demand for produce and goods, increasing production of these products. The standards for produce also increased with variety. Production of foodstuffs in the U.S. was forever altered. Many small sustenance farms suddenly grew into large commercial producers. Apple production, for example, grew from small acre plots to orchards often hundreds of acres in size. With this increased acreage came an exponential jump in pest populations. Growers were suddenly faced with challenges of newly emerging pests and increasing labor costs for control of those pests. These factors together led to an increased use of pesticides.

Inorganic pesticides, such as arsenic, copper, lead, and sulfur, have been mixed into various formulations for hundreds of years and were quite effective in controlling diseases and pests. These chemicals, most popular for use in agriculture from the mid-1800s to the mid-1900s, tend to be stable in the environment and are soluble in water. Sulfur, one of the oldest pesticides, is quite effective in controlling mites of all species and is quite useful as a fungicide against powdery mildew. Bordeaux mixture was a combination of copper and lime and was accidentally discovered in 1885 as a fungicide when a French farmer applied it to his grapes to keep children from eating them. Copper arsenate (copper acetoarsenite), famously known as Paris green, was green because of its copper content and was the first commonly used arsenical according to Ware and Whitacre (2004). It was an effective insecticide in the 1860's against the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), and the codling moth, *C. pomonella*, in the 1870's. London purple, a mixture of arsenic, lime, and acids, was another successful insecticide and was also used to control Colorado potato beetle in the late 1800's. Calcium arsenate was a heavily used arsenical in the early- to mid-1900's. Used mainly in the south and southeast United States to control grasshoppers and the boll weevil, *Anthonomus grandis grandis* (Boheman), in cotton, it was also used as a general insecticide on a variety of vegetable crops (Murphy and Aucott, 1998).

Arsenicals are considered stomach poisons. They only exert their toxic effects once ingested by insect pests and have a very complex mode of action. First, they uncouple oxidative phosphorylation by substitution of the arsenate ion for phosphorous, which is an important energy-producing step of cells. Next, the arsenate ion inhibits certain enzymes that contain sulfhydryl groups. And finally, both the arsenite and arsenate ions coagulate protein by causing the shape or configuration of proteins to change (Ware and Whitacre, 2004). Of course, the most heavily used arsenical throughout the country and worldwide was lead arsenate.

Lead arsenate

Lead arsenate, $PbHAsO_4$, was first used in 1892 as an insecticidal spray against the gypsy moth, *Lymantria dispar* (Linnaeus), in Massachusetts. It replaced Paris green because of the phytotoxic effects Paris green had on the foliage of trees when used at a high rates. When lead arsenate was used as a foliar spray (Fig. 3), it adhered to the surface of the plant well, allowing the pesticidal effects to last a long time (Peryea, 1998). Due to this persistence, lead arsenate quickly became one of the most commonly used insecticides in fruit tree orchards and one of the earliest insecticides used against major pests, like the codling moth. The codling moth, *C. pomonella*, is a very destructive insect to apples. Damage occurs to the fruit when the larvae tunnel into the sides and calyx end of the apple all the way to the core. This damage greatly lowers the storage quality and market value of the fruit leading to a loss in yield (Hull et al., 2002). According to the American Pomological Society (1976), without treatment the codling moth would regularly damage 20% -95% of the apples in every orchard.



Fig. 3. Apple trees being sprayed with lead arsenate at Blandy Experimental Farms (Boyce, VA) – 1920s – Blandy Farm Archives.

Initially, farmers on site mixed lead arsenate (Fig. 4) by reacting soluble lead salts with sodium arsenate, however lead arsenate was also sold commercially as powders and pastes.



Fig. 4. A former pesticide-mixing site and shed in Mint Spring Recreational Park (Crozet, VA) – 2002.

The formulations became more refined over time and eventually two principal forms emerged; basic lead arsenate, $Pb_5OH(AsO_4)$, (Fig. 5) was used in certain areas in

California and acid lead arsenate, PbHAsO_4 , was used in all other locations (Peryea, 1998).

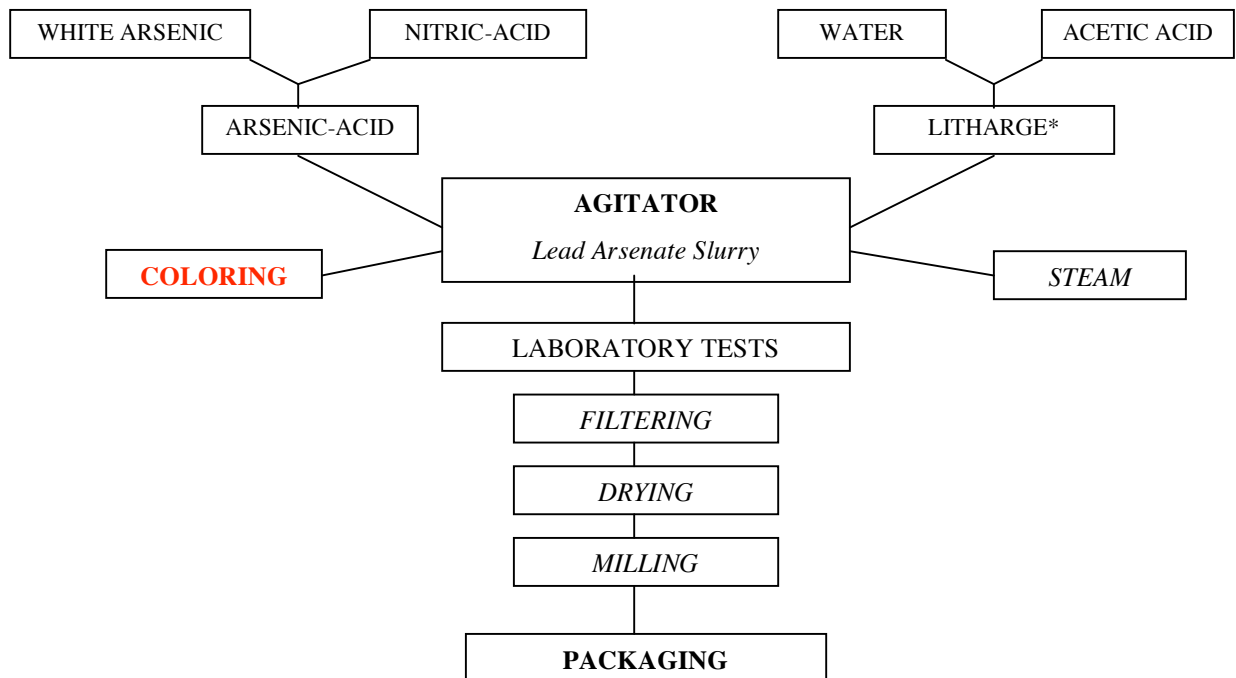


Fig. 5. Diagram showing the process of making lead arsenate. This diagram was redrawn from the textbook “Spray Chemicals and Application Equipment” by McClintock and Fisher originally published in 1945. *Litharge is a yellow lead oxide, PbO , also called lead monoxide.

Virginia, at one point, played an important role in mining arsenic and lead and was a leading source for the mid-Atlantic region of the United States. Briton Arsenic Mine is located in Floyd County, in Southwest Virginia and began mining in 1903 until it closed the operation after World War I in 1919 (Chaffin, 2003). According to Chaffin (2003), this operation also converted the arsenopyrite (FeAsS) to white arsenic (As_2O_3) on site and then shipped to various pesticide manufacturers. Lead was mined in Wythe County, Virginia and had a deep history during the Revolutionary and Civil Wars until it closed in the early 1980s.

Due to the great success of controlling the codling moth in apples, lead arsenate became the primary insecticide used in apple orchards. According to Marlatt (1904), in the United States Department of Agriculture (USDA) Agriculture Statistics yearbook, it was stated, “essentially all commercial apple orchards were treated with arsenic”. Several

sprays of lead arsenate, at a rate of two to four pounds per 100 gallons of water, were applied to the apples during a season. This generally occurred one to three times a season and gradually increased to five to six times a season. According to Murphy and Aucott (1998) the USDA's Agricultural Statistics yearbooks state that in 1929 the U.S. consumption rate of lead arsenate was 29.1 million pounds, peaking in 1944 with an estimated 86.4 million pounds and then declining to only 3.9 million pounds by 1973. From the peak usage in the 1940's until the 1970's, lead arsenate use declined because more effective pesticides became available, however, it was still used extensively and the application rates and amounts continued to increase. The exorbitant amount is documented in the 1966 Agriculture handbook (USDA, 1966), which suggested that to control codling moth in apples a grower should use three pounds of active ingredient per 100 gallons or 30 pounds of active ingredient per acre. By the end of the 1930's other pests became major problems for crops that were no longer susceptible to these high doses of lead arsenate. A search began for alternatives to lead arsenate, however, the substitutes were found to be less effective in insect control or were more toxic to plants and animals.

With the heavy use of lead arsenate well documented, researchers across the country began to look at the spray residues on the fruit. According to Shepard (1939), it was discovered that in 1919, common washing practices were failing to adequately remove arsenic residues from produce. A study conducted by the Virginia Agricultural Experiment Station (Hough et al., 1931) concluded that three sprays of lead arsenate applied in May and June did not require removal of spray residue at the time of harvest. However, when a third or fourth spray of lead arsenate was applied in the month of July followed by dry weather, excessive residues remained on the apples at harvest. According to Hough et al. (1931), wiping or brushing the apples only removed approximately one-third of the total arsenical residues while washing fruit in a diluted hydrochloric acid solution consistently removed excessive residues (approximately 70 percent) (see final rinse in Fig. 6). According to Frear and Worthley (1935), the smaller apples from the lower limbs of the trees usually carried the greatest amount of spray residue and were collected for their study. A hydrochloric acid bath (various strengths)

in a flotation washer was successful in removing only 70 percent of lead and 75 percent of arsenic residues from the apples. Adding wetting or foaming agents to the bath did not show any significant removal of residues. However, increasing the temperature of the bath increased the removal to approximately 80 percent of lead and 85 percent of arsenic. The variety of apples also played an important factor in the ease of the residue removal. When lead arsenate was later used in an oil-spray program, it was necessary to remove the spray residue with a two-unit (tandem) type washer (Walker, 1949). The fruit were put through the first unit containing 40 to 60 pounds of sodium silicate per 100 gallons of water at 90 to 100°F. Then the fruit went through the second unit containing 1.5 percent hydrochloric acid at 90 to 100°F. Finally, the apples were then rinsed with copious amounts of fresh water. Of course, the removal of residues from the surface of an apple is affected by many factors, including temperature, humidity, wind speed, rainfall and the chemical makeup of the spray mixture (Frear and Worthley, 1935).

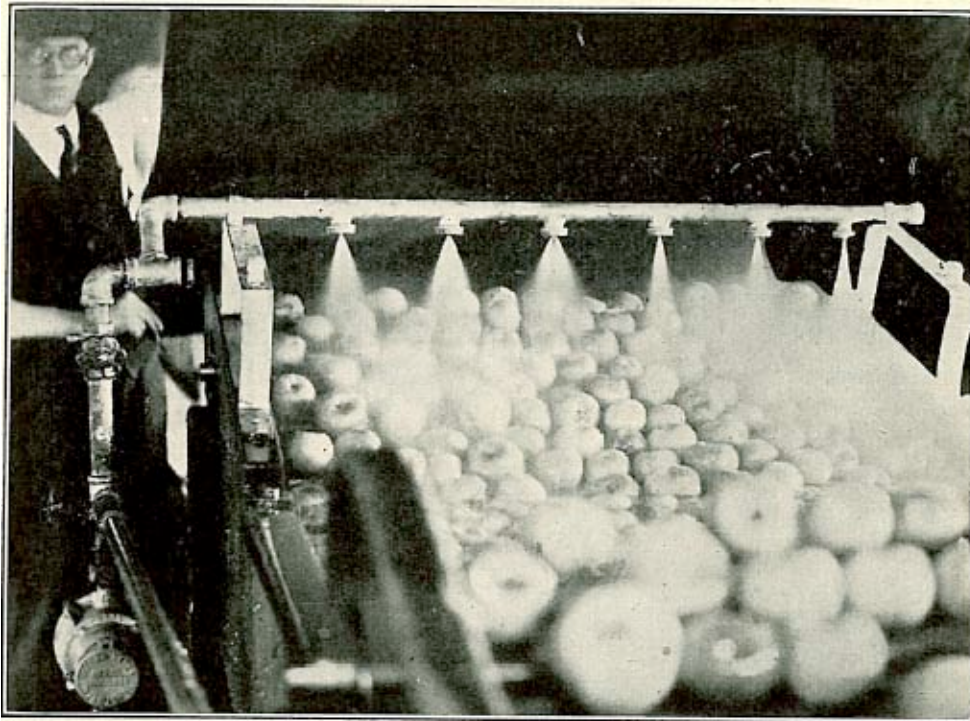


Fig. 6. Apples going through a final fresh water rinse through spray nozzles after an acid bath. – (Hough et al., 1931).

Finally, a revolutionary break-through occurred for pest control in 1947 that would change pest management and the environment forever, the synthetic organic insecticide DDT. With the introduction of DDT, the use of inorganic insecticides began to decline soon after, as these synthetic insecticides were more effective against pests. The codling moth had already developed a resistance to the arsenical compounds and DDT became a much more effective control agent. On August 1, 1988 all insecticidal uses of lead arsenate in the United States were officially banned and registration was cancelled by the EPA (USEPA, 1988).

Soil Residues

The heavy use of lead arsenate in apple orchards during those many decades may have contributed to major problems in the environment, including the build-up of arsenic (As) and lead (Pb) in the soil. Naturally occurring arsenic and lead are quite stable and do not break down in the environment, accumulating with each use over time in orchard soils. Depending on soil type, both elements, particularly lead, tend to linger in the top 5-20 cm of the soil. Leaching of arsenic has occurred below the 20 cm level (Veneman et al., 1983). If given the right soil conditions (pH, mineralogy, and precipitation), arsenic has been found to leach farther into the ground (Peryea and Creger, 1994 and Warner, 1996), and possibly contaminate groundwater.

Farmers and homeowners that are using old orchard sites for crop production or gardening have to be aware of soil residues. It has been documented that crops planted in contaminated soils can uptake heavy metals (Kenyon et al, 1979; Levander et al., 1977; Merry et al, 1986). The amount of lead taken up by the plants is proportional to the amount applied to the soil (Kenyon et al, 1978), however, most plants would not hyperaccumulate either arsenic or lead. Crops that include carrots, turnips, and peanuts can be very sensitive to certain metals and this can lead to phytotoxicity (Alloway, 1990). Food crops that are more tolerant to the toxicity of these metals are more dangerous because they will not show signs of toxicity and could be harvested. This could affect the health of people or livestock that consume these foods.

When lead arsenate-contaminated soil is amended with a fertilizer containing phosphate, the fertilizer can enhance the release of adsorbed arsenic to the solution phase by competing for adsorption sites, thereby increasing solubility, mobility, and phytoavailability (Peryea, 1998). This makes arsenic more available for plants or trees to uptake and could affect plant growth or food safety. There is also the possibility of arsenic moving off-site by sediment run-off or through ground water if soils are very sandy (Peryea and Kammereck, 1998).

The Association for the Environmental Health of Soils (1998) conducted a survey “Study of State Soil Arsenic Regulations” and submitted it to all 50 states. The objective of the study was to determine how arsenic in soil is regulated nationally. Questions were asked to help define how soil screening thresholds and remedial action levels are established and how risk assessment is used in the process. A total of 34 states responded to the survey. According to the study when asked whether the states had specific cleanup levels for soil arsenic, 21 of the 34 replied yes and 11 replied no. Background levels, site-specific levels and risk-based levels were the main reasons mentioned as rationale as to where to set the cleanup levels for individual states. It was noted that Virginia did not respond to this study.

Health Risks

In November 2005, the U.S. Environmental Protection Agency (under authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)) released its biannual list of Hazardous Substances. The top two substances on the list for the last 10 years have been arsenic and lead. These substances are most commonly found at sites on the National Priorities List (NPL) and are determined to pose the most significant potential threat to human health due to their known or suspected toxicity and potential for human exposure at these NPL sites.

Listed number one on the EPA’s Hazardous Substances List is arsenic. Arsenic is a natural element found in both the earth’s crust and in water. Arsenic is also found in plants, which absorb lead and arsenic through their roots, and animals that consume these

plants and drink contaminated water. In 1977, the FDA found that small amounts of arsenic were consumed by people daily in food (Levander et al., 1977). According to Peryea (1999) arsenic is released into the environment through ore smelting, cement manufacturing, and the combustion of fossil fuels in electrical power plants that can settle into nearby soil. Arsenic can also leach from lumber that has been treated with chromated copper arsenate (CCA), which can increase soil arsenic levels near the site where the wood is in contact with the soil (Stilwell, 2005). Effective December 31, 2003, no wood manufacturers may treat wood with CCA for residential uses (around homes and children's play areas). The EPA and the Consumer Product Safety Commission (CPSC) are currently conducting a study on the effectiveness of sealants in preventing leaching of arsenic from CCA-treated wood (USEPA, 2005).

Short term, or acute arsenic poisoning can appear very quickly, usually within an hour if ingested orally or if there is exposure to very high levels not normally found in the environment. Symptoms that may appear first are difficulty in swallowing or burning lips followed by excruciating abdominal pain, forceful vomiting, diarrhea, thirst, and cramps in the legs. This eventually can lead to spasms, shock, paralysis, coma and death. In a few cases of acute arsenic poisoning "Mees lines" may appear. Mees lines are transverse white bands on the nails. Arsenic can be extremely toxic for acute exposure and it is estimated that a minimal lethal dose for humans is 50-300 milligrams (mg). (ATSDR, 2000).

Chronic, or long-term exposure, can lead to either non-cancerous health effects or carcinogenic effects. Non-cancerous symptoms of chronic arsenic exposure include numbness, tingling or burning sensations in the extremities (a sensation of "pins and needles"), hair loss, weakness, loss of appetite, nausea or vomiting. Over a long period of time damage to the central nervous system and liver and kidneys may occur. One of the most common characteristics of chronic arsenic exposure is the appearance of skin disorders including small corns or warts on the palms, soles of the feet (Fig. 7) and torso, thickening of the skin and darkening pigmentation on the neck, eyelids, nipples and underarms. These corns or warts may ultimately develop into non-melanoma forms of

skin cancer. Research has shown that populations exposed to arsenic in drinking water have a higher risk of developing liver, kidney, lung, bladder and prostate cancer (ATSDR, 2000).



Fig. 7. Cancerous lesion on hand (left) and nodular hyperkeratosis on feet (right) caused by chronic exposure to natural arsenic in groundwater in Bangladesh (Wilson, 2000 and Chowdhury et al, 2000).

The EPA calculated the lifelong ingestion of 0.05-0.1 mg/kg/day associated with a risk of skin cancer (ATSDR, 2005). Arsenic ingestion (oral, dermal, or inhalation) has also been reported to increase the risk of cancer throughout the body, specifically in the liver, kidneys, bladder, and lungs. Also, humans that have long-term exposure to high levels of airborne arsenic in or around smelters have greater risks for developing lung cancer (ATSDR, 1989). The federal government has established a Maximum Contaminant Level (MCL) of 10 parts per billion (ppb) for arsenic in drinking water (ATSDR, 2001) and OSHA has established a maximum permissible airborne exposure limit of 10 $\mu\text{g}/\text{m}^3$ for inorganic arsenic (ATSDR, 2001). However, no federal safety levels have been established for arsenic in soils. Arsenic is found in organic and inorganic forms. Inorganic arsenic may be present in two forms, arsenate, AsO_4 , (As V = pentavalent) and arsenite, AsO_2 (As III = trivalent). The trivalent form of arsenic is more toxic than the pentavalent form and is believed that the pentavalent form exerts a toxic action only after conversion to the trivalent form (Rybolt, 1970).

Listed number two on EPA's Hazardous Substances List, lead is also naturally occurring and can be found in all parts of our environment (Hammond et al., 1972). Not only was lead used in insecticides, it was also used in gasoline until 1995 (Peryea, 1999) and paints until it was banned from home use in 1978. Lead dust is released by smelters and mines that can contaminate nearby soil. It can also be found in everyday items like pottery glazes, lead shot, and fishing weights and can leach from improperly glazed ceramic-ware and leaded crystal. However, because of health concerns its uses have been reduced or eliminated altogether (ATSDR, 1993). The main sources of high lead contamination in soils originate from four sources: paint, gasoline, insecticides, and industrial fallout (Peryea, 1999).

Lead can affect almost every organ and system in the human body. The effects are the same whether swallowed or inhaled. The most sensitive system is the central nervous system. Lead can cause neurological problems, especially in children (Hammond et al., 1972). If exposed to high levels of lead, it can lead to premature births, decreased mental capacity, learning difficulties, and reduced growth in young children. Unborn children can also be exposed to lead through their mothers (ATSDR, 1993). In adults, lead exposure primarily affects the peripheral nervous system. First symptoms include loss of appetite, fatigue, anemia and abdominal pain (ATSDR, 1999). Eventually, vision, hearing, and muscle coordination may be impaired. The EPA requires lead in air to not exceed 1.5 ug/m^3 and limits lead in drinking water to 15 ug/L . The EPA considers lead a hazard if lead exceeds 400 parts per million (ppm) in bare soil in children's play areas.

In old orchards treated with lead arsenate, it was found that rodents (pine voles, meadow voles, and white-footed mice) inhabiting these soils had lead concentrations in kidney, liver, and bone tissues markedly higher than in tissues from control animals (Haschek et al., 1979). Lead accumulation correlated with the degree of substrate feeding and movement of the rodents. Predators, however, showed no increase in mortality by feeding on contaminated prey from lead-contaminated orchards (Stendell et al, 1989). Arsenic accumulation was not tested in the rodents.

Mortality of orchard workers in Washington State who were exposed to lead arsenate during a 1938 study was re-examined in 1990 to determine whether there was excess mortality that could be attributed to lead arsenate exposure. The study found that there was no significant elevated mortality for cancer among men or women from the original study (Tollestrup et al, 1995). However, the study could have been flawed by the low number of study subjects, the type of arsenical compound, the lower cumulative concentration of arsenic exposure, or the fact that no other diseases were studied among the subjects (Tollestrup et al, 1995).

The scope of the problem in Virginia

Lead arsenate was used, not only in apple orchards, but also on many crops in Virginia. It was very popular in other fruit orchards, such as cherry and peach. It was also extensively used in tobacco and cotton. This fact shows that lead arsenate was used in great abundance throughout the state. It is estimated that at some point between 1880 and 1950 the chemical was used to treat pests on most agricultural lands in Virginia.



Fig. 8. Panoramic view of a commercial apple orchard in bloom - Virginia Tech Digital Archives, Newman Library (date unknown).

The extent of the apple industry in Virginia in the 20th century is staggering. From surveys conducted by the Virginia Agricultural Statistical Survey (VASS) and the Virginia Agriculture Experiment Station, there were over 10,395,095 apple trees (8.1 million fruit bearing and 2.3 million non-bearing) in the state according to the Census of Agriculture (1925). The 10 million apple trees covered approximately 300,000 acres, depending on row and tree spacing. See the distribution map of apples in Virginia in 1925 (Fig. 9).

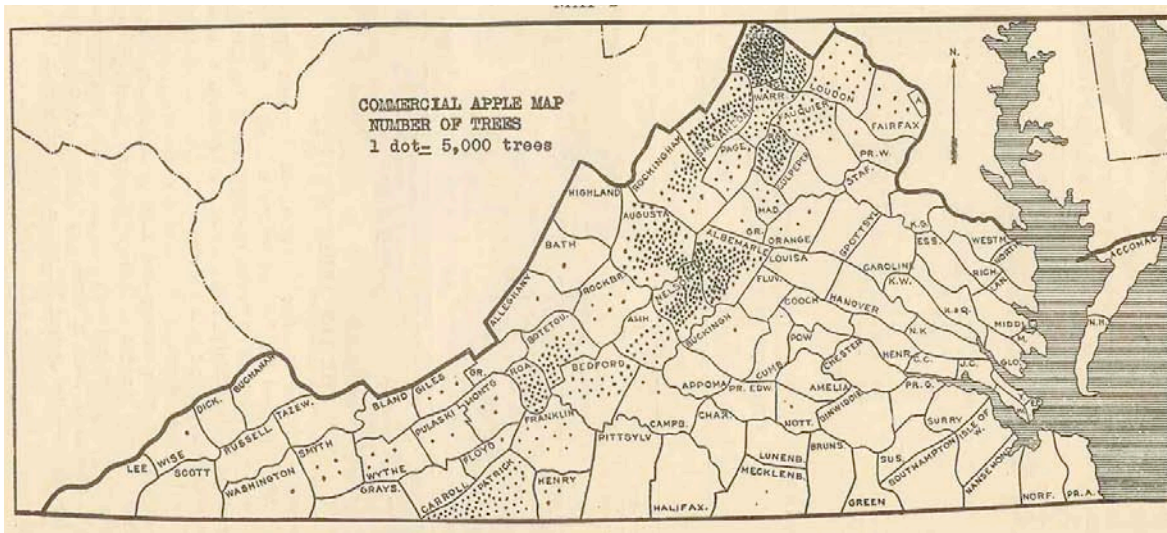


Fig. 9. Map showing distribution of commercial apple orchards in Virginia in 1925 (1 dot = 5,000 trees) – (Taylor, 1926).

According to the 1925 Census, 4.3 million apple trees were reported as commercial trees (Fig. 8) (43% of the total number of apple trees reported). Approximately 125,000 acres of orchards in Virginia were commercial growers, where lead arsenate would have been sprayed extensively to combat pests. The implication of the size of commercial orchard operation in the state is an astounding estimated 77,400 tons of lead arsenate applied in Virginia over a 20-year period (see Table 1 for calculation).

Table 1. An estimated total amount of lead arsenate (tons) applied over a 20-year period in Virginia’s commercial apple orchards.

Number of Trees	Trees/Acre	Acres	Gal./Tree	Pounds a.i./100 gallons	Loading /Tree	Loading /Acre	Loading /Year	Loading /Acre (20 Yrs)	Loading /VA (20 Yrs)	Loading (Tons)
4,300,000	35	122,857	10	3	0.3	10.5	63	1,260	154,800,000	77,400

There were 116,000 farms (62% of total farms in Virginia) that reported growing apples in the 1920 Census of Agriculture. Most of the non-commercial orchards sold apples locally, but could not ship due to poor quality. Likely, they were not sprayed at all or not sprayed intensely enough to control pests like the codling moth. So lead arsenate might have been used, but not at the number of applications or coverage of a commercial orchard.

The leading commercial apple orchard counties in Virginia were Albemarle, Clarke, Frederick, Nelson, and Warren. Winchester had the largest cold storage facility for apples in the United States and anchored the Virginia apple industry that was the third leading producing state in the country (Taylor, 1926). Staunton and Crozet were also major apple shipment centers.

The peach orchard industry in Virginia was growing during the same time period. Over 500,000 peach trees were grown in the 700 commercial peach orchards in Virginia in 1925 (Fig. 10).

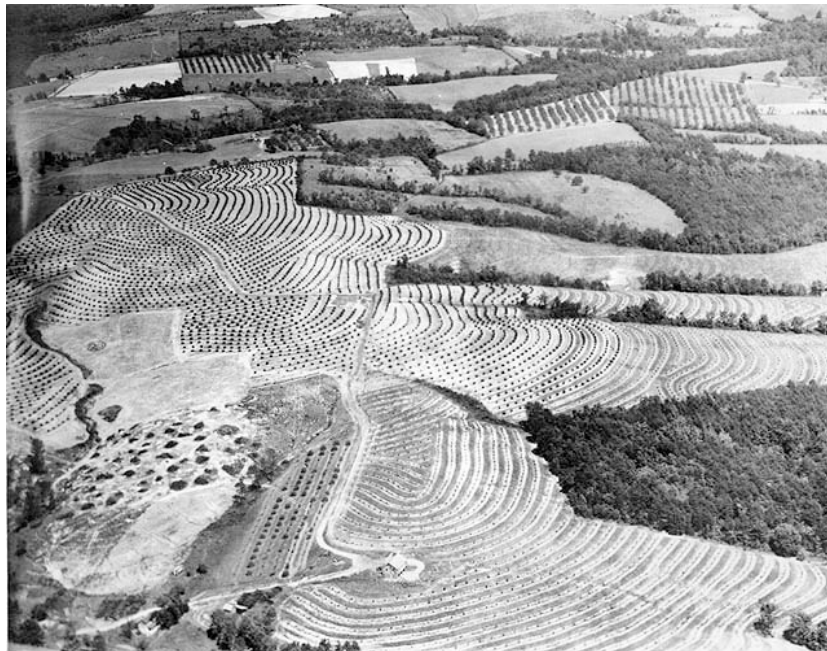


Fig. 10. A commercial peach orchard in Frederick County, VA - Virginia Tech Digital Archives, Newman Library.

Whereas the northern counties of the Shenandoah Valley were the center of the apple industry in Virginia, the peach orchards were centered around Albemarle County, specifically Crozet. The rail access in Crozet, coupled with the active Agriculture Research Station in the area created a hub for the peach industry in the state (Taylor, 1926). The map (Fig. 11) shows the distribution of peach orchards in the state in 1925.

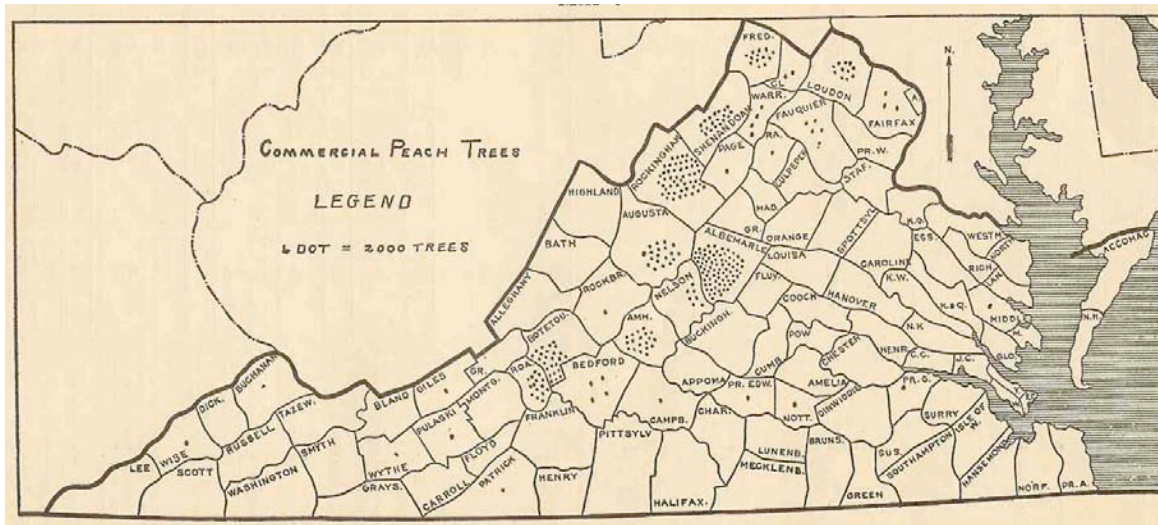


Fig. 11. Map showing distribution of commercial peach orchards in Virginia in 1925 (1 dot = 2,000 trees) – (Taylor, 1926).

Virginia's apple industry was an amazing infrastructure at one time but has been in a steady decline for many decades. Much of the decline can be attributed to poor tree maintenance and not replacing dead trees. Today the industry is weak and Virginia may one day see the end of fruit production in the Commonwealth. It is likely that the crops will always be grown here, but commercial operations are slowly being pushed out as land values continue to increase.

Land use patterns have also changed as more people moved from urban environments into the country. Commercial orchards were usually built close by to centrally located shipping hubs. Overtime, these former orchard sites increased in value because of their locality to towns or cities and became convenient sites for new homes. Building houses and subdivisions on former agricultural lands where pesticides were once heavily used has caused many homeowners to pose questions about soil residues and safety. Many

homeowners are finding themselves questioning the soil in their backyards and the public health threat to their drinking water and what can be done to reduce their potential risks of exposure to lead and arsenic.

This issue has been addressed in other states, however, no one in Virginia has investigated the potential problem. This project was initiated because Virginia Cooperative Extension had few answers for Virginians who had been contacting them for years seeking answers to their questions about the risks of lead and arsenic residues on their properties. Not only homeowners, but also realtors and developers had concerns regarding this issue. Many wanted to know what they were getting involved with when purchasing, buying, or selling a piece of property. This issue gained an even higher profile in 1999 when several clients called Virginia Tech in reference to a major soil residue problem in a North Carolina subdivision that was once an apple orchard. They were concerned that a similar situation could exist in Virginia.

Soil contamination in other states

North Carolina

At almost 500 acres, Barber Orchard was once a thriving commercial apple orchard located in mountainous Haywood County, three miles west of Waynesville, North Carolina. Production in the orchard began around 1908, but with a declining market, it was eventually sold by the Barber family in 1977. Several men purchased the property but tried and failed at the apple business due to foreign competition and a decline in demand in the 1980s. In 1988, the farm went bankrupt and was sold at auction to a developer and divided into parcels of nine to 40 acres. Residential housing was planned and many homes were built between 1993-1994, but most of the property remained undeveloped. By 1999, there were 90 homes built and about 200 undeveloped lots in the subdivision.

In January 1999, a local resident heard a rumor of birth defects in children born to women living in the former apple orchard. Based on the advice of a former orchard worker, a resident contacted the North Carolina Department of Environment and Natural

Resources (NCDENR) Division of Water Quality (DWQ) to test the well water for pesticide contamination. The NCDENR detected high levels of benzene hexachloride (BHC) and notified the Haywood County Health Department and the State toxicologist, Dr. Ken Rudo (North Carolina Department of Health and Human Services Press Release, June 1999). The State toxicologist recommended that the resident stop drinking the water and to drink bottled water instead. This recommendation initiated a large-scale sampling effort by the DWQ. Of the 88 wells sampled, 34 contained BHC concentrations above the State standard of 0.019 parts per billion (ppb). Soil sampling was also being conducted on 16 properties, at this time, by the North Carolina Department of Agriculture and Consumer Services. High concentrations of arsenic and lead were found that exceeded the State of North Carolina Inactive Hazardous Sites Program’s soil remediation goals (400 ppm for lead and 4.4 ppm for arsenic). These results were forwarded to EPA Region 4. More sampling was initiated in June of 1999. Of the 55 properties sampled, the EPA found arsenic soil concentrations above 40 parts per million (ppm) at 25 locations. Also, 21 wells sampled exceeded the EPA’s accepted levels for BHC. Other pesticides found in the ground water included endrin, endrin ketone, and endosulfan sulfate (ATSDR Public Health Assessment – Barber Orchard, 2002). Arsenic and lead were not detected in the ground water samples. Due to the potential health risks, the EPA initiated an emergency removal action at Barber Orchard in 1999. A removal is a short-term cleanup intended to stabilize or clean up a site that poses an imminent and substantial threat to human health or the environment. See Table 2 for the initial soil sampling results for arsenic and lead and the cleanup levels for the site.

Table 2. Arsenic and Lead Soil Concentrations and Cleanup Levels at Barber Orchard**

Contaminant	Concentration Range (ppm)	Frequency of Detection/Total	EPA Region 4 Emergency Response Level (ppm)	EPA Remedial Level (ppm)	NC Soil Remediation Goal (ppm)
Arsenic	*ND – 1,340	210/273	40	20	4.4
Lead	*ND – 3,090	273/273	400	400	400

*ND = not detected

**Washington State Area-wide Soil Contamination Task Force Final Report - Institutional Frameworks Case Study – Barber Orchard, 2003.

Emergency cleanup of 28 residential lots began in September 1999 and continued until August 2000. The cleanup involved soil excavation (Fig. 12) where arsenic levels exceeded the EPA's short-term exposure cleanup criteria. An estimated 31,500 tons of contaminated soil was removed from the lots and transported to EPA approved landfills in Buford, GA and Johnson City, TN. The lots were then replaced with clean fill and restoration of the properties was completed in August 2000. The total cost of the soil excavation is estimated to have cost \$4,000,000 (EPA Public Affairs Press Release, 2000) and was completed under the authority and direction of the Agency's Emergency Response and Removal Branch. The site was officially listed on the National Priorities List (NPL) on September 13, 2001.



Fig. 12. A bulldozer removes soil from a yard at Barber Orchard in Haywood County, North Carolina in 1999 – © 2000 Raleigh News & Observer. This process was part of the cleanup provided by the EPA during the emergency removal action in 1999-2000.

According to the EPA, it is suspected that the contamination occurred because of long-term pesticide application, spills, leaks and improper disposal of pesticides and pesticide containers. A central mixing area was identified in the former orchard that consisted of two 500-gallon concrete tanks. From the mixing area, pesticides were transported to other areas of the orchard with high-capacity pumps through an elaborate underground

pipeline system that was buried about one foot below the ground. Trees were then conveniently sprayed with pesticides throughout the orchard by connecting a hose and nozzle to the pipeline. Pipes reportedly would freeze, causing them to rupture and leak, during the winter months. During the initial sampling in 1999, pipes from the underground system were observed on the lots and in many areas were protruding from the ground. Sediment samples were collected from one of the leaky pipes and extremely high levels of arsenic (2,460 ppm) and lead (6,970 ppm) were discovered!

In 2001, the North Carolina Department of Environment and Natural Resources awarded Haywood County a \$1.5 million grant that will help pay to extend Waynesville's water line 3.5 miles to the Barber Orchard subdivision. The North Carolina Rural Economic Development also gave the county a grant of \$350,000 and Congress appropriated \$475,000 for the new water line. With the new \$2.3 million water line replacing contaminate wells, this should make the subdivision more attractive to buyers and property values are expected to rebound. According to a realtor for Coldwell Banker in Waynesville two houses were sold in the subdivision in 2001 just below the asking prices of \$270,900 and \$274,500 (McLeod, Smokey Mountain News: 2001). Waynesville real estate appraiser, Fred Spencer, said appraisers are still reluctant to estimate values for properties in the subdivision but local banks are lending money for purchases. The public water line was slated for completion in the summer of 2002, according to the Assistant Haywood County Manager, Rick Honeycutt. However, due to many hold-ups the project went on hold for three years. Construction began on the water line in May 2004 and was completed in 2005 for a total of \$3.5 million.

A public health assessment of Barber Orchard was released by the EPA on July 2, 2002. According to the Agency for Toxic Substances and Disease Registry (ATSDR), Barber Orchard is considered a "past public health hazard" and current exposures to site contaminants are not likely to result in adverse health effects. "The site currently poses no apparent public health hazard because people are no longer drinking untreated water and because the contaminated soils that small children could contact frequently have been cleaned up." However, the site could pose a problem in the future if undeveloped lots are

not characterized properly and remediated, if necessary, before new residential construction begins. In September 2004, EPA issued the Record of Decision (ROD), which explained that EPA intended to clean up the site by removing the contaminated soil, dispose of materials properly in off-site landfills, and once the cleanup is completed, building can begin. The grant provided by the EPA to build a new water line stipulated that property owners cannot build on the land until arsenic levels in the soil are below 40ppm (USEPA, 2006).

Professors and students from Western Carolina University (WCU) are currently conducting several research studies at Barber Orchard with funding from a \$100,000 gift from Blanton J. and Margaret S. Whitmire, a wealthy and influential family from Western North Carolina. With the expensive and disruptive nature of the bulldozing to remove the contaminated soil, WCU is reviewing other possible ways of remediating the soil in the undeveloped lots of the subdivision. Under field and greenhouse experiments WCU studied the use of corn, pea plants, Indian mustard (*Brassica juncea*) for phytoremediation of lead, and the brake fern, *Pteris vittata*, to draw out arsenic from the soil. A non-toxic chemical agent, EDTA, was applied first to “loosen” the metals from the surrounding sand and clay, making them more available to the plants (Quillin, RN&O 2000). Fern shoot arsenic concentrations were as high as 20 times the soil arsenic concentrations under field conditions (Salido et al, 2003). Results indicated that increasing soil pH may also improve arsenic removal. However, by increasing the pH of the soil this would reduce the removal of lead. It’s estimated to take eight years to reduce the soil arsenic to safe levels of 40 mg/kg or ppm. The EDTA was found to improve lead extraction (Salido et al., 2003). This process is cost-effective, but slower and could be a suitable alternative, especially for soils that do not require immediate remediation (Salido et al, 2003). However, it’s also important to realize that by adding EDTA to the soil to “loosen” the metals allows the lead to become more bioavailable and could possibly leach into the ground water or move off-site. A second study at WCU will research the possible uptake of lead and arsenic by garden vegetables and the safety to consumers.

Washington

Washington State has already prepared itself for the repercussion of using lead arsenate in orchards that at one time covered thousands of acres of land. In 1989, the Model Toxics Control Act (MTCA) was established to raise funds to clean up hazardous waste sites and prevent future contamination of the environment. Money is raised from a tax on toxic substances, and the Washington State Department of Ecology implements the regulations. It instructs the state Department of Ecology to introduce cleanup standards for sites contaminated by toxic substances, including lead, arsenic, and DDT (Warner, 1996). The MTCA was originally setup to focus on cleaning up the Puget Sound, but it has become apparent that thousands of acres of orchards will need to be cleaned up. The MTCA's cleanup action levels in soil are 22 ppm for arsenic, 250 ppm for lead, and 1ppm for DDT (Warner, 1996). Topsoil removal is the main step in action regarding remediation. Many Washington residents want to make changes to the MTCA that will cost less and speed up the remediation process. Members of the Citizens Advisory Committee for the MTCA think levels should be appropriate for the scope of the contamination and the climate and it may be necessary to establish different levels based on the particular climate and situation (Warner, 1996).

In 2002, the Washington State Departments of Agriculture, Ecology, and Health and the Office of Community Trade and Economic Development chartered a group comprised of 18 members, including representatives of local government, elected officials, agriculture, environment, business/development, financial institutions, and education/schools, known as the Area-Wide Soil Contamination Task Force. These members were asked to provide findings and recommendations to the Agencies on steps that can be taken to better address area-wide soil contamination problems. Area-wide soil contamination is low-level contamination that is dispersed over a large geographical area, ranging in size from several hundred acres to many square miles (Washington State Area-Wide Soil Contamination Project Overview, 2002). Due to historical activities, like pesticide use, many areas of Washington State have low-to-moderate levels of arsenic and lead. In general, arsenic levels up to 100 parts per million (ppm) and lead levels between 500-700 ppm are considered "low-to-moderate" levels. The levels of arsenic and lead generally

associated with area-wide soil contamination are not high enough to trigger an emergency response action under the state cleanup regulations. However, there is concern that ongoing exposures to arsenic and lead, even at low levels, over a long period of time could lead to health problems for some people.

With population growth and changes in land use, many of these areas have been developed into schools, parks, and residential neighborhoods. It is estimated that 188,000 acres of orchard land (apple and pear) is potentially affected by the historical use of lead arsenate. The estimated total acreage in the state of Washington affected by soil contamination, including smelters and orchards, is 677,000 acres (Washington State Area-Wide Soil Contamination Task Force Report, 2003). Based on this information the Task Force started the Area-Wide Soil Contamination Project. The Project was a two-year effort to develop a multi-agency, statewide strategy to respond to area-wide soil contamination (Washington State Area-Wide Soil Contamination Project Overview, 2002). It was started because the Agencies realized that a lack of adequate knowledge about the size and location of area-wide contamination problems and possible solutions could not be solved by traditional contaminated soil cleanup approaches (i.e. MTCA).

New Jersey

Burlington Heights, located in Burlington Township in Burlington County, NJ, is a housing development located on a former orchard. Burlington County is historically one of New Jersey's leading agricultural counties and is located in south-central New Jersey. According to Murphy and Aucott (1998) the total amount of arsenic applied in Burlington County from 1900-1980 was approximately 2.0 million pounds. Soil was sampled in 1995 by a developer who wanted to develop the rest of the orchard. Arsenic levels were found that exceeded the New Jersey Department of Environmental Protection (NJDEP) soil cleanup criterion of 20 ppm. Based on the sampling results, the NJDEP realized that there might be historical pesticide contamination at existing residences. In 1996, NJDEP conducted emergency soil removal from existing residential yards at Burlington Heights. The emergency removal process, included sampling yards, removing contaminated soils, and replacing them with clean fill and sod. NJDEP paid

\$500,000 for public outreach, sampling, soil removal, and soil and sod replacement at Burlington Heights.

Due to the cleanup effort to remediate Burlington Heights the NJDEP was required to recommend strategies for addressing historical pesticide contamination throughout the state. The NJDEP formed the Historic Pesticide Contamination Task Force in 1997 to help the Department “identify technically and economically viable alternative strategies that will be protective of human health and the environment for sites with contamination due to historical use of pesticides.” (NJDEP, Historical Pesticide Contamination Task Force: Final Report, 1999) The Task Force made recommendations to assist those involved with properties, which may be contaminated due to the historical use of pesticides. Similar to the Task Force in Washington this Task Force is comprised of nine members representing several interest groups, including agriculture, environment, real estate development, banking, local government, and research institutions. Primary pesticides of concern include, arsenic, lead, DDT, and aldrin. These pesticides were selected based on several factors, including their extensive agricultural use for many years, their persistence in the environment, and the fact that they have been detected at elevated concentrations at various locations in New Jersey. Murphy and Aucott (1998) calculated cumulative lead and arsenic applied in the state of New Jersey from 1900-1950 based on the national consumption and crop recommendations as 48 to 200 million pounds in apples alone. For arsenic, the NJDEP set the cleanup criterion at 20 ppm and for lead the cleanup criterion was set at 400 ppm.

With all the media coverage of the Burlington Heights cleanup and the formation of the Task Force other townships began to look at their history and whether their township was possibly contaminated from historical pesticide use. Mount Laurel Township, also located in Burlington County, is another township that has discovered high arsenic in the soil due to naturally occurring arsenic and historical pesticide contamination from pesticide use. Mount Laurel was one of the first Townships to enact an ordinance requiring soil testing and cleanup of properties prior to new development, both residential and non-residential, in the Township. Testing and remediation requirements apply only

to properties that were formerly agriculture use or part of an orchard, instead of testing all proposed property for development (Washington State – Institutional Frameworks Case Studies: Mount Laurel Township, New Jersey, 2003).

Lending institutions in New Jersey have now adopted requirements for environmental site assessments as a condition for granting loans to develop agricultural properties due to the statewide attention of the formation of the Historic Pesticide Contamination Task Force. In fact, according to the New Jersey Bankers Association, some banks in New Jersey have chosen to no longer lend to farms (Washington State – Institutional Frameworks Case Studies: Mount Laurel Township, New Jersey, 2003). Banks often ask developers or property owners to provide a “No Further Action Letter” from NJDEP providing proof of cleanup or through an environmental site assessment indicating no cleanup is necessary. By requiring this letter, banks have identified contamination at agriculture sites undergoing development.

Wisconsin

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) oversees the cleanup of sites with lead and arsenic contamination from historical mixing, loading, and application of pesticides (Washington State Area-Wide Soil Contamination Task Force – Wisconsin, 2003). Wisconsin’s Lead Arsenate Program, now housed within the DATCP, is developing and implementing a proactive approach to prevent contact with contaminated soils at lead arsenate sites. The Lead Arsenate Program is largely funded by a grant from the EPA to identify old orchard sites, develop a GIS database and Internet map server, and conduct public education and outreach. After the land use has changed from agriculture to non-agriculture, properties contaminated with arsenic and lead are typically cleaned up through the state voluntary program. The DATCP (1994) has set guidelines for site assessments to help property owners and potential developers in identifying areas of potential contamination. The guidelines are based on background levels (naturally occurring sites), pesticide-use level sites (orchards, etc), and priority level sites (spills, mixing, and loading sites). The cleanup action levels

stated by the Wisconsin Lead Arsenate Program for priority-level pesticide sites are 100 ppm for arsenic and 400 ppm for lead.

Remediation

The complexity of soils and the presence of multiple contaminants make most remediation efforts arduous and costly (Sparks, 1993). Two types of methods are being used to decontaminate polluted soil sites, *in situ* and non-*in situ* techniques. *In situ* methods are used at the contamination site. This minimizes exposure to the contaminant and soil doesn't need to be excavated. These remediation techniques involve the use of biodegradation and phytoremediation.

Biodegradation involves the use of naturally occurring microorganisms that assist in degrading soil contaminants. A number of factors are involved that could affect biodegradation of soil pollutants including pH, temperature, moisture, indigenous microbes, and the availability of nutrients (Sparks, 1995). It is important to remember that microbes may be effective in degrading one pollutant but not another.

Phytoremediation is the use of plants to clean up contaminated environments such as soil, water, or sediments (Arthur and Coats, 1998). Plants, known as hyperaccumulators, take up toxic metals through their roots and transport them to stems or leaves where they can be removed by harvesting. The process of using these hyperaccumulators for remediating soils is termed, "phytoextraction" (Arthur and Coats, 1998). One possibility that is being researched is the brake fern, *Pteris vittata* (Fig. 13).



Fig. 13. Brake fern, *Pteris vittata*, is being sold by Edenspace (©2001-2006) as the edenfern™ and is used to remove high levels of arsenic from contaminated soil.

Researchers at the University of Florida and the University of Georgia discovered this fern and have reported that it can accumulate up to 10 times the concentration of arsenic found in the soil (Ma et al, 2001). The fern was found flourishing at a site in Florida, which had been contaminated with chromated copper arsenate (CCA). The brake fern is one of very few plants that are able to accumulate arsenic and may be a promising answer to removing arsenic from contaminated soil.

It is very important to be familiar with the chemistry of the pollutant. Depending on soil type (clay, sandy loam, silt loam, etc), pH, soil moisture and temperature, arsenic and lead may or may not be biologically available. To make these metals more available to the plants, chelating agents may be added, pH may be lowered and adding calcium or other minerals would increase the availability. Of course, by increasing the availability of the metals it increases the possibilities for arsenic and lead to leach into the groundwater or move off-site. However, there are not too many chemicals readily available at this time that actually allow both arsenic and lead to become bioavailable. The cost of using plants to decontaminate these polluted soils could be less than one-tenth the price of either digging up and transporting the soil to a hazardous waste landfill, or making it into concrete (Comis, 1995), but the process time can be very slow taking many, many years. Instead of looking at phytoremediating the soil, perhaps, “phytostabilization” is the approach that should be implemented for contaminated sites.

This would include studying how to stabilize lead and arsenic in the environment and to prevent leaching into the groundwater or movement off-site.

Non-*in situ* methods of remediation involve the removal of the soil from the contamination site, usually by excavation. The soil is then treated on-site, or is transported to another location, like a landfill, and treated. There are obvious concerns about exposure to the contaminants, during the moving and hauling process (Sparks, 1995). These methods are much quicker but tend to be extremely expensive, costing millions of dollars.

Standards for arsenic and lead in the environment

In the United States, very few uniform standards exist for evaluating toxic levels in soil. What concentrations levels are considered safe in soil for a specific chemical? A specific chemical is toxic to a certain extent for different species, whereas soil types and environmental conditions also heavily influence the harmful effects of the chemical as well. Eventually uniform soil quality criteria may need to be developed for regulatory purposes, similar to water quality criteria. Bioremediation of soils would be considerably simpler if standards could be attained that would provide more straightforward and consistent guidelines for evaluation of toxic levels in soils (Arthur and Coats, 1998).

Farming techniques

In a typical commercial orchard in the early 1900's unique farming techniques were used to culture apples and other fruit trees. To achieve maximum yield from an orchard it should be well pruned, well cultivated, and well fed (Dickens and Headlee, 1910). However, one of the most important aspects of the commercial orchard was the fungicide and insecticide spray schedule. Not only was the spray schedule important but spray mixing, materials and equipment also played vital roles in a successful commercial operation.

Copper sulfate, lime and Bordeaux mixture were the main fungicides applied in commercial orchards. Copper sulfate was used alone during the dormant season and lime

was mainly used for the purpose of neutralizing acid solutions. Lime combines well with other materials, making a combination that sticks well and kills fungal spores and insects. The copper sulfate and lime were mixed on-site and usually kept as stock solutions during the growing season. The two stock solutions were then combined to make Bordeaux mixture, and called a 3-4-50 mixture (3 pounds copper sulfate, 4 pounds of lime and 50 gallons of water) (Kansas State Agricultural Experiment Station Bulletin, 1915).

Fungicides and insecticides were usually applied together (Table 3), maximizing both time and money spent by the grower. Contrary to the belief at the time (1915) by some growers, Bordeaux mixture alone had no insecticidal qualities and had to be combined with an insecticide. It was recommended to add two pounds of lead arsenate to each 50 gallons or 10 pounds to a 250-gallon tank (Kansas State Agricultural Experiment Station Bulletin, 1915). Lime-sulfur was also mixed on-site and stored for use during the growing season. It was combined with lead arsenate at the rate of two pounds to each 50 gallons of solution for insecticidal purposes (Kansas State Agricultural Experiment Station Bulletin, 1915).

The spray schedule could be divided up into three important sprays, the dormant spray, the summer spray and the petal-fall spray.

- The dormant spray was preferably applied in the spring before the buds open but was also applied in the fall after the leaves are gone. A nozzle with a fine mist spray would have been used to coat the entire tree, including all the limbs and the trunk.
- The summer spray was applied with a fine mist nozzle to completely coat the leaves and fruit from every angle. Once the water from the spray evaporated, the fruit and foliage could be examined for complete or partial coverage.
- The petal-fall spray was the most effective single application for the control of the codling (Kansas State Agricultural Experiment Station Bulletin, 1915). After the petals fall off the tree the calyx are left open a short time. This was where the majority of insects pest enter the fruit. So it was of the utmost importance that the calyx cups are filled with insecticide when sprayed to prevent the pests from entering.

Table 3. General spray recommendations for apples*

Insect or Fungi	Spray to Use and Time of Application
1. <i>San Jose scale</i>	Dormant strength commercial or home-boiled lime-sulfur (6-7-8). Just before the buds swell.
2. <i>Apple scab</i> <i>Plum curculio</i> <i>Spring cankerworm</i> <i>Apple rust</i>	Lime-sulfur, summer strength (6-7-8), plus two to four pounds arsenate of lead. When cluster buds are showing pink, but before blossoms open.
3. <i>Codling moth</i> <i>Apple scab</i> <i>Black rot</i> <i>Rust</i>	Lime-sulfur, summer strength (6-7-8), plus two to four pounds of arsenate of lead. Start when petals are two-thirds off the blossoms.
4. <i>Apple blotch</i> <i>Plum curculio</i> <i>Codling moth</i> <i>Black rot</i>	Bordeaux mixture (3-4-50) plus two pounds arsenate of lead, if the weather is dry. Three weeks after No. 3. If wet, use lime-sulfur and follow with the Bordeaux as soon as dry.
5. <i>Apple blotch</i> <i>Black rot</i> <i>Plum curculio</i> <i>Codling moth</i>	Bordeaux mixture (3-4-50) plus two pounds arsenate of lead. Two to four weeks after No. 4.
6. <i>Codling moth</i> <i>Apple blotch</i> <i>Bitter rot</i> <i>Black rot</i>	Bordeaux mixture (3-4-50) plus two pounds of arsenate of lead. Eight to ten weeks after No. 3.
7. <i>Bitter rot</i> <i>Blotch</i> <i>Codling moth</i>	Lime-sulfur or Bordeaux mixture (3-4-50) plus two pounds arsenate of lead. Shortly before fruit begins to ripen.

* This was a general guideline reproduced from the Kansas State Agricultural College: Agricultural Experiment Station Bulletin (1915) and not all applications were likely needed. Sprays No. 2, 3, 4, and 6 are those ordinarily recommended.

Lead arsenate came in two forms, powder or paste, and was either purchased or made by the grower (Fig. 14). The dry formulation was easily stored from season to season and the paste formula was more easily mixed with water (Kansas State Agricultural Experiment Station Bulletin, 1915). However, the dry formulation was usually more than double the price than the paste. Whether using the dry or paste formulation, it was especially important to keep the mixture agitated so the solution would not separate before it was sprayed on the trees. Paris green, arsenite of lime, and nicotine were other insecticides recommended for use.



Fig. 14. Powdered lead arsenate displayed in two different types of packaging.

Reliable machinery was also very important to ensure efficient spraying. The best kind of machine suited for an orchard depended upon the size of the trees and the acreage. The first consideration when choosing the right equipment was power, and second was the pump, then the hose, extension rods and nozzles (Dickens and Headlee, 1910). Although hand pumps were recommended at the time (less than 500 trees) (Dickens and Headlee, 1910), power sprayers were the choice for large commercial orchards (500 to 2000 trees) (Dickens and Headlee, 1910). Power for pumping the liquid was obtained three ways, traction gearing, by hand, or by gas engine (Kansas State Agricultural Experiment Station Bulletin, 1915). Gas engines supplied high and continuous pressure and were found on the best sprayers.

Selecting the right nozzle was also of the utmost importance. The nozzle affects the spray application and works differently depending on the pressure obtained by the pump. For example, during the petal-fall spray the spray had to be delivered from above and applied in a downward fashion to fill the calyx cups. According to the Kansas State Agricultural Experiment Station Bulletin (1915) The “Bordeaux” nozzle was frequently recommended during petal-fall, however, it delivered a flat, undesirable spray. The “Friend” nozzle had a medium-sized aperture, and was found by the College to be

especially effective during petal-fall. In “Spraying Apples” (Dickens and Headlee, 1910), there are two types of spray used, the strong dashing type and mist type. The “Bordeaux” nozzle produced the first type of spray and the “Friend” nozzle or the Vermorel produced the second. Dickens and Headlee (1910) recommended the “Friend” type of nozzle, stating it to be more satisfactory because it never catches the branches of the tree.

An important indicator of the type or quality of spray produced was measured by the “effective spray drive”. This term was applied to represent the distance from the nozzle opening at which the spray turned the leaves sufficiently to wet them on both sides while the nozzles were in motion as in spraying. A nozzle with six holes in the whirl disc (Fig. 15), usually preferred by farmers for its effective spray drive, produces a spray cone that carried three times farther than the fan-like cone produced by a nozzle with only two holes in the whirl disc (Hough, 1928).

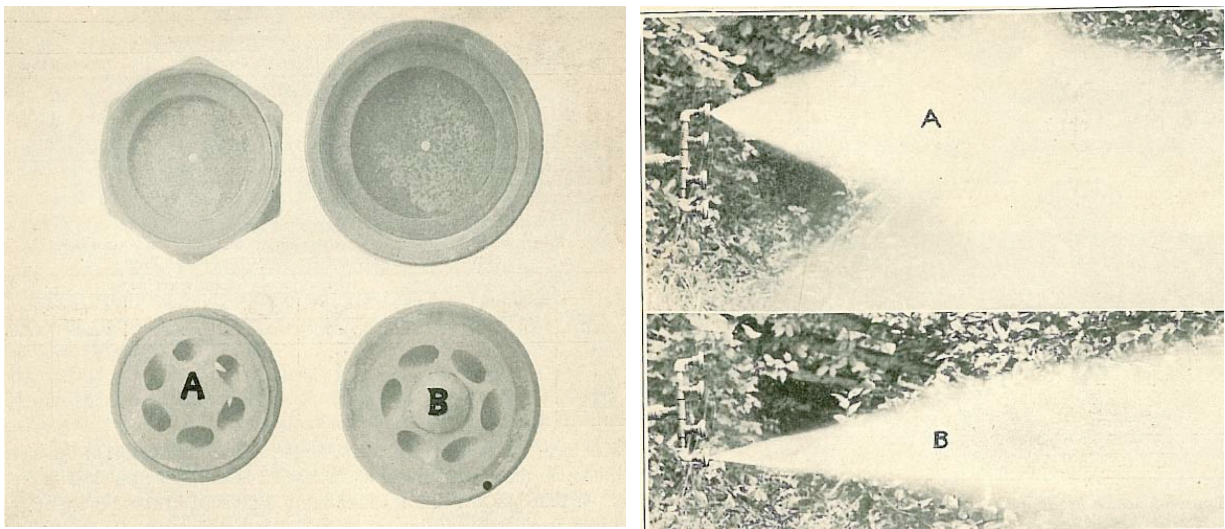


Fig. 15. Six-hole whirl discs (left) and a spray pattern of a nozzle (right) with a six-hole whirl disc (B). Spray pattern of a nozzle with a two-hole whirl disc (right) is seen in (A). The six-hole whirl disc sprays three times farther than the two-hole whirl disc. – (Hough, 1928).

Not only did nozzles and their arrangement affect spray efficiency, but also personnel, condition in which the sprayer was kept, pump capacity, and correct selection of spray equipment also was thought to play an important role (Hough, 1928).



Fig. 16. Apple trees sprayed with a hand-held boom. The applicator is standing on a “tower” while spraying the apple trees and is followed by a horse-drawn wagon carrying water. - Virginia Tech Digital Archives, Newman Library.

In 1915, wooden tanks were the rule and metal tanks were the exception because of the corroding effects of certain spray solutions. A round tank was preferred because agitation was more easily accomplished and all the solution could be removed from the tank. Another important piece of equipment that was a necessity for successful spraying large trees was a “tower” (Fig. 16). Made of wood or metal, it allowed the sprayer to actually spray down onto the tree. This is especially important during the petal-fall spray when the insecticide must reach the inside the calyx cups.

To supply water to the spray equipment in the orchard some operations used elaborate underground piping systems (Fig. 17). This process usually involved pumping water from a spring fed well through pipes throughout the entire orchard. Tanks were usually established throughout the orchard for storage and gravity sometimes played a role in distributing water to pumps or hydrants.



Fig. 17. Rusty pipes pulled from the orchard and piled together at Snead Farm, Shenandoah National Park, VA – 2001. These pipes were once part of an underground system used to deliver water and possibly pesticides throughout the orchard.

The spray chemicals were transported in barrels and loaded onto wagons pulled by one or two horses. The wagons would be pulled to the top of the orchard and the barrels would be attached to a pump by hoses, which connected to a water tank. Water would be continuously pumped to the barrel (by hand or by gas engine) to mix the chemicals properly. Then the trees were sprayed individually by hand, making sure to coat the tree entirely. However, sometimes the pipes in the orchard were used to pump chemicals up to the storage tanks making application easier for the workers. Instead of pulling the chemicals by wagon, they could now hook their hoses up directly to the hydrants located throughout the orchard and spray. This process is called chemigation. This was a very risky process because of the possibility of leaks in the pipes. The long-term effect of leaking pipes over many years on the environment was demonstrated in the contamination of Barber Orchard in Waynesville, NC.

Methods and Materials

Sampling

Potential orchard sites were assessed on an individual basis. However, age, location, size, and commercial/noncommercial were the main determining factors. Before modern air blast sprayers were used to apply pesticides to orchards, most pesticides were applied manually with spray booms to individual trees (Veneman et al., 1982). This technique was discussed in depth in the farming techniques section above. This resulted in localized accumulation of lead and arsenic in the soil. Using current soil sampling methods, in which samples are collected at random, would most likely miss this “spotty” distribution pattern of contaminants (Veneman et al., 1982). However, random sampling was necessary to use when no trees were left for reference.

Soil samples were taken from several apple orchards in the state of Virginia that were operational before 1970 to determine if arsenic and lead were present. Due to the varying site conditions, several sampling techniques were used.

1. If apple trees were present, samples were taken from individual trees selected at random throughout the orchard. Samples were taken around the tree drip line and under the canopy.
2. If no trees were present, but evidence of the grid pattern commonly found in orchards (“tree-rows”) was still visible, then soil samples were taken from the row and mixed together.
3. A third sampling method was used when no apple trees were left and there were no visible signs of where the trees once stood. These samples were taken at random but were not mixed together. In most cases this was where a forest existed today on a known orchard site.

Obvious potential hot spots could be found around trees at the drip line, mixing/tank loading sites (Fig. 18), and dumping sites.



Fig. 18. Mixing/loading site at Hetzel Farm, Berryville, VA (left) and mixing site at Mint Spring Recreational Park, Crozet, VA (right).

Soil samples were taken with a stainless steel soil probe. A soil probe, 24 inches in length, takes small core samples no more than 12 inches in depth. This is ideal when looking for arsenic and lead in soil because they both commonly are found in the top few inches of soil.

Once the soil samples were collected, they were placed in plastic bags and labeled accordingly. Samples were stored at room temperature until they could be prepared for processing. To prepare the samples, all vegetation, rocks, and debris were removed by using three types of mesh screen, 1/2 inch, 1/4 inch, and 1/8 inch. The soil was then stored in small soil sampling boxes provided by the Virginia Tech Soil-Testing Laboratory and labeled accordingly. Once again they were stored at room temperature until sent to the laboratory for analysis.

Lab Techniques

Many attempts were made to process the samples on the Virginia Tech campus, however, due to unforeseen events this became an impossible task. The microwave digester located in the Virginia Tech Department of Crop and Soil Environmental Sciences was

used several times to completely digest several soil samples. Then the digested samples would have been analyzed for total lead and arsenic in the Virginia Tech Soil Testing Lab using inductively coupled plasma mass spectrometry (ICP-MS). Multiple problems occurred with the microwave digester. Due to improper maintenance, untrained personnel, and unavailable resources to repair, maintain, and properly operate this equipment, the digester was not available for processing samples in our laboratories. It was also at this time that we learned using ICP-MS to analyze the digested soil to determine total arsenic may cause false positives for high levels of arsenic if high concentrations of aluminum (Al) are present. The gaseous hydride (HGAA) method was another option available to determine total arsenic but this equipment was not available on campus. With no alternatives left to process the soil samples, they were eventually sent to a state certified laboratory, A&L Eastern Agricultural Laboratories Inc. in Richmond, Virginia, for processing.

A&L Labs, used three methods to detect lead and arsenic residues in soil samples sent to them:

- **Microwave assisted acid digestion** (USEPA Method-3051, 1994)
- **Inductively Coupled Plasma-Atomic Emission Spectrometry**
(ICP-AES) (USEPA Method-6010B, 1996)
- **Gaseous Hydride Atomic Absorption** (HGAA) (USEPA Method-7061A, 1992)

Microwave digestion of sediments, sludges, soils, and oils is described in depth in EPA Method 3051 (1994). This method involves placing soil samples in a vessel in an acid solution and then using high temperature and high pressures in a controlled environment. It is intended to dissolve the sample prior to analysis using inductively coupled plasma – atomic emission spectrometry (ICP-AES) to determine total lead levels or gaseous hydride atomic absorption (HGAA) to determine total arsenic levels in the sample.

“A representative sample of up to 0.5g is digested in 10mL of concentrated nitric acid for 10 minutes using microwave heating with a suitable laboratory microwave unit. The sample and acid are placed in a microwave vessel. The vessel is capped and heated in the microwave

unit. After cooling, the vessel contents are filtered, centrifuged, or allowed to settle and then diluted to volume and analyzed by the appropriate SW-846 method.” (Summary of Method - SW846-3051)

ICP-AES measures characteristic emission spectra by optical spectrometry and is used to determine trace elements, including metals, in solution. This is described in detail in EPA Method 6010B (1996). In this experiment, ICP-AES is used to only determine the total amount of lead in the soil sample.

“ Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by a radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and intensities of the emission lines are monitored by photosensitive devices.” (Summary of Method - SW846-6010B)

The disadvantage of using ICP-AES for arsenic detection is the background radiation from other elements, mainly aluminum (Al). If high levels of Al are present in the sample, ICP will give a false positive for arsenic. To avoid this possibility, the gaseous hydride method is used to detect total arsenic in the sample. ICP-AES is only used to determine total lead.

Gaseous hydride AA utilizes a chemical reduction to reduce and separate arsenic selectively from the sample solution and is described in detail in EPA Method 7061A (1992). EPA Method 7061A is an atomic absorption procedure for determining the concentration of arsenic in wastes, soils, and groundwater. The advantage of gaseous hydride over ICP is being able to isolate from complex samples that may cause interferences. The typical detection limit for this method is 0.002 mg/L.

“Samples are prepared according to the nitric/sulfuric acid digestion procedure described in this method. Next, the arsenic in the digestate is reduced to the trivalent form with tin chloride. The trivalent arsenic is then converted to a volatile hydride using hydrogen produced from a zinc/hydrochloric acid reaction. The volatile hydride is swept into an

argon-hydrogen flame located in the optical path of an atomic absorption spectrophotometer. The resulting absorption of the lamp radiation is proportional to the arsenic concentration.” (Summary of Method – SW846-7061A)

Results and Discussion

Due to the real estate disclosure law in Virginia, the sample selection in this study was mostly restricted to sites on public lands. The Virginia Residential Property Disclosure Act states, “that by law, sellers of residential real estate must provide purchasers with one of two documents regarding the physical condition of the property being sold.” A disclaimer form states the seller is making no warranties on the property’s conditions unless otherwise stated in the purchase contract and a disclosure form gives answers to specific questions to the best of the seller’s knowledge. With only a few exceptions, sample locations were found in national parks, on public forest lands, on state game and inland fisheries land, municipal sites, institutional farms, and on one farm owned by a former faculty member at Virginia Tech who released us from liability regarding the disclosure issues. Our primary reason for avoiding private property was to avoid liability for the landowner and ourselves. A list of sampling sites can be found in Table 4.

Table 4. Summary of soil sampling sites in the Commonwealth of Virginia.

1. Glen Alton Farm – Jefferson National Forest – Giles County, VA

GPS coordinates: 37°25'46.90" N, 80°32'56.59" W

Elevation – 2577 ft

- 1 acre apple orchard
- orchard estimated to be 70 years old (production from 1930's - 1960's)
- soil samples collected in June 2001

2. Smyth/Wythe County Farm – Jefferson National Forest

GPS coordinates: 36°56'09.72" N, 81°21'37.11" W

Elevation – 3078 ft

- 1930's commercial apple orchard
- estimated to be 200+ acres
- soil samples collected in August 2001

3. Blandy Experimental Farm – VA State Arboretum – Boyce, VA

GPS coordinates: 39°03'52.23" N, 78°03'52.60" W

Elevation – 596 ft

- 2 orchard locations on site – 5 to 10 acres each
- approximately 80-90 years old
- soil samples collected in December 2001

4. Snead Farm – Shenandoah National Park – Warren County, VA

GPS coordinates: 38°51'29.85" N, 78°12'03.24" W

Elevation – 2018 ft

- 1930's commercial apple orchard
- 200+ acres
- soil samples collected in October 2001

Table 4 (continued). Summary of soil sampling sites in the Commonwealth of Virginia.

5. Hetzel Farm – Clarke County – Berryville, VA

**GPS coordinates: 39°11'17.58" N, 77°53'53.31" W*

Elevation – 452 ft

- 2 orchard locations – 15 acres and 100 acres approximately
- exact age unknown
- soil samples collected in August 2001

6. Folly Farms – Bath County, VA

**GPS coordinates: 38°02'46.68" N, 79°52'32.08" W*

Elevation – 1759 ft

- 10-15 acres
- soil samples collected in October 2001

7. June Cleek Farm – Bath County, VA

**GPS coordinates: 38°02'46.68" N, 79°52'32.08" W*

Elevation – 1759 ft

- 20+ acres
- soil samples collected in October 2001

8. Mint Spring Recreational Park – Albemarle County – Crozet, VA

GPS coordinates: 38°05.147' N, 78°43.792' W

Elevation – 1070 ft

- commercial orchard during most of the 1900's
- 200+ acres
- soil samples collected in June 2002

**Approximate locations*

Collection of samples and locations

Collecting samples proved to be very challenging. Due to the real estate disclosure laws discussed previously, privately owned land was to be avoided. Also, most orchard sites over 70 years old were usually no longer evident and were now full-grown forests. Historical information, like aerial photographs, hand drawn maps, the testimony of local citizens, landowners or retired growers, and various historical records were relied on to

locate most of the sampling sites. To begin the overall search the US Forest service, the National Park Service and local Cooperative Extension agents were contacted. Old aerial photographs identifying two orchards located in the Jefferson National Forest that fit the criteria were found right away, saving weeks of looking through old records. Next, the Virginia Department of Game and Inland Fisheries (VDGIF) and local growers were contacted about other possible locations in the state. Several private landowners also gave us permission to sample on several sites located in Bath County and Clarke County (Berryville, VA). Former commercial orchards located in the Shenandoah National Park, a recreational park in Albemarle County, VA, and the official State Arboretum of Virginia at Blandly Experimental Farm (Boyce, VA) were also found. See Fig. 19 for a distribution of all sampling sites in the Commonwealth of Virginia.

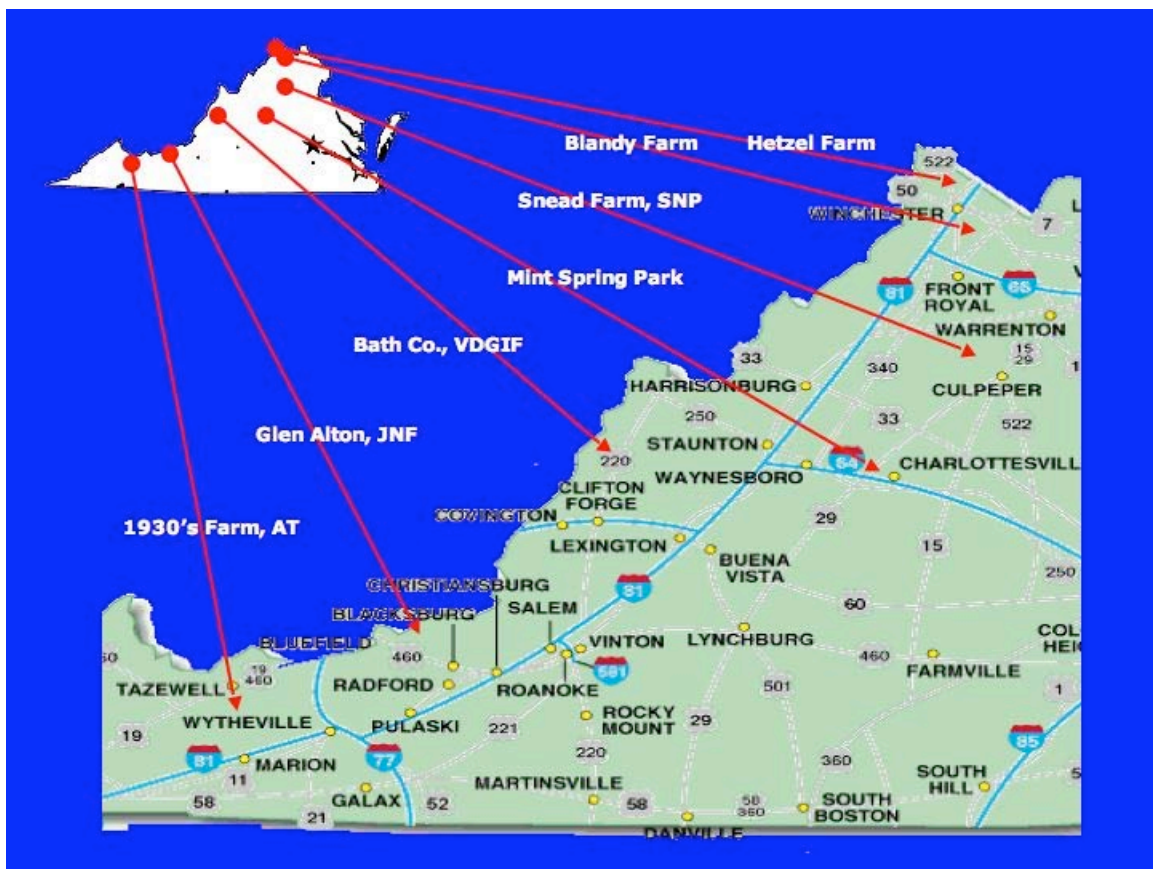


Fig. 19. Distribution of orchard soil sampling sites across the Commonwealth of Virginia (2001-2002).

Difficult terrain, poison ivy, snakes, rocky soil, and even a black bear at Mint Spring Recreational Park, often hampered soil sample collections. Access to remote sites also

involved crossing private lands to reach some sites. This created a situation that depended on local landowner cooperation for access.

Soil Analysis

Soil sample results shown in Tables 5 through 12c are for total arsenic and total lead. Figures highlighted show the highest level found in orchard.

Glen Alton Farm – Jefferson National Forest – Giles County, VA

This apple orchard is located on a 300-acre farm that was donated by a family to the Jefferson National Forest in 1999. Over half of the trees still stand in the one-acre plot (Fig. 20).



Fig. 20. Glen Alton Farm apple orchard in Giles County, VA – 2001.

By looking at aerial photographs supplied by the New River Valley District of the U.S. Forest Service one can tell that these apple trees have been there for at least 40 years. Well maintained out buildings and an apple-packing shed are filled with old, stacked apple packing crates indicating that this site might have been a small but productive, commercial orchard.

1 acre apple orchard at Glen Alton



USGS aerial photo

Fig. 21. Glen Alton Farm (Giles County, VA) – USGS aerial photograph. The area highlighted is the one-acre apple orchard still in existence. Soil samples were taken from this area.

Samples were taken around the trees still standing in the orchard (Fig. 21). Individual soil samples were taken at the drip line, inside the drip line and at the base of each tree. These were mixed into one sample. The technique was used for several trees in a row and then repeated for the following rows throughout the rest of the orchard.

Table 5. Total lead and arsenic residues (ppm) found in soils sampled at Glen Alton Farm. Lead (*Pb*) concentration range: **18 – 226 ppm**. Arsenic (*As*) concentration range: **6.75 – 38.45 ppm**

Sample	Pb	As
1	76	11.26
2	76	11.26
3	53	10.01
4	53	14.34
5	48	9.10
6	63	14.34
7	44	8.53
8	47	9.21
9	31	7.96
10	28	6.94
11	226	29.64
12	25	8.63
13	32	18.99
14	38	14.28
15	32	13.66
16	18	9.68
17	31	6.75
18	19	7.69
19	88	38.45
20	22	8.42
21	25	9.68
AVG	51.19	12.80

Soil analysis results showed slightly elevated levels of lead throughout the orchard. One hot spot (hot spots are where high levels of contamination exist in a specific location) was found in the corner of the orchard that measured 226 ppm of lead in the soil. This area could have been a possible dumping site for pesticides, gasoline or leaded paint. Arsenic levels were only slightly raised throughout the orchard suggesting that lead arsenate was probably applied to these trees but to a lesser extent or for only a short period of time.

Smyth/Wythe County Apple Orchard – Jefferson National Forest

This orchard was once a thriving mountain commercial orchard in the 1930’s. An aerial photograph (Fig. 22) from 1935 supplied by the Jefferson National Forest showed a steep, isolated mountain location several hundred acres in size. However, after looking at a 1960’s aerial photograph it was evident that the orchard had been abandoned for quite

some time and was overgrown. Unfortunately, a copy of the 1960's aerial photograph from the US Forest Service was not made to compare with the 1930's aerial photograph in this thesis.

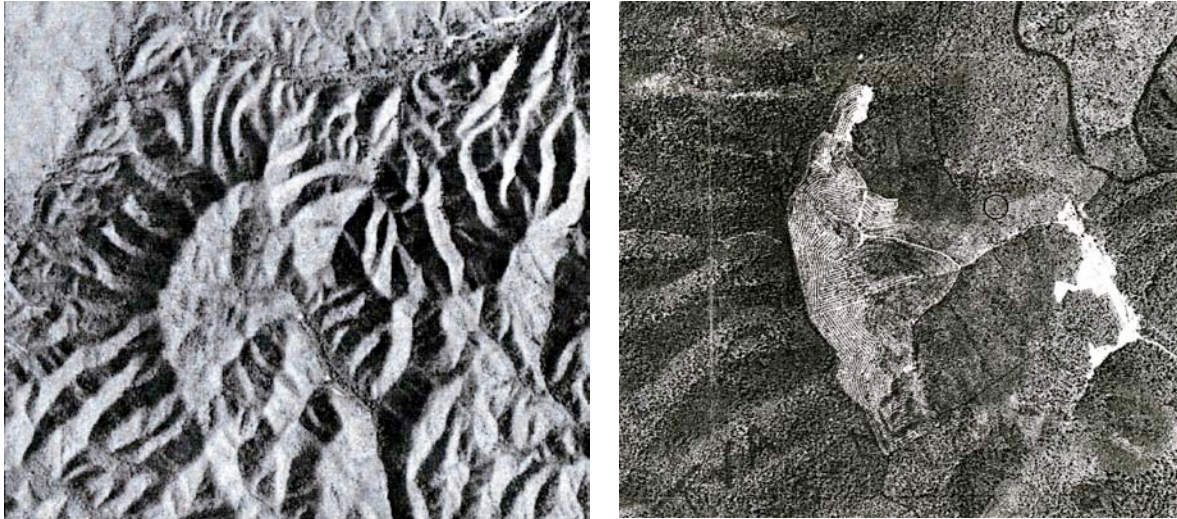


Fig. 22. Smyth/Wythe County, VA Apple Orchard – USGS satellite photo (left) and 1930's aerial photo (right). The orchard is in the crescent shape located in the very steep mountain range off the Appalachian Trail.

After consulting several maps, a local Extension agent, and speaking to a local farmer whose property was adjacent to the old farm, about how to access this orchard we realized it would be very difficult. Reaching the orchard by road would mean trespassing on private property. It was decided the best way to reach the old site was to hike the Appalachian Trail (AT) that just happened to pass the old farm road. This would prove to be much more difficult than anticipated. With only an aerial photograph, a hiking map, and a topography map the exact location was hard to determine. Also, the steep terrain and overgrown forest only made choosing where to take the soil samples even more difficult. Surface and sub-surface samples were taken at this site with a soil auger to determine if leaching was present. But because of these problems, the samples taken were not representative of the actual orchard soil residues. This led us to conclude that we were never able to locate the actual orchard site.

Table 6. Total lead and arsenic residues (ppm) found in soils sampled at Smyth/Wythe County Apple Orchard. Lead (*Pb*) concentration range: **33 – 39 ppm**. Arsenic (*As*) concentration range: **5.28 – 6.96 ppm**.

Sample	Pb	As	Soil depth*
1	39	5.28	surface
2	13	4.76	sub-surface
3	33	6.96	surface
4	18	6.12	sub-surface
AVG	25.75	5.78	

*Soil auger was used to take soil samples at the soil surface and below the surface of the soil.

Soil analysis results showed mainly background levels present for arsenic and slightly elevated lead levels on the surface, supporting research that lead does not leach past the first few inches of soil. However, some samples were taken not from the actual orchard site but near an old forest service/old farm road. Leaded gasoline residues may have contributed to these elevated lead levels on the site, while arsenic levels remained comparable to background levels.

Blandy Experimental Farms – The State Arboretum of Virginia – Boyce, VA

This 700-acre farm in Clarke county is owned and operated by the University of Virginia and was donated to the University by Graham Blandy upon his death in 1926. This farm is also home to the official State Arboretum of Virginia. There were two commercial orchard sites once located on the farm.



Fig. 23. Blandy Experimental Farm (Boyce, VA) apple orchard in bloom and apple packing shed in the 1920s. – Blandy Farm Archives.

A photograph dating from the 1920's shows the apple trees where they once stood (Fig. 23). Another photograph shown earlier (Fig. 3) shows an applicator spraying trees on the original site in the 1920's – that application was believed to be lead arsenate.



Fig. 24. Blandy Experimental Farm orchard (Boyce, VA) – 2001. The apple packing shed still exists but is out of frame to the left. The stone wall is still standing and can be seen in Fig. 23.

Today, the trees are no longer there but the landscape has remained relatively unchanged leaving behind open fields (Fig. 24). The small slopes between rows where the trees once stood are still somewhat visible making soil sampling easier. One thing that has remained is the old apple-packing shed. It was renovated in 1996 into a one-room schoolhouse called the Parkfield Learning Center and is used for workshops, lectures, and meetings.



Fig. 25. Blandy Experimental Farm (Boyce, VA) – USGS aerial photograph. The land outlined in the photograph is where the original orchards were located. Soil samples were taken from both sites.

Soil was analyzed from two orchard location sites on the farm (Fig. 25). The first orchard site is located behind the Quarters. Originally used as slave quarters in the 1800’s and then as dormitories for students staying at the farm, they are now used as offices on the farm. The second orchard site is located behind the Parkfield Learning Center, also known as, the Schoolhouse.

Table 7a. Total lead and arsenic residues (ppm) found in soils sampled at Blandy Experimental Farm – Orchard #1. Lead (*Pb*) concentration range: **89 – 105 ppm**. Arsenic (*As*) concentration range: **21.83 – 38.45 ppm**.

Sample	Pb	As
1	89	26.94
2	92	38.45
3	105	34.79
4	90	21.92
5	95	24.50
6	94	32.21
7	99	21.83
AVG	94.86	28.66

Table 7b. Total lead and arsenic residues (ppm) found in soils sampled at Blandy Experimental Farm – Orchard #2. Lead (*Pb*) concentration range: **59 – 70 ppm**. Arsenic (*As*) concentration range: **17.75 – 24.33 ppm**.

Sample	Pb	As
1	59	24.33
2	70	23.82
3	66	18.43
4	69	17.97
5	70	17.75
6	67	18.88
AVG	66.83	20.20

Soil analysis results show a uniform distribution of elevated levels of arsenic and lead in the soil at both orchards. Because no apple trees existed, soil samples were collected for each tree row and mixed together, explaining the uniformity of the data. The lead levels are double the typical background levels usually found in soil but still less than the recommended cleanup level of 200 ppm set in North Carolina. Arsenic levels, however, are elevated to the North Carolina recommended cleanup level of 20 ppm, which could warrant further testing.

Snead Farm – Shenandoah National Park – Warren County, VA

This 250-acre farm located in Warren county was once a thriving commercial orchard during the early half of the 20th century until 1962 when it was sold to the federal government by the Snead family for water rights to the Dickey Ridge Visitor Center along the Skyline Drive located in the Shenandoah National Park (Fig. 28). Several families owned and operated the Dickey Hill orchard before the Sneads. These families planted the original trees in the orchard dating back to 1897.



Fig. 26. Snead Farm stone house foundation and barn (Shenandoah National Park) – 2001. The house was burned down to prevent people from squatting on the land. The barn and several outbuildings are still maintained by the park.

Due to increasing labor and equipment costs, stricter regulations for grading and inspecting, and a declining overseas market in the 1930's only large farms could compete under the existing economic conditions. When the park was created in 1936, the Dickey Hill orchard was still too profitable to be condemned. However, by the 1960's, the orchard was no longer considered viable and was eventually incorporated into the Park.



Fig. 27. Snead Farm apple orchard overgrown in Shenandoah National Park. No apple trees are left standing, however, the tree rows are still visible in this photograph. These are evident here as terraces on the hillside.

Some apple trees remain scattered around the property in what can only be described as a dense mature forest (Fig. 27). The barn is still standing and is well maintained by the Park, but only the house foundation remains (Fig. 26). The house was torn down to prevent squatters from moving onto the property. Piles of old, rusty pipes show signs of a once extensive irrigation system that supplied water to the entire orchard (Fig 17). The steep, and extremely rocky terrain made soil sampling challenging, but the terraces are still visible allowing one to follow where the trees once stood in their rows.

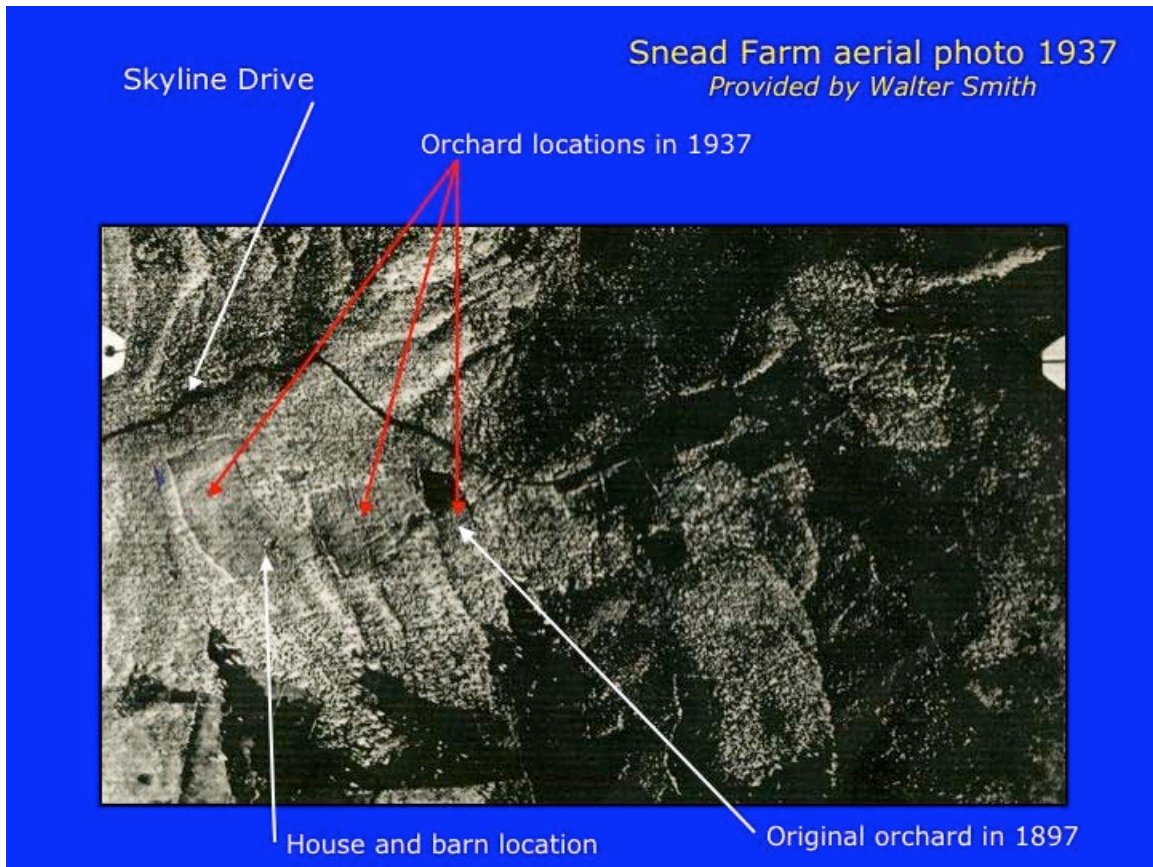


Fig. 28. Snead Farm in Shenandoah National Park – 1937 aerial photograph. The original orchard from 1897 is identified along with the commercial orchard in 1937. Soil samples were taken from behind the house and barn location. Picture provided by Walter Smith.

Table 8a. Total lead and arsenic residues (ppm) found in soils sampled at Snead Farm – Obtained in the main orchard behind the farmhouse. Lead (*Pb*) concentration range: **104 – 701 ppm**. Arsenic (*As*) concentration range: **25.67 – 228.81 ppm**.

Sample	Pb	As
1	618	145.73
2	136	39.98
3	104	25.67
4	602	228.81
5	701	220.17
6	193	51.83
7	422	152.78
AVG	396.57	123.57

Table 8b. Total lead and arsenic residues (ppm) found in soils sampled at Snead Farm – Obtained near the apple packing shed. Lead (*Pb*) concentration range: **474 – 548 ppm**. Arsenic (*As*) concentration range: **116.49 – 154.50 ppm**.

Sample	Pb	As
1	474	154.50
2	548	116.49
AVG	511.0	135.50

Table 8c. Total lead and arsenic residues (ppm) found in soils sampled at Snead Farm – Obtained near the old well and pile of pipes.

Sample	Pb	As
1	436	41.60

Table 8d. Total lead and arsenic residues (ppm) found in soils sampled at Snead Farm – Obtained around apple trees left on farm. Lead (*Pb*) concentration range: **167 – 774 ppm**. Arsenic (*As*) concentration range: **51.50 – 286.12 ppm**.

Sample	Pb	As
Broken apple tree	167	51.50
Broken apple tree	336	51.50
Split apple tree	774	286.12
AVG	425.67	129.71



Fig. 29. Broken apple tree (left) and split apple tree (right) at Snead Farm in the Shenandoah National Park. These apple trees are the only signs left of a commercial orchard in the 1930's.

Soil analysis results show very high levels of contamination for both lead and arsenic. There are definite examples of hot spots that were located in the orchard. These spots could have been contaminated during mixing or spilling of pesticides in the orchard, or simply a high amount of lead arsenate was sprayed and has accumulated on the top few inches of the soil. In only two locations were there apple trees left standing (Fig. 29) so soil samples were taken in visible tree-rows and combined together for each row. This site definitely warrants more testing and research.

Hetzel Farm – Clarke County – Berryville, VA

These two orchards are located on two different sites of land that is privately owned by a former faculty member at Virginia Tech. Because these orchards are privately owned, GPS coordinates (located in Table 4) of the sampling sites were given as an approximate location. The first location was the older of the two. It was no longer in production and was in the process of being pushed out. The trees left standing were less than an acre.



Fig. 30. Hetzel Farm apple orchard (#2) in Berryville, VA – 2001.

The second orchard (Fig. 30) was still being maintained but there are plans in the future to push out the trees and to start an organic farming business. The owner was interested in finding out about any pesticide residues located on the property since no pesticides will be used with the organic farming business. All the trees, although not the original trees, were still in place making the decision of where to take the soil samples easy.

Table 9a. Total lead and arsenic residues (ppm) found in soils sampled at Hetzel Farm – Orchard #1. Lead (*Pb*) concentration range: **20 – 195 ppm**. Arsenic (*As*) concentration range: **4.78 – 15.24 ppm**.

Sample	Pb	As
1	24	5.75
2	26	6.56
3	22	5.08
4	195	4.78
Tank Site	20	15.24
AVG	57.40	7.48

Table 9b. Total lead and arsenic residues (ppm) found in soils sampled at Hetzel Farm – Orchard #2. Lead (*Pb*) concentration range: **10 – 49 ppm**. Arsenic (*As*) concentration range: **3.08 – 11.37 ppm**.

Sample	Pb	As
1	25	5.11
2	19	4.32
3	23	6.17
4	10	4.54
5	27	3.08
Tank Site 1	32	5.78
Tank Site 2	49	11.37
AVG	26.43	5.77

Soil analysis results are very similar to the samples taken from Glen Alton. Individual trees were still standing in the orchard so samples were taken around the drip line of apple trees and were not mixed. Lead levels show slightly elevated levels with the exception of one hot spot. Arsenic levels were very close to background levels with only a slight elevation near one of the mix/loading tank sites. The possible reason for this could be that lead arsenate was not used as extensively as previously thought because of the age of the orchard.

Folly Farms and June Cleek Farm – Bath County, VA

These two orchard sites located in Bath County are both privately owned. Because these orchards are privately owned, GPS coordinates (located in Table 4) of the sampling sites were given as an approximate location. The circumstances that allowed us to take samples from these sites were quite unusual. An avid foxhunter from Northern Virginia had moved to the area several years ago and bought up most of the farms surrounding his own farm, totaling several thousands of acres. Many of the farms he purchased had been owned by several local families for generations. He did not want to kick out the families still living on the farm and did not want to develop it, but wanted it only for preservation and to access the land whenever he held fox hunts. The elderly farmers still living on the property allowed us permission since no development would ever occur on the property.



Fig. 31. Former apple orchard site at June Cleek Farm (Bath County, VA) – 2001.

Folly Farms had one orchard, several acres in size, that still had many old apple trees left standing (Fig. 32).



Fig. 32. John Pound of the Virginia Department of Game and Inland Fisheries (VDGIF) taking a soil sample below an apple tree at Folly Farms (Bath County, VA) in 2001.

The second orchard site, located on June Cleek's farm, was now rolling pasture, with only a few trees still standing and producing apples (Fig. 31). There were, however, many stumps left in the ground to show where the trees once stood. Samples were taken around the existing trees (along the drip line and under the canopy) and around and between existing tree stumps.

Table 10. Total lead and arsenic residues (ppm) found in soils sampled at June Cleek Farm. Lead (*Pb*) concentration range: **17 – 19 ppm**. Arsenic (*As*) concentration range: **2.62 – 3.26 ppm**.

Sample	Pb	As
1	17	3.26
2	19	2.62
3	19	2.69
AVG	18.33	2.86

Table 11. Total lead and arsenic residues (ppm) found in soils sampled at Folly Farms. Lead (*Pb*) concentration range: **28 – 41 ppm**. Arsenic (*As*) concentration range: **11.37 – 22.74 ppm**.

Sample	Pb	As
1	41	22.74
2	30	11.37
3	28	11.37
AVG	33.00	15.16

June Cleek Farm showed little to no lead or arsenic contamination in the soil analysis results. Most of the numbers represented the background levels found in the soil. Folly Farms produced lead and arsenic levels that were only slightly elevated. Both orchards were non-commercial sites suggesting only small lead arsenate applications. The soil results suggest no potential health risk.

Mint Spring Recreational Park – Albemarle County – Crozet, VA

This recreational park owned by Albemarle County was once part of a thriving commercial orchard located in Crozet, VA. The orchard was successful for over 90 years and was run by the same family until part of it was sold to the county to be used as a park. The several hundred acres of apple trees are now completely overgrown with weeds, poison ivy, and wild grapevine, and are surrounded by a new growth forest (Fig. 33).



Fig. 33. Apple tree overgrown with grapevine in Mint Spring Recreational Park (Crozet, VA) in 2002. The majority of the existing orchard was overgrown with grapevines and surrounded by new-growth forest.

Many of the trees are still standing today along a hiking trail to the top of the mountain. Others were removed during the construction of the park. Adjacent to the park is the rest of the original orchard that is still run commercially by the Wayland family. According to a former orchard worker, lead arsenate was made on site at the farm, used in the orchard and was also shipped out for sale. Other parts of the orchard were sold for development years ago and houses are now located there. Homeowners in the development were concerned about their drinking water after learning of the orchard's history of pesticide use and were able to get the county involved.

A fishing lake and swimming lake are located in the park and are the main attraction for visitors. With the county concerned about possible exposure to their patrons they hired Froehling & Robertson, Inc. (F&R) in Richmond, VA in April 2002 to sample surface water, groundwater, and sediment from both lakes to determine if there was any contamination. F&R found that the water in both lakes showed minimal signs of lead and arsenic. These residues were low enough to not be considered a problem. However, the sediment in the fishing lake was found to have slightly elevated levels of lead and arsenic (Lead = 74 mg/kg, Arsenic = 18mg/kg) and it was suggested that further investigation was needed in the potential bioaccumulation of pesticides in the fish. By looking at a

USGS topographical map, it is evident that an intermittent channel and incidental runoff from the mountain ran through the former apple orchard and into the fishing lake. With the historical use of pesticides well documented in the orchard this is believed to have caused the slightly elevated levels in the lake sediment. This information was shared with us by the Albemarle County Department of Engineering and Public Works and permission was given by the Albemarle County Department of Parks and Recreation to take soil samples from the park for this research project in hopes that more information would be generated about the site.

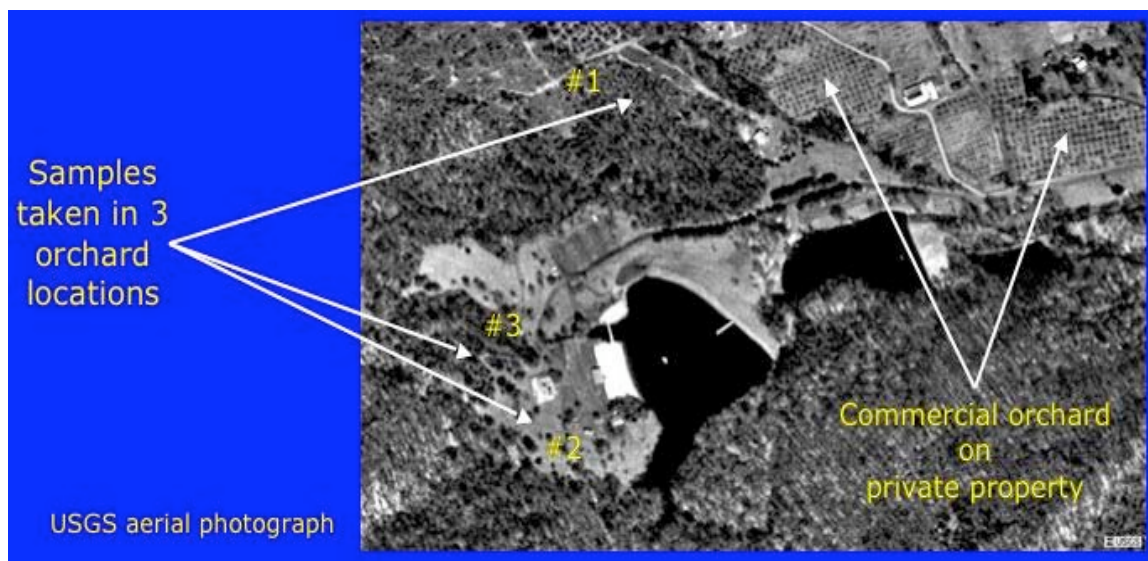


Fig. 34. Mint Spring Recreational Park (Crozet, VA) – USGS aerial photo. The three soil sampling sites are identified and part of the present commercial orchard is visible.

Samples were taken from three locations in the park (Fig. 34). Site #1 was located up a walking trail on the mountain. Site #2 was located near the swimming lake. Site #3 was located on a walking trail near the parking lot by the swimming lake.

Table 12a. Total lead and arsenic residues (ppm) found in soils sampled at Mint Spring Park – Mountain trail samples #1. Lead (*Pb*) concentration range: **182 – 389 ppm**. Arsenic (*As*) concentration range: **30.08 – 129.60 ppm**.

Sample	Pb	As
1	182	46.50
2	386	116.43
3	228	65.53
4	389	129.60
Pesticide Shed	336	30.08
Pesticide Shed	204	30.08
AVG	287.50	69.70

Table 12b. Total lead and arsenic residues (ppm) found in soils sampled at Mint Spring Park – Lake samples #2. Lead (*Pb*) concentration range: **353 – 490 ppm**. Arsenic (*As*) concentration range: **46.50 – 84.22 ppm**.

Sample	Pb	As
Foundation	353	46.50
1	490	84.22
AVG	421.50	65.36

Table 12c. Total lead and arsenic residues (ppm) found in soils sampled at Mint Spring Park – Lake trail samples #3. Lead (*Pb*) concentration range: **233 – 494 ppm**. Arsenic (*As*) concentration range: **39.49 – 81.43 ppm**.

Sample	Pb	As
1	494	81.43
2	233	39.49
3	271	67.32
4	420	54.14
AVG	354.50	60.60

Soil analysis results suggest heavy use of lead arsenate showing high levels of both lead and arsenic found in the soil. For some of the sampling sites, the trees were still present and individual samples were taken around the drip line. However, for some of the sampling soil was mixed. The samples indicate an overall contamination, not just hot spots located intermittently. These high levels pose a possible health risk and this site needs further research and testing.

Summary and Conclusions

In the North Carolina reports of Barber Orchard, action levels for cleanup of that site were set at **200 ppm** for lead and **40 ppm** for arsenic. These numbers were determined by using several factors but were mainly based on the background levels found naturally in the soil. Because lead and arsenic are naturally found in soil, some levels of these compounds will be found. This naturally occurring level of arsenic and lead is known as the background level. Background levels for arsenic found in soil in Virginia ranged from **2 to 10 ppm**. Background levels for lead found in soil in Virginia ranged from **13 to 39 ppm**. These numbers are based on the lowest levels of arsenic and lead found during soil sampling. There haven't been any studies in Virginia that pinpoint the exact background levels in Virginia. There is a study from Virginia Tech, "A Baseline Study of Heavy Metals in Virginia" (Jones and Thomas, 1999) that looked at background levels in three areas of Virginia; the Coastal, Piedmont, and Valley and Ridge areas. However, the study is incomplete and lists background levels for only a few soil series. For this thesis, all the soil samples were taken from the Valley and Ridge area of Virginia. The two soil series listed in Virginia Tech's study for the Valley and Ridge area are Carbo and Frederick. According to this study, arsenic (As) background levels for Carbo soils (A horizon) are approximately **25 ppm**, while lead (Pb) levels are approximately **70 ppm**. Background As levels for Frederick soils (A horizon) are approximately **30 ppm**, while Pb levels are approximately **60 ppm**. After consulting the Virginia Tech Soil Survey and the Natural Resources Conservation Service (NRCS) website, only a few of the sampling sites in this thesis had soil survey map information listed; Blandy Experimental Farm, Mint Spring Recreational Park and Snead Farm (Table 13). After looking over the site maps, neither Carbo nor Frederick are found at any of these sites. The background levels for As seem to be quite high compared to the data from this thesis. It isn't stated where soils were sampled in the Valley and Ridge area and may have been sampled in agriculture land. This just shows how different the background levels can be throughout the state and why a more comprehensive study is needed to determine the true baseline in Virginia.

Table 13. Summary of soil surveys for Blandy Experimental Farms, Mint Spring Recreational Park, and Snead Farm.

	Sampling site #1	Sampling site #2	Sampling site #3
Blandy Experimental Farm	51B = Timberville silt loam, 0 to 7 percent slopes	35B = Poplimento silt loam, 3 to 8 percent slopes	N/A
Mint Spring Recreational Park	90B = Unison very stony silt loam, 7 to 15 percent slopes	81B = Thurmont loam, 2 to 7 percent slopes	81C = Thumont loam, 7 to 15 percent slopes
Snead Farm*	31E = Myersville-Catoctin silt loams, 25 to 65 percent slopes, very stony		

*Warren County soil survey showed all the sampling sites at Snead Farm were in 31E.

Comparing lead and arsenic levels found at two orchard sites, Mint Spring Recreational Park and Snead Farm, showed results well above the background level as well as the predetermined standards for cleanup set by North Carolina and the EPA.

Table 14. Summary of results from soil sampling sites in the Commonwealth of Virginia. The **averages** of the arsenic and lead from each site are reported in PPM.

Contaminants	Glen Alton Farm	Smyth/Wythe County Apple Orchard	Blandy Experimental Farm	Snead Farm	Hetzel Farm	Folly Farms	June Cleek Farm	Mint Spring Recreational Park
As	12.8	5.8	24.4	107.6	6.6	15.2	2.9	65.2
Pb	51.2	25.8	161.7	442.3	41.9	33.0	18.3	354.5

Mint Spring Park showed soil contamination with lead levels as high as **494 ppm** and arsenic levels as high as **130 ppm**. Snead Farm had levels ranging from moderate to high levels of contamination with lead as high as **774 ppm** and arsenic as high as **286 ppm**.

Both orchards suggest heavy use of lead arsenate during the years of commercial production. There is a correlation with the high levels of arsenic and lead and those sites sampled that were confirmed commercial orchards. The data shows that orchards that were grown on small farms and not for commercial production had low to moderate levels of arsenic and lead in the soil proving that smaller amounts of lead arsenate were applied to these non-commercial sites.

The highest levels of arsenic and lead were found at Snead Farm. This former commercial orchard has many similarities with Barber Orchard, the Superfund site in North Carolina. One major similarity being that both orchards used an underground piping system to deliver water throughout the orchard. Barber Orchard was found to have used this system to pipe pesticides through the orchard, eventually leading to the contamination of the ground water. There is no proof that such practices were applied at Snead Farm but one can only wonder. Most of the pipes have been removed from the orchard and piled together. Further testing of the pipe sediment could show whether they contained any pesticides, proving whether chemigation was practiced at Snead Farm. This could be a red flag for possible groundwater contamination at this site. This site could also be a good area to study the flora and fauna to look for possible bioindicators. Because Snead Farm is protected land it is the ideal site to do further testing and research in Virginia.

Snead Farm and Mint Spring Recreational Park remain unchanged and protected from development, allowing the soil there to remain undisturbed. These former orchards should remain undisturbed because they are public domains and should pose no health risk to visitors in either of these parks. However, if these sites should ever become developed, precautions would need to be taken and the soil would possibly need remediation to prevent any human exposure to these elevated residue levels.

Practical solutions and recommendations for landowners

Landowners who find themselves with soils contaminated with either high levels of lead or arsenic have several practical choices to deal with the problem. Unless large quantities of grading are required on a site, soil removal is usually not a practical solution. At this point, phytoremediation might be a potential solution in the future but this method is probably not a realistic alternative for the homeowner. However, there are several actions one can take to deal with the problem.

1. One practical option available to landowners is to do nothing. Homeowners can deal with soil residues by leaving the soil undisturbed or avoid contact with the soil altogether.

2. If planting vegetable gardens or flowerbeds, raise the beds by bringing in clean topsoil. These beds should be lined with heavy plastic to prevent mixing of new soil with contaminated soils. This can occur very easily if the beds are mixed or cultivated during planting. Avoid direct contact of plants with contaminated soils by covering the soils with plastic mulch, organic mulch, or turfgrass. Always, wash the vegetables harvested from these sites thoroughly before cooking to be safe. Vertical gardening techniques such as pole or trellis growing could also lessen the contact with vegetables and soil. More information about vertical gardening techniques can be attained from your local extension agent.
3. Avoid using phosphate fertilizers on any soil that may have high levels of arsenic. The phosphate will out compete the arsenic in the soil allowing the arsenic to become more bioavailable. This would make arsenic more available to be taken up by plants, leach or move off-site.
4. Growing grass is considered a sufficient barrier for family safety. Landowners should monitor the activity of children to help avoid unnecessary contact with soil. One basic tenet should always be followed: a thorough hand wash will greatly negate the possibility for ingestion of lead and arsenic residues.

Further research needed in Virginia

This study provides an insight into the history of commercial orchards, the implication of lead arsenate as an insecticide and a discussion about the problems that can result from contamination. However, more extensive studies are needed in Virginia. Several areas that need more research include:

- Movement off-site (water contamination) -- Contamination can spread through surface runoff or through sub-surface water systems. Much of the area in Virginia that was previously covered with commercial orchards contain karst topography, a condition that can result in sub-surface ground water close to the soil surface level. Surface runoff may be a more serious concern because of the availability of the contaminants in the topsoil. Research should be done to determine the effect of both of these conditions.

- Leaching (water contamination) – The full implication of leaching needs further examination. The result of other chemicals being applied to contaminated soil may cause lead arsenate to leach further into the soil and contaminate ground water. With many of the communities affected by lead arsenate contamination using well systems, a more thorough hydrologic analysis needs to be performed to determine the true effect of contamination on water supplies.
- Compost uptake – The possible uptake of arsenic and lead by leaves and grass clippings requires further examination. Specific species may take up harmful levels and, in consumed products such as vegetables, further study of a broad range of species is necessary.
- Bioindicators – Grasses, fauna and other plants may possibly indicate the presence of arsenic and lead in soils. This could be a beneficial tester in areas with potential contamination. If a specific plant or organism is found to be present in a know contaminated area it could be studied to determine if it holds any specific properties to show why it would flourish in high levels of arsenic or lead. The converse may also be true, plant material that could be grown for aesthetic or productive benefits may not grow in highly contaminated soils. Bioindicators could show the effects high levels of lead and arsenic may have on the ecosystem.
- Snead Farm – Due to the high levels found at this site and it’s similarities to Barber Orchard more research is needed at this site. Determine if chemigation was used on site, if there is groundwater contamination, and possible affects these high levels of arsenic and lead have had on the ecosystem.

This thesis is just a sample of what could potentially be a problem in Virginia and is in no way declaring all apple orchards as hazardous Superfund sites. In fact, lead arsenate was also used extensively in peach orchards, as well as many other agricultural crops in Virginia. This study brings attention to an area of great concern for many landowners and all agricultural property that at one time used lead arsenate. Further study and research needs to be done in Virginia to draw more concrete conclusions.

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